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Exploring the Presence of Balanced Growth: Empirical Evidence from Denmark

Abstract   The aim of present study was to explore existence of long-run association between consumption, income and investment implied by Balanced Growth proposition of Neo-classical-growth-model of the Solow and Swan (1956). Using quarterly data on consumption, income and investment from 1995q1 through 2018q4. The study have tested the balanced growth hypothesis for the Denmark. Using standard Vector-Auto-Regression technique of *Johansen (1988)* and *Johansen and Juselius (1990)* analysed the output shocks to both consumption and investment. Although, there exists cointegration implying long run relationship, the results are not consistent with the balanced-growth-hypothesis (BGH) with given data sample for Denmark.

Key Words: Balanced Growth, Consumption, Investment, Output, cointegration, Time Series, Impulse Response, Variance Decomposition

JEL Codes: C50, E21, F43, O47

Introduction

Balanced growth hypothesis has two "different meanings in economics Jargon. In macroeconomics, balanced growth occurs when output and capital stock grow at the same rate over time. In development economics, balanced growth refers to the simultaneous, coordinated expansion of several sectors of an economy".

King *et al.*, (1991) have analysed the BGH for US and found that cointegrating-relations amongst the real flow variables are consistent with the BGH and that for a three variable real model, innovations in the balanced growth component account for more than two thirds of the unpredictable variation in output in 2-5 years.

The concept of balanced growth hypothesis and its measurement occupies a pivotal place in macroeconomics with differing definitions and measuring strategies. It mentions an equilibrium in which major aggregates generally output and capital stock grow at same rate over time and real interest rate remains constant. Balanced growth is linked with constant-returns-to-scale in macroeconomics while for some economists it is positively related to increasing returns to scale. "Rosenstein-Rodan (1943)" argued that post-war-industrialization required coordinated investments across all industries. According to him, further expansion of different sectors is complementary because output of one sector increases the size of market for remaining sectors.

Murphy *et al.*, (1989) formalized a multisector model using key ideas of balanced growth hypothesis by considering firms in individual sectors of economy adopt constant-returns-to scale-technologies found that technology becomes profitable for large scale markets and model generates a multiple equilibrium that may be Pareto-optimal.

Many studies including Kosobud *et al.*, (1961) found evidence for the BGH in which output, investment and consumption exhibited positive trend in growth. Real business cycle models imply that a permanent shift in productivity leads to long-run equi-proportionate shifts in paths of output, consumption and investment with differential movements in consumption- investment and output and their dynamic adjustments.

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The standard approach is to identify the lasting productivity-shocks as the shocks to common stochastic trend in consumption-investment and output using procedures used by "Johansen (1988) and Johansen and Juselius (1990)". Balanced-growth model implies Y_t has a common stochastic-trend and the cointegrating space "$c_t - y_t$ and $I_t - y_t$"are I (0).

Literature Review

Solow and Swan (1956), in their contribution, argued that the driving force behind sustained economic growth was technological advancement. Solow (1957) estimated that only some 12.5% of the increased output per head in the United. States. over 1909 - 1949 was crdited to increases in capital / labour ratio (movements along the production function), with technological progress (upward movement of the production function) explaining the remaining 87.5% of the secular growth in productivity. He argued, also, that the pace of the upward shift in the production function tended to be roughly constant from year to year, albeit with a parametric shift mid-way through this period of observation that doubled the rate of productivity growth. These findings generated new debates - both theoretical and empirical.

Macroeconomics is concerned with solving the basic questions of what causes fluctuations in the output, unemployment, consumption and investment. Macroeconomic fluctuations can be described in terms of less-efficient response of economy to the changed tastes and technology shocks. Interest in economic growth has been a fundamental part of the economics since its beginning. In this context, study of the BG and convergence focuses on the modelling and empirical evidence that pertain to interrelated questions of growth of key macroeconomic variables in short and the long run. Macroeconomists over recent decades have been trying to articulate a framework capable of considering these questions. These attempts emerged in the form of a seminal contribution from Solow (1956) and Swan (1956) which has opened a growth-theory debate for a quarter of a century.

In a seminal paper titled "the dynamic effects of the aggregate demand and supply disturbances" concluded that fluctuations in GNP and unemployment were due to supply and demand disturbances. Demand disturbances having short run effects on output and unemployment due to nominal rigidities (sticky prices and Wages). The productivity disturbances affect the output in long-run and that both supply and demand disturbances had no long-run effect on unemployment. Decomposing macroeconomic fluctuations into temporary fluctuations and trend growth. Building on a Structural Vector Auto Regression (SVAR) in real GNP growth (Δy) and the unemployment rate (U) using data sample from 1950:2 to 1987:4 in quarterly frequencies; their results accorded with the theoretical assumptions (Blanchard and Quah, 1989).

Blanchard's (1989) paper "A Traditional interpretation of macroeconomic fluctuations" provide further insights into the working of key macroeconomic "variables including real output y, rate of unemployment U, Price level p, real wage w and nominal money supply M". He concluded that fluctuations in the major macroeconomic variables can be interpreted in terms of shocks to demand, money, labour supply, productivity, price and wage setting. Supply-side shocks associated with decreases in nominal prices and wages play an significant role in medium to long-run while demand shock associated with the movements in output dominate fluctuations in the short run.

King et al., (1991) in their well-known empirical work on the sources of macroeconomic fluctuations used the monetary policy variables to get insights about theoretical ideas floated by Lucas (1975) and Barro (1976) have tested the BG hypothesis for the post-war United States data. Their results supported the BG theory but raised questions regarding the role of the productivity shock and the monetary shocks in explaining the fluctuations in the system of variables.

Lucas (1975) and Barro (1976) concluded that any interpretation of macroeconomic fluctuation is biased towards the monetary policy variables. Incorporating this finding of Lucas (1975) and Barro (1976), King et al., (1991) tested United States quarterly data on consumption, investment and output from 1949:1 to 1988:4 and 1954:1 to 1988:4 to get empirical support for BG. Their research finding based on a VECM approach raised some questions not only regarding the variables considered as the major source of macroeconomic fluctuations but also about the need for testing the validity of the claims of Barro (1976) by employing the monetary policy variables. Using Cobb-Douglas-production-function with constant-returns-to-scale, they checked the validity of their research finding by

constructing a model with three real variables and then augmenting it with a set of three nominal variables. They found a substantial drop in explanatory power of the BG ("productivity") shock from 70% to a 45% after including the nominal variables. This raised two questions; firstly, the BG shock is not the only source of variations in the macroeconomic fluctuations. Secondly, monetary policy factors are not successful in explaining the fluctuations over business cycle periods.

The contributions of the King *et al.,* (1991) are consistent with the results of the Nelson and Plosser (1982) who revealed using a time series macroeconomic data for the United States that any macroeconomic model which rely on "monetary-disturbances as the source of the purely transitory fluctuations may never be successful in explaining a large fraction of the output variations and concluded that stochastic variations due to real factors are an essential element of any model of macroeconomic" fluctuations.

Hossain and Chung (1999) tested long run implications regarding one sector neoclassical growth theory for Australia, New Zealand, South Korea and Taiwan. They have used variance decomposition to examine the extent to which innovations in the common stochastic trend are able to explain the fluctuations in short run and they found favourable results. They found that the productivity shock alone is not capable of explaining all fluctuations in macro-data but investment innovations also play important role in the fluctuations in the common stochastic trend in the system (Whelan, 2004). Their application of exogeniety tests provided useful information about the variables. They found that stochastic trend for Taiwan data is due to innovations in investment not the innovations to output. The study further showed that only the Australian data is consistent with predictions of neoclassical growth theory whereas results are mixed for New Zealand, South Korea and Taiwan.

Whelan (2004) had revealed that addition of new "data from the U.S. National-Accounts rejects earlier widely-cited results that supported the one-sector model BG predictions. This is significant particularly because the idea of stable great ratios of real consumption or of real investment to real GDP has generally been considered a central stylized fact in macroeconomics. The fact that real investment appears to have a different long-run trend growth rate from real consumption in United. States data should have important implications for macroeconomic analysis, given that many empirical and theoretical studies take one-sector growth model as reference point for characterizing long-run behaviour of an economy". This result of the Whelan (2004) is consistent with that obtained by the Hossain and Cheung, (1999).

In his seminal work, Mills (2001) used the Generalized-Impulse-Response-Functions (GIRF) of "Pesaran and Shin (1996, 1998) along with the Horvath and Watson (1995)" tests for known cointegrating-vectors and checked for the great ratio stationarity for the United Kingdom from 1955:1 through 1997:4. He found strong support for the existence of the GRS for the post-war UK quarterly data. With three dimensional-VAR frameworks of consumption-investment and income found that the GIRF converge to non-zero constants if consumption, investment and income are integrated of order one. The graphical display of the GIRF for the three real variables and two great ratios supported the theoretical assumptions where three variables converge to constants while the two great ratios to zero with the extremely slow convergence back to equilibrium in case of the investment: output ratio.

A re-interpretation of the great ratios, BG and stochastic trends came out in the shape of a work by Rafiq (2006) for the Euro Area. He has tried to answer the question" Are business cycles mainly due to permanent productivity shocks for the Euro Area?" He has replicated the work of the King *et al.,* (1991) to reinvestigate robustness of results between Euro area and the United States. He has emphasized that role played by the monetary and inflation shocks were relatively in-significant. Extending the model with nominal variables showed very little impact on the results. His contribution to the literature includes the contention that real-interest-rate-innovations reflect that the central bank has played significant role in contributing to investment fluctuations and less to output fluctuations. He concluded that the Euro Area data is consistent with one common stochastic trend which was due to permanent productivity shocks and hence dominant source of the business cycle fluctuations (Khan *et al.,* 2020) for the Euro Area.

Various empirical studies have investigated BG for different regions or countries. These studies have employed different data sets and methodologies to assess empirical support for this theory. The outcome of these studies remains, however, inconclusive. The empirical literature on BG and consequent great ratio stationarity (GRS) evolved in different dimensions including testing GRS "(Klein

and Kosobud, 1961) and applying new time series techniques employing the concepts of unit roots and cointegration (King *et al.*, 1991; Neusser, 1991; Serletis, 1994; Serletis and Krichel, 1995; Hossain and Chung, 1999; Mills, 2001; Harvey *et al.*, 2003; Whelan, 2005)". These studies examined long-run behaviour of consumption-investment and output – the component elements of the "great ratios", and find mixed empirical support for a common rate of growth. More recently, echoing Solow's (1957) assertion of the potential for parametric shifts in the rate of technological progress, the empirical literature has begun investigating BG and GRS with econometric methods that permit structural breaks in unit root and cointegration testing, but still with mixed results (Attfield and Temple, 2010; and Kemper *et al.*, 2011).

Despite the large volume of research in this field, limited evidence on the validity of neoclassical growth theory in terms of testing the output per capita convergence (Khan and Daly, 2018) in leading European economies ignoring balanced growth hypothesis. This study will address these two gaps by extending the work of "King *et al.*, (1991). Johansen (1988) and Johansen and Juselius (1990)" techniques will be employed for Denmark.

Some recent developments in the area of BGH investigations have reported different results for countries like China, Turkey and SAARC region countries (Li, et al., 1998; Li and Daly, 2009: Attifield and Temple, 2010; Khan, 2014: Khan &Daly, 2018).

Methodology, Data and Theoretical Background

We consider the formulation of a RBC model used King *et al.*, (1988) with permanent productivity shocks, output Y_t is produced via a usual constant returns to scale Cobb-Douglas production function:

$$Y_t = \lambda_t K^{\theta} N^{1-\theta} \qquad (1)$$
$$\text{Log}(Y_t) = \log(\lambda_t) + \theta k_t + (1-\theta) \ell_t \qquad (2)$$

Where "K_t is the capital stock and N_t represents labour input. λ_t is the total factor productivity, λ_t, follows a logarithmic random walk":

$$\text{Log}(\lambda t) = \mu_\lambda + \log(\lambda_{t-1}) + \varepsilon_t \qquad (3)$$

Where the innovations, $\varepsilon t \sim (0, \delta^2)$. "The μ_λ represent-average-rate of growth in productivity, ε_t represents deviations of actual growth from this average.

$$E_t \log(\lambda t+s) = E_{t-1}(\lambda_{t+s}) + \varepsilon_t \qquad (4)$$

A "positive productivity shock raises the expected long-run growth path. There is a common stochastic trend in the logarithms of consumption, investment, and output. The stochastic trend is log $((\lambda t)/\theta$, and its growth rate is $(\mu_{\lambda +} \varepsilon_t)/ \theta$, the analogue of the deterministic model's common growth – rate restriction, μ_λ/θ. With common stochastic trends, the ratios C_t /Y_t and I_t /Y_t become stationary stochastic processes". Balanced growth implies that C_t/Y_t and I_t/Y_t are stable ratios. Therefore, in logs, c_t-y_t and $i_t - y_t$ must be I (0). The random walk in log(λ_t) implies $Y_t \sim I(1)$ and since c_t-y_t and i_t-y_t are I(0), therefore c_t and i_t must be I(1) but the vector $z_t = [c_t, i_t, y_t]$ cointegrates.

The specification with wold representation becomes;

$$\Delta Z_t = \mu + c(L) \varepsilon_t \qquad (5)$$

Where "ε_t is the vector of one-step-ahead linear forecast errors in Z_t. The ε_{ts} is are serially uncorrelated with mean zero and covariance matrix $\sum_e$. considering a structural-model of form"

$$\Delta Z_t = u + \gamma(L) \acute{\eta}t \qquad (6)$$

Where "$\acute{\eta}t$ is an n X x1 vector of serially uncorrelated structural disturbances with a mean of zero and a covariance matrix $\acute{\eta}t$". Alternatively, these identifying restrictions can be imposed by rewriting the model in terms of the stationary variables $Z_t = (\Delta y_t, c_t - y_t, i_t - y_t)'$. Theory of the real business cycle with balanced growth hypothesis states that for three variables (c_t, i_t, y_t) and one common stochastic trend – productivity shocks implies, n=3 and n-r = 1, so, there are r=2 cointegrating vectors. We can restrict $b_1 = -1$ and $b_2 = -1$.

$$\text{Assume} \quad Zt = \begin{bmatrix} Ct \\ I_t \\ Y_t \end{bmatrix} \quad \quad (7)$$

Assume c_t, y_t, and I_t be natural logarithms of consumption, income and investment respectively and let $Zt = (c_t, y_t, I_t)$. If z_t is I (1) and great ratios $c_t - y_t$ and it $- y_t$ are stable (Stationary), then a VECM may be written as;

$$\Delta Zt = \alpha\beta'z_{t-1} + \gamma 1\Delta z_{t-1} + \gamma k\ \Delta z_{t-2} + + \xi t \quad \quad (8)$$

Where $\Delta zt = zt - zt\text{-}1$ while ξt is a GZaussian error

$$\alpha = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \\ \alpha_{3\cdot1} & \alpha_{32} \end{bmatrix} \quad ; \quad \beta` = \begin{bmatrix} 0 & 1 & 0 & -1 \\ 0 & 0 & 1 & -1 \end{bmatrix}$$

Data Properties and VAR Specification

Data properties are essential for the proper model selection. Therefore, unit root and cointegration tests were performed to assess the stationary properties and cointegration features of the data. The data has been obtained from OECD, Various issues of International financial statistics (IFS) and IMF. The sample range is 1995q1 up to 2018q4, which comprise 96 observations. Visual representation of time series supports our results achieved with the Johansen cointegration test that the three variables share a common trend.

The method is very simple because it considers all the variables as endogenous. Estimation with VAR is "simple and the usual OLS method can be used to estimate each equation separately. The forecasts obtained are in many cases better than those obtained from the more complex simultaneous equation models. A VAR model is a theoretical model because it uses less prior information. In case of simultaneous equation model's exclusion or inclusion of certain variables plays a crucial role in the identification of the model. Due to its emphasis on forecasting, VAR models are less suitable for the policy analysis.3. Taking the example of a three variable (as in this study) VAR model where we decide to include five lags of each variable in each equation. Then, we will have eighteen (15) lagged parameters in each equation plus the constant term, for a total of nineteen (16) parameters. Unless we have very large sample size, estimating that many parameters will lead to a lot of problems including" a lot of loss of degree of freedom.

The stationary of the series had been checked through Augmented Dickey-Fuller (ADF) unit root tests (Khan *et al.*, 2020), "results are summarised in table 1. Which shows that all variables appear to be integrated of order one. i.e., I (1). For output (income), the null hypothesis of non-stationarity of the first difference of the series is rejected at the 1%, 5% and 10%level". For all other series the null is clearly rejected at the 1%, 5% and 10% significance level. The data are found in the appendix. The stationary VAR (3) set-up used in the empirical analysis is of form:

$$Y_t = c + \delta t + A_0 Y + A_1 Yt\text{-}1 + \ldots\ldots\ldots + A_p Y_{t\text{-}p} + u_t \quad \quad (9)$$

Where Y_t is "the *n*-dimensional vector of variables, the A_i are (*nxn*) coefficient matrices and u_t is a vector containing the reduced form residuals which are assumed to be normally distributed white noise with a constant covariance matrix". The variables in equation (9) may be cointegrated. The model for DF test is;

$$\Delta yt = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{P} \delta i\ \Delta\ y_{t-1} + \varepsilon_t \quad \quad (10)$$

Where Δ is first difference operator, y is "variable under investigation and ε_t is a random error term. The lagged variables provide for correction for possible serial correlation. The null hypothesis is given by $\rho = 0$. This is tested using t-test in table 2. The alternative hypothesis is that process is stationary around the deterministic trend". i.e., if data do not contain a deterministic trend then, this model should provide a more powerful test of the unit root hypothesis.

Empirical Results

The empirical results of the structural VAR are presented and discussed in this section. At first the VAR specification is introduced. Using the IRF and variance decompositions the properties of the identified structural shocks are analysed.

Table 1. Unit Root Tests Results

Series	Levels			First-differences		Dec.
	C	C & T	Dec.	C	C & T	
Y	1.6181	1.1700	N.S.	-6.55	-7.95	S
I	-0.6471	-3.021	N.S.	-5.30	-5.51	S
C	-0.1689	-1.7120	N.S.	-8.69	-4.73	S

Note: ** indicate significance at 5%

The Lag-order of VAR model several "lag order selection criteria along with the Likelihood ratio (LR) tests for parameters reduction were performed. Where Akaike criteria (AIC), Schwartz Bayesian criterion (SBC), the Hannan-Quinn (HQ), Final prediction error (FPE)" all reported five lags in Table 2 below:

Table 2. Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	520.5334	NA	1.67e-09	-11.69394	-11.52503	-11.62589
1	606.0790	161.3700	2.94e-10	-13.43361	-13.01134	-13.26349
2	625.0308	34.45794	2.35e-10	-13.65979	-12.98415	-13.38759
3	648.1884	40.52583	1.71e-10	-13.98156	-13.05255	-13.60728
4	701.8398	90.23187	6.21e-11	-14.99636	-13.81399	-14.52001
5	723.2923	34.61650*	4.71e-11*	-15.27937*	-13.84364*	-14.70095*
6	728.3059	7.748350	5.21e-11	-15.18877	-13.49968	-14.50828
7	734.4488	9.074702	5.63e-11	-15.12384	-13.18138	-14.34127
8	743.4564	12.69255	5.73e-11	-15.12401	-12.92819	-14.23937

LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion
*Note: * indicates lag order selected by the criterion*

The VECM is specified by allowing a constant and trend in both the I (0) and the I(1) components, model is estimated using five lags. The VAR-model therefore was estimated with a constant, seasonal trend and five lags. The cointegration vectors can be identified by imposing linear restrictions on the long run parameters of the VECM and testing these restrictions by likelihood ratio tests. The VAR-model based on equations (2) and (3) can be estimated subject to the cointegrating restrictions.
Table 3. Johansen Cointegration Test for Zt = (yt, ct, it)

Null Hypothesis	Trace statistics	Critical Values** at 5%	Maximum-Eigen value statistics	Critical values 5%	Prob. Values
r= 0	57.21**	35.19	38.09**	22.29	0.0239
r =1	19.11	20.26	14.21	15.89	0.0037

*Note: ** indicates rejection of null hypothesis and significance at 5%*

The Johanson trace-test for cointegration significantly indicates the existence of one cointegrating vector. The Trace statistic value is 57.21 at r=0 which clearly is greater than critical values of 35.19 at 5% level. At r=1, the trace test value 19.11 of less than critical value of 20.26 at 5% to acceptance of null hypothesis at r=1. i.e there is one cointegrating vector.

The Maximum Eigen value test statistic values given in table 3 shows that computed value of test-statistics 38.09809 is greater than the critical values at 5% leads to rejection of null-hypothesis. While at r =1, the maximum Eigen value test statistic is 14.22 which is smaller than critical value of 15.89 at 5% level of significance leading to acceptance of null-hypothesis that there exists at most one cointegrating vector.

To compute the likelihood ratio test, we use the system of log likelihood from this estimation for the restricted (LR) and use the log likelihood from the case where r = 1 in the Johansen cointegration test results and call this unrestricted (LU).

$$\text{Log Likelihood (Unrestricted)} = 733.48$$
$$\text{Log Likelihood (Restricted)} = 718.11$$
$$\chi^2 = 2\,(LU\text{-}LR) = 30.74$$
$$\chi^2\,(4,\,0.05) = 9.49$$

Table 4. Wald Test of BG restrictions for Denmark

Chi-square(n-k) d.f	Probability	Critical values	Decision
14.3643	0.0007	5.99	Reject

Table 4 above shows that BG restrictions have been rejected for Denmark, thus confirming results from cointegration analysis. In the unrestricted system, there are four free parameters to estimate. On the other hand, in the system where we imposed over-identifying restrictions, there are no free parameters. Hence, we imposed four restrictions. The calculated value of which is 30.73 greater than critical value of 9.49 leading to rejection of null hypothesis. This result indicates that the restrictions do not hold for the balanced growth hypothesis. This result shows that there is no cointegrating relationships between three flow variables and that our data yields inconsistent results with the balanced growth hypothesis theory.

Structural Identification

The impulse response functions show the dynamic reactions of consumptions and investment to a standard deviation shock to real output Yt. The vertical axis refers to the log of the variables considered while the horizontal axis indicates the time horizon in quarters. The IRF depicts the different impacts of income shocks on consumption and investment. The observed dynamic response of the variables matches the predictions of the BGH. A positive shock induces a permanent increase in the level of the real output. The impulse responses and the Variance decomposition is shown in figures 1, (2) and (3).
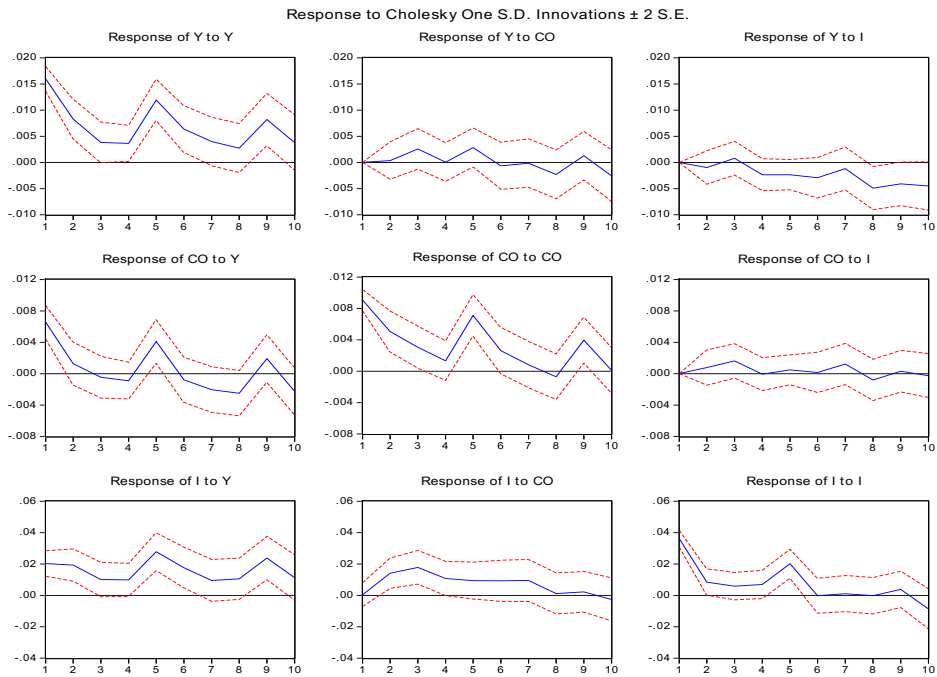
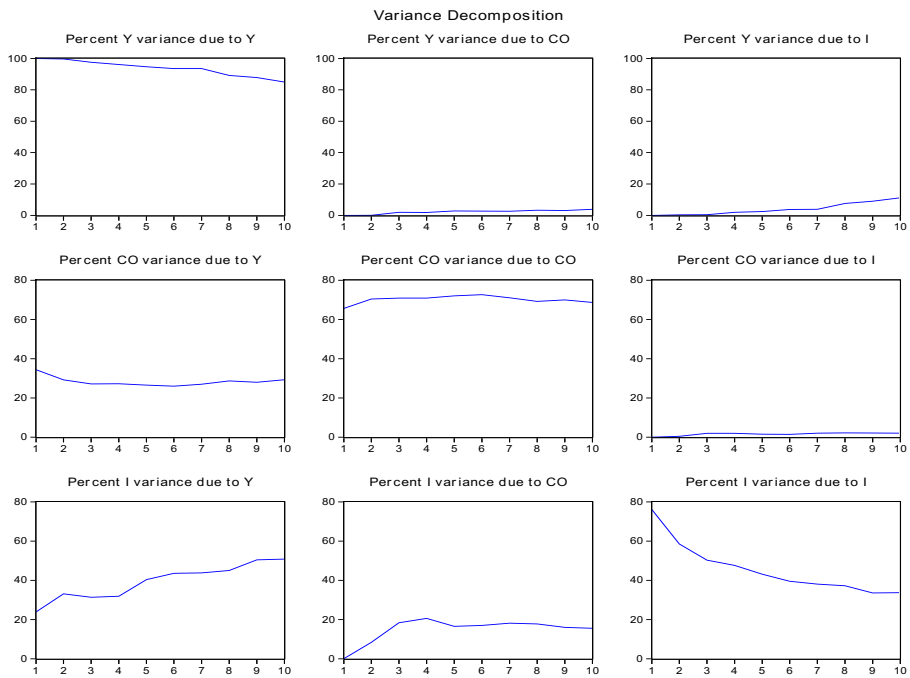**Figure 1:** Response to Cholesky one S.D innovations _+2S.E.
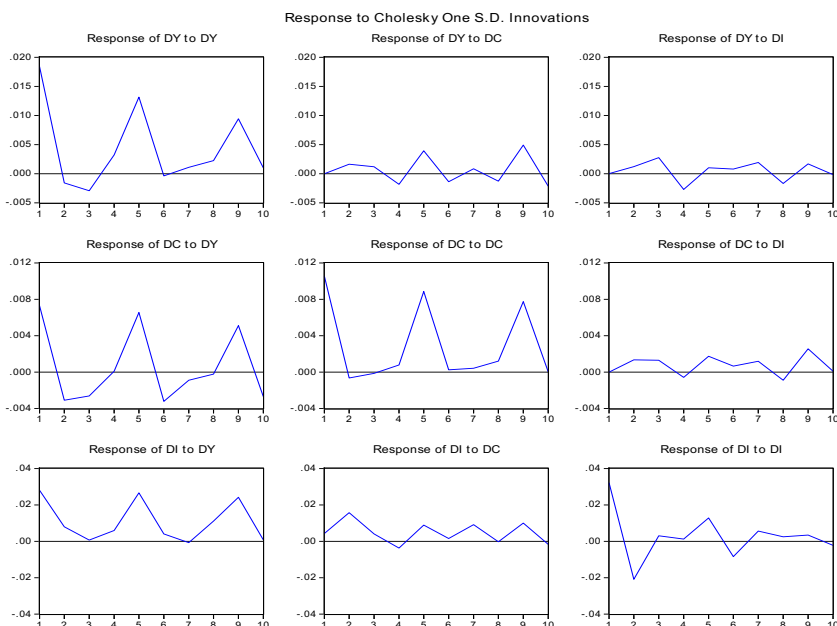

Figure2: Variancede Compositions

Figure3: Response to Cholesky one S.D Innovations

Conclusion

We have analysed the properties of the macroeconomic data of Denmark to assess observed significance of the standard RBC models with productivity-shocks. We have examined the long run relationship between income, consumption and investment using quarterly data for period 1995q1 up to 2018q4. Our empirical investigation consists of the application of cointegration analysis to ascertain the long run relationship between three flow variables. The cointegration analysis shows that although there exists long run relationship but results obtained are in-consistent with Balanced Growth Hypothesis for data sample used for Denmark. Future studies can focus on reinvestigating balanced growth hypothesis and Great Ratio stationarity taking into account, dynamics and structural breaks for different group of countries including Pakistan.

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