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Assessment of the Relationship between Central Bank Interest Rate, Inflation and Growth in Central Africa Countries with the New Leading-Lagging Method

Abstract: This paper assesses the causal relationship between central bank interest rate, inflation and GDP growth in Central African countries using a new leading-lagging method over the period 1990-2019. The results show a short-term relationship between the three variables, with strong evidence of unidirectional non-linear causality running from the interest rate to inflation for the region as a whole. However, analysis by the country reveals some divergences on the causality between variables despite the fact that all six countries benefitted from the central bank monetary policy at one time or another, either with respect to GDP or INF. The empirical implications of these results are the relative independence in central bank decisions and the absence of synchronization between region's economies.

Keywords: Monetary Union, Central Bank, leading-lagging method, non-desired value

JEL Classification: E52, E58, O11, C02, F15.

1. Introduction

For six and a half decades, the Phillips curve that highlights a relationship between inflation and growth or unemployment still raises questions. One of the obvious questions which emerged was how to keep inflation low and stable?

A number of decisions taken by central banks in recent years bear witness to the importance of this issue. As illustration, following the outbreak of the global financial crisis in 2007, the economic growth slowed down from 5.6% to 0.1%. Therefore, central banks eased monetary policy by reducing interest rates until short-term rates came close to zero and, at the same time, the world inflation dropped from 5.3% to 3.1%. More recently, in response to rapidly growing inflation, central banks around the world have tightened monetary policy by increasing interest rates. In the light of these cases, we conclude that inflation and interest rate tend to move in the same direction. However, the conventional view among economists is that higher interest rates lead to lower inflation, suggesting that there is a negative relationship between the two variables. The rationale behind this view is that higher interest rates increase the cost of borrowing and dampen demand across the economy, resulting in excess supply and lower inflation (Khan and Senhadji, 2001; McKinnon, 1973).

A problem for an economic analysis is that policymakers often respond to changes in economic outlook with a lag, and their policy changes, in turn, take time to affect inflation. Because of these lags, policymakers have to anticipate future inflation trends when deciding on the present interest rate. For example, for the sake of stability of inflation, a central bank facing the prospect of higher-than-targeted inflation would raise interest rates enough to increase the real (inflation-adjusted) cost of borrowing, thereby reducing aggregate demand and returning inflation back toward the desired level. If they anticipate a fall in the future inflation rate, then in the present they will lower the interest rate. So, there is a time lag between the decision and the effect because interest rates influence inflation through several channels (Mishkin, 1989). It is then the lagged value of the variables that determines the direction of the relationship. The same applies to the relationship between the inflation rate and the growth rate and/or between the interest rate and the growth rate (Fisher, 1993; Ghosh and Phillips, 1998; Mallik and Chowdhury, 2001; Aydin, Esen, & Bayrak, (2016).

Several economists refer to the theoretical idea that there is a direct negative relationship between the interest rate and economic growth, (McKinnon, 1973; Shaw, 1973). However, Shaukat, Zhu & Khan, (2019) have empirically shown that this inverse relationship (mainly negative) only exists because the interest rate has a negative impact on certain variables (like foreign investments, trade openness, and institutional strength) which in turn have a negative impact on the growth rate. The analysis by Shaukat et al. thus implicitly shows the existence of adjustment lags and hazards, which mean that the direction of the relationship between macroeconomic variables cannot be assessed on the basis of current values alone. It is important to take account of their lagged values.

More, the Taylor rule (Taylor, 1993), which relates the monetary authorities' policy rate to the vector of variables describing the state of the economic system and which is a benchmark for many economic policy makers, assumes symmetry throughout the business cycle, whereas the business cycle is fundamentally asymmetric.

To our knowledge, the quality and meaning of the relationship between interest rate, inflation and growth has not been the subject of any study in the Central African Economic and Monetary Community (CEAMC) zone. However, nonlinearities in the Phillips curve and their relevance for the conduct of monetary policy have been explicitly recognized by policy makers. The Phillips curve nonlinearity has various policy implications mostly in monetary unions. One of the implications is that the same policy action may have different real effects on countries. The effects of policy action depend on the phase of the business cycles (Cristini and Ferri, 2021). Moreover, the effectiveness of contractionary policies in reducing inflation would be greater than expected on the basis of a linear model; analogously, in periods of high unemployment, expansionary policies would be less inflationary than expected (Gross and Semmler, 2019).

The aim of this paper is to examine the relationship among the three macroeconomic variables (interest rate, inflation, economic growth) at different time and frequency scales using a new high resolution lead-lag (LL) method in CAEMC made up of the six countries: Cameroon (CMR), Central African Republic (CAR), Chad (CHA), Republic of Congo (COG), Equatorial Guinea (GNQ) and Gabon (GAB).

We will focus on decadal and bi-decadal developments because the CBI's (Central Bank Interest Rate) monetary policy will have time windows of this length for their policy decisions. To see changes in time on this scale, we linearly detrended the time series (Seip and Zhang, 2024). A feature of economic variables is that they often have "optimal" or "natural" values that are different from zero (Brunnermeier and Sannikov, 2016; Jones, 2016). Thus, LL- relations may change or become non-significant when an optimum value is met. We use the nomenclature $LL(x,y) > 0$ if x is a leading variable to y. With $LL(x,y) > 0.32$, x is significantly leading y. To be a causal variable for another variable, the causal variable must be a leading variable to the effect, or target, variable. However, it is not a sufficient criterion.

The study has two stages. *First*, we examine the relation between the GDP, the INF, and the CBI as if the six countries were one economic entity. This would correspond to the normal treatment of regions in a monetary union or a federal state, like the US. The result of this first study will form a backdrop for the next stage. In the *second* stage, we examined whether there are clusters among the countries where the LL relations are similar to the lead-lag relations for the CAEMC region as a whole. We show, by examining the time series for CAEMC Central Bank`s (BEAC) short term interest rate and for GDP and the average inflation rate for the CAEMC area, that the BEAC's monetary policy will favour, from time to time, all countries in the CAEMC region, most probably without explicit intent.

The contributions of our paper are fourfold. To our knowledge, most of the studies analyses the relationship between interest rate, inflation and economic growth using econometric method. We use a new method to determine lead-lag, (LL) - relations between paired variables. One of the characteristics of the LL- method is that it can determine the LL- relations for very short time series and thus also detect changes when one variable goes from being leading to being lagging. Second, this analysis also allows us to assess the level of synchronisation between the economies of the CEAMC, given that they form a monetary union. Thirdly, this analysis can also allow us to assess the independence of the Central Bank. If the central bank's interest rate is a leading variable to all countries aggregate GDP or to the average inflation for all countries, then the Central bank is independent of the interests of each country.

This paper is organized into five sections. In addition to the first introductory section, section 2 is about the literature review. Section 3 presents data and methodological issue. Section 4 discusses the results and section 6 concludes the paper.

2. Literature review

The relationship between central bank interest rate, inflation and economic growth is a topic of ongoing debate in macroeconomics both theoretically and empirically. Theoretically, classical and neoclassical believed that there is a negative relationship between inflation, interest rate and economic growth (Hayek, 1933; Tobin, 1969; Gokal and Hanif, 2004). According to the classical "neutrality of money" view, increases in inflation hamper growth by increasing firms' cost of production. The neoclassical theory of investment explains the negative relationship between interest rate and growth through firms cost capital. They argue that the higher rate of interest causes an increase in firms' cost of capital which in turn reduces output. A related viewpoint is that rising inflation is not the cause of depressed economic growth but rather just a symptom of underlying economic problems that depress growth, such as supply-side disruptions or fiscal imbalances. This view was supported by monetarists who consider that an increasing money supply represents the main reason for generating inflation or deflation in an economy, and this issue affects economic growth (Friedman, 1961). Friedman de-emphasized the importance of interest rate as variable affecting the demand for money while singling out inflation expectations as an essential influence on variations in velocity (Bibow, 2002). However, the Fisher hypothesis suggests in contrast that inflation is the main determinant of interest rates, and as the inflation rate increases by one per cent, the rate of interest increases by the same amount. Keynesians and structuralists disagreed with the monetarists and classical view and stated that the inflation-growth relation is positive in the short run, at least under certain conditions (Keynes, 1936; Ball, Mankiw & Romer, 1988; Bernanke, Laubach, Mishkin & Posen, 1999). They argue that inflation is essential to enhance output growth. But such theories have a difficulty to explain "stagflation," which is simultaneous high inflation and slow economic growth.

Empirically, the Fisher hypothesis that states that there is a positive relationship between inflation and interest rate has attracted a great deal of attention from economists. Fama and Schwert (1977) tested the Fisher hypothesis in the US and found evidence of a positive relationship between inflation and interest rate. The same result was obtained by Westerlund (2008) who used error correction model (ECM) to test the Fisher hypothesis for 20 OECD economies for the period 1980-2004. Gul and Ekinci (2006) investigated the interaction between nominal interest rates and inflation for Turkey over the period of 1984-2003. Their result supports the idea that there is a long-run relationship between interest rates and inflation for Turkish markets. They also found that causality exists in only one direction from nominal interest rates to inflation. In contrast, with the Generalized Method of Moment (GMM) estimator, Umoru and Oseme (2013) find that the effect of interest rate variation on expected inflation in Nigeria is negative and significant. Gocer and Ongan (2020) use a nonlinear ARDL model and find an asymmetrical long run relationship between inflation and interest rates in the UK. As for studies taking into account the three variables, the findings of Ramlan & Suhaimi (2017) showed a positive relationship between interest rate and growth and a negative relationship between inflation and growth in the case of Malaysia. Davcev, Hourvouliades & Komic (2018), in the case of Bulgaria and Romania, concluded that inflation and interest rate have a significant impact on growth, but the nature of the relationship varies across countries. Hayat et al. (2021) analyze the impact of inflation and interest rate on output growth in the context of Pakistan using the wavelet transformation approach and Granger causality tests. They show that the causal relationship between these variables is unidirectional in the short-run and medium-run but bi-directional in the long-run. Studies above are generally based on the assumption that the relationship is linear.

A further different studies on the relationship between interest rate, inflation and growth have been made taking into account the influence of others variables and/or the non-linearity between variables. Kumar, Acharya & Ho, (2020) as well as Taderera, Runganga, Mhaka & Mishi (2021) find that a positive relationship between interest rate, inflation and economic growth can only occur under certain conditions. First, a profitable banking sector is essential for economic growth, and changes in interest rates have the potential to affect bank profitability. Second, policymakers should allow a high sustainable inflation rate for promoting economic growth, while the interest rate can be used as a monetary policy tool in order to achieve the considered inflation rate that will affect economic growth positively. They pointed out that while inflation targeting brings sanity within the financial sector, this might retard growth as the desirable inflation level would be beyond the targeted inflation level. Agarwal and Baron (2023) test a bank credit channel through which unexpected increases in inflation lead to short-run macroeconomic fluctuations in the US. They find that unexpected increase in inflation tends to be contractionary for the banking sector, an effect that is, in turn, transmitted to the macroeconomy. In the framework of the models that take into account the non-linearity between variables, the relationship between economic growth and inflation is affected by the threshold inflation. If inflation rates are below threshold value, the relationship is generally positive or insignificant, but if the inflation rates are above the threshold value, the effect of inflation on growth is usually found to be negative and significant. Most of these studies are made for countries that target price stability. That is studies made by Anidiobu, Okolie & Oleka (2018), Omay and Kan (2010), Vinayagathasan (2013), Aydin et al. (2016), Cristini and Ferri (2021), Kusumatrisna, Sugema and Pasaribu (2022). Looking at the literature, we find that very few studies, if any, have focused on Central African countries. We fill the gap by analysing the relationship between interest rate, inflation and economic growth in central African countries using a high resolution lead-lag analysis which puts us in line with those who take into account the existence of a non-linear relationship between the variables.

3. Data

We examine three sets of data, the GDP and inflation for the whole CEMAC region and for the single countries, and the CBI that are common for all CEMAC counties. We use GDP, INF and CBI data from 1990 to 2019 at annual frequency.

3.1. GDP and CBI

Gross domestic product, GDP, is obtained from World Development Indicators (WDI) and is in constant 2010 US$[1]. It is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. The data for GDP for each country and for the CEMAC area is shown in Figure 1a. The data are shown as detrended, centered and normalized time series in Figure 1b. Principal component analysis (PCA) plots of the GDP for all six countries and for the sum of the GDP's are shown in Figure 2c. During the period 1990 to 2019, the GDP of the whole region showed high instability in the economies. Comparing figure 1a and figure 1c, we see that the GDP of CHA and COG is counter cyclic to CAR in spite of the countries having similar economies. However, CAR experience a considerable decrease in its GDP in the year 2012 caused by civil war. Also, GNQ and GAB show counter cyclic in GDP in spite of similar economies, but GNQ is extremely dependent on oil export (27.8 % GDP on average 2014-2018).

Central Bank interest rate, CBI, is shown in raw format and detrended, centered and normalized in Figure 1d. The CBI is obtained from BEAC's database[2]. After an increase in its CBI in 1993, it gradually reduces its interest rate until 2017 from which the interest rate starts increasing again until 2019.

Figure 1a: Gross domestic product raw data

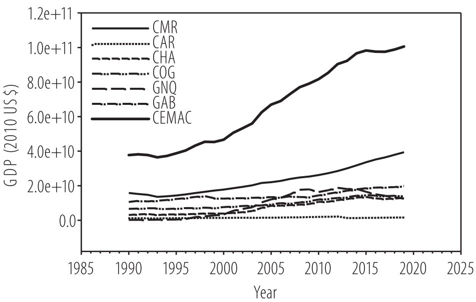
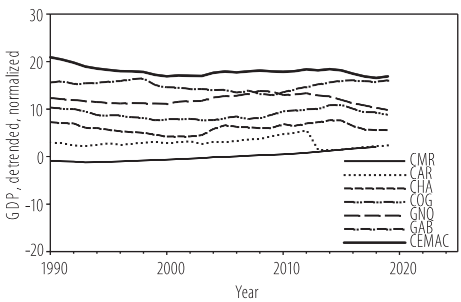


Figure 1b: Gross domestic product data centered and normalized to unit standard deviation



[1] https://databank.worldbank.org/source/world-development-indicators

[2] https://www.beac.int/economie-stats/statistiques-marche-monetaire

Figure 1c: Gross domestic product loading plot for the raw data

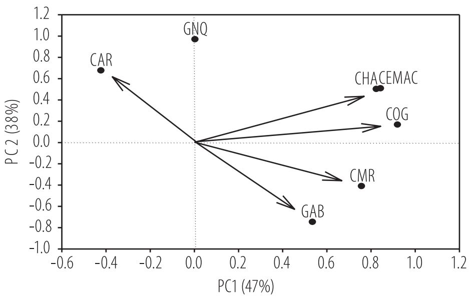
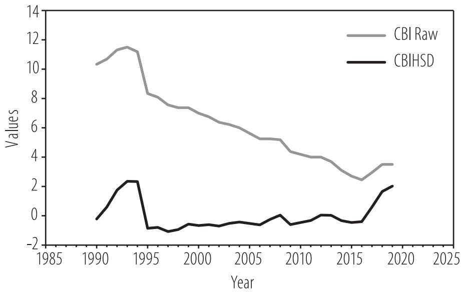


Figure 1d: CBI raw data and detrended, centered and normalized



3.2. Inflation

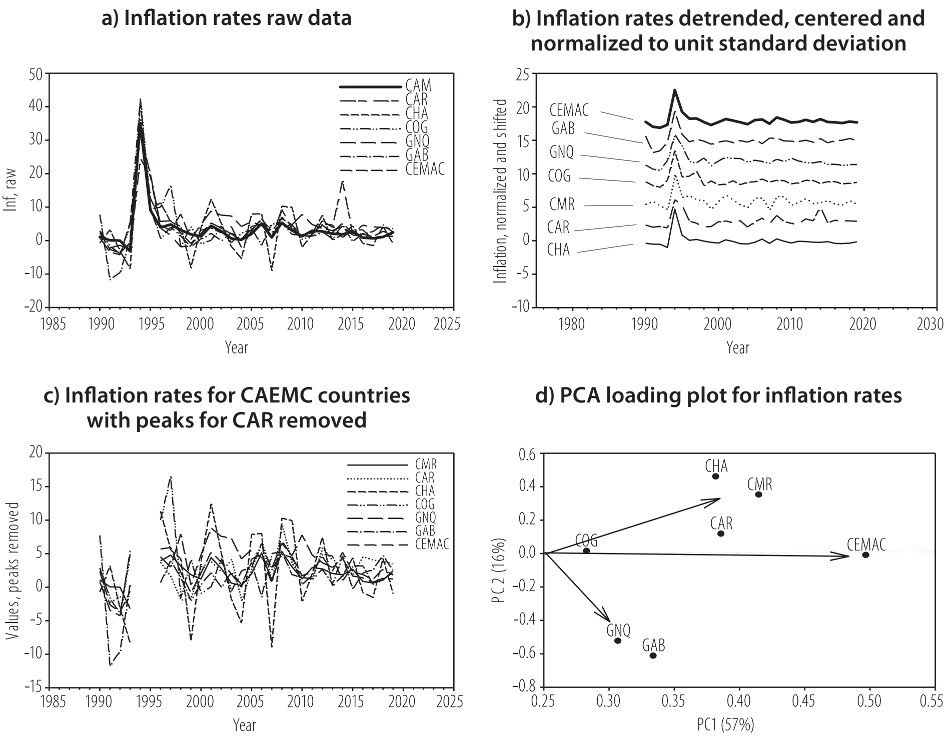
Inflation. *INF* is expressed by the consumer price index (CPI). The data of INF is shown in raw format in Figure 2a and detrended, centered and normalized to unit standard deviation in Figure 2b. Data are also, obtained from the WDI. All countries had extremely high inflation rate in 1994-1995 giving an average of 13% in 1994. This high inflation rate was related to the devaluation in 1994 that increased the cost of all inputs, equipment and imported consumer goods. It also caused behavioural changes in the economic agents in anticipations of future price levels. The devaluation was accompanied by changes in political economic measures such as customs duties and taxation (Bank of France, 1995). The GNQ is a country which has had the most stable inflation after 1996, whereas CHA shows fluctuating inflation patterns. Since the PCA is a least square technique and would be dominated by high values, we removed the years with high inflation and show a PCA plot for the remaining years, Figure 2d. An alternative would have been to stabilize the variance by applying the log function to the inflation series, (Bjornland, Brubakk & Jore, 2008; Agoba, Abor, Osei & Sa-Aadu, 2017). Neither of the countries shows a development of inflation that resembles the average inflation for all countries. GNQ and GAB show similar inflation patterns (Fig 2d). Table 1 presents some statistics of GDP and INF.

Table 1: Key statistics of GDP and INF

	CAR	CMR	CHA	COG	GAB	GNQ	CAEMC
GDP							
Mean	1.64E+09	2.26E+10	7.37E+09	9.73E+09	1.41E+10	9.18E+09	6.46E+10
Median	1.58E+09	2.16E+10	7.17E+09	8.65E+09	1.34E+10	1.04E+10	6.26E+10
Maximum	2.35E+09	3.79E+10	1.35E+10	1.46E+10	1.92E+10	1.88E+10	9.89E+10
Minimum	1.28E+09	1.36E+10	3.05E+09	6.52E+09	1.06E+10	2.15E+08	3.65E+10
Std. Dev.	2.76E+08	7.42E+09	3.83E+09	2.89E+09	2.57E+09	7.19E+09	2.31E+10
INF							
Mean	4.170500	3.370387	3.870368	4.514115	2.638352	5.232289	3.966002
Median	4.170500	2.013540	3.822601	3.094490	1.885708	4.415900	2.850518
Maximum	4.507900	35.09446	41.72490	42.43968	36.11625	31.84102	31.85763
Minimum	3.833100	-3.206555	-8.974740	-3.935468	-11.68611	-4.278743	-2.834152
Std. Dev.	0.205204	6.494648	9.399381	8.340476	7.687528	6.691686	5.933797

The six countries have a common Central Bank. The Mean of Central Bank interest rate (CBI) is 6.29%, the maximum is 11.50%, the minimum is 2.45 % and the standard deviation is 2.74

Figure 2: CAEMC countries



4. Method

Several methods are available to establish cause and effect relations (Machamer and Wolters, 2007; Sugihara et al., 2012; Stips, Macias, Coughlan, Garcia-Gorriz and San Liang, 2016). However, causality requires that the cause comes before the effect. To be a causal variable for another variable, the causal variable has to be a leading variable to the effect, or a target variable. Several studies restrict the topic to potential causality and require economically plausibility for support. Kestin, Karoly, Yang & Rayner, (1998) provide an overview of methods. We adopt a method developed by Seip and Grøn (2017), which determines LL relations for paired synoptic series of n = 3 consecutive observations. Significance at the 95% level can be established with n = 9 samples. In contrast to e.g. Granger causality calculations, the LL- method use here does not require the time series to be stationary. Before applying the method, some preliminary aspects must be done.

4.1. Detrending and smoothing

Detrending. We linearly detrended all 3 time series. Detrending for the CBI data may be questioned. However, during our study period, the economic policy may have changed such that the impact of the CBI on the economy would differ over time. When detrending a time series, it is usual to apply linear detrending to minimize shifting the series along the time-axis. We tested the linear detrending method versus a 1st difference method as it applied to the US GDP (e.g. Estrella and Hardouvelis (1991) and found that a linear detrending would shift a peak recession on the average one month, whereas a 1st difference method would shift a peak recession on the average 5 months (1^{st} differencing a sine function gives a cosine function that is shifted ¼ of the sine functions cycle period.) Applying the Hodrick–Prescott filter also have its caveats (Hamilton, 2018; Seip and Zhang, 2024).

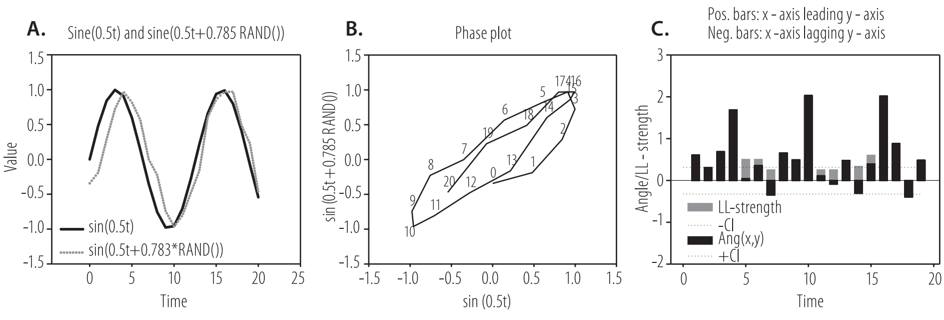
Smoothing. There is no canonical way to smooth data to identify with certainty movements that are the result of a given cause and its effect. If the series contains dynamic chaos, identifying component series that represent causes and effects may be difficult (Ellner and Turchin 2005, Cai et al, 2020). However, several methods have been used to identify embedded series that correspond to real processes (Huang et al., 1998; Alley, Brook & Anandakrishnan, 2002). We smoothed the series with the LOESS algorithm in SigmaPlot©, using fractions (f) = 0.07 to 0.2 of the series and a second order polynomial equation, (p) = 2 for interpolation. By smoothing, we avoid high frequency components, and thus noise. Lastly, the LL method identifies common cycles between paired series. When cycles are longer than 7 time steps, the probability that they occur by chance is less than p = 0.05 (Seip and Grøn, 2016), supporting the hypothesis that the smoothed series represent real cause - effect processes.

4.2. The leading-lagging (LL) method

The LL method calculates the running average LL relations, cycle times and lead and lag times (Phase shifts between cyclic series). The explanation of the method follows closely the description given in Seip and Grøn (2016) and consists of 4 steps.

In step 1, we illustrate the method with sampled sine functions, x = sin(0.5 t), leading the candidate target sine function, y = sin(0.5t- φ RAND()), where φ = π/4, and RAND() is a random component. The random component makes the example slightly more realistic (Figure 3a). With the candidate leading sine function, x = sin(0.5 t), on the x-axis, and the candidate target sine function, y = sin(0.5t- φ RAND()), on the y-axis, the rotation in a phase plot will largely be counterclockwise, as shown in Figure 3b. The angle between two successive trajectories is shown as black bars in Figure 3c. In the example, the candidate leading series on the x- axis is almost consistently leading the target series on the y-axis with a phase shift of π/4.

Figure 3: Example of leading- lagging (LL) relations and LL strength:
A. Two sine functions; the full line function is a candidate cause, and the dashed line function is the target. The candidate cause generally peaks before the target.
B. In a phase plot with the candidate cause on the x-axis and candidate target on the y-axis, the time series rotates counterclockwise (negative by definition), and θ is the angle between two consecutive trajectories.
C. Angles between successive trajectories (black bars) and LL strength (gray bars).



Note that for paired perfect sine functions, the phase plot will be elliptical with a center in the origin and the long axis with the direction 1:1 or 1: -1. See the text for details. The dashed lines suggest confidence limits for persistent rotation in the phase plot and persistent leading or lagging relations in the time series plot.

Source: Seip and Grøn (2016)

In step 2, we give the LL relationship a numerical representation. To see which variable peaks first, we quantify rotational directions, with the formula:

$$\theta = \text{sign}\,(v_1 \times v_2)\ \text{Arcos}\left(\frac{v_1 \cdot v_2}{|v_1|\,|v_2|}\right) \tag{1}$$

Here, v_1 and v_2 are two consecutive trajectory vectors in the phase diagram, and x denotes the vector product.

In step 3, we calculate the LL strength of the mechanisms that cause two variables to rotate either clockwise or counterclockwise in a phase portrait. It is measured by the number of positive rotations (counterclockwise rotations by convention) minus the number of negative rotations, relative to the total number of rotations over a certain period, 9 time steps in this study:

$$LL = (N_{pos} - N_{neg})/(N_{pos} + N_{neg}) \tag{2}$$

We use the nomenclature LL(x, y) = [-1, 1] for LL strength; LL (x, y) < 0 implies that y leads x, y→x, and LL(x, y) > 0 implies that x leads y, x→y. The light gray bars denote LL strength averaged over n = 5 (the sample is short). However, the dashed lines suggest confidence limits for n = 9. The LL strength for the series in Figure 4a is equal to 0.49 on a scale from -1 to +1. Thus, we can use the rotational directions in phase plots for two cyclic series to infer which series precedes the other in the sense that its peak (trough) is less than ½ of a cycle length before the peak (trough) of the other. However, the LL relations apply to all sections of the time series of 3 consecutive steps or longer. The LL strength passes through non-significant LL portions of the time series when LL relations change sign.

The LL method is relatively new. It has been applied earlier to a set of sentiment-based leading indices to the German industrial production (Seip, Yilmaz & Schroder, 2019). The leading indices were recognized by the LL- method as leading indices 77% to 78% of the time series duration. When the index was not leading, the German economy was abnormal.

The number of angles that must rotate in the same direction for the LL relation to be significant was found by applying Eq. (2) to two series of 9 observations generated by Monte Carlo simulations. The number 9 is a trade-off between the possibility of finding local LL relations and determining confidence interval. The LL strength of a time series is significant at the 95% interval if the LL strength < -0.32 or the LL strength > + 0.32. However, if the series are smoothed, the 95% confidence interval would increase.

Non-desired values of GDP and INF.

Our procedure for testing the hypotheses rest on the assumption that for the years with extreme values, the CBI would be a leading variable to GDP or INF since the BEAC would then adapt its monetary policy to stabilize the economy. The GDP and INF would then respond to the policy with a time lag. First, we identified time windows in the lead-lag time series for GDP and INF where CBI was a leading variable to the GDP and INF. At these dates the lead-lag relations have positive signs according to our definition. Second, we constructed three new auxiliary time series that have positive signs when GDP, INF or both have either very low or very high values of GDP growth, INF, or both. That is, GDP and INF have non-desired values. Thus, positive values in the LL-relations for GDP and CBI that correlates with positive values for a country's non-desired states would suggest that the BEAC is focusing on the GDP for that country. The same reasoning applies to the LL relations for CBI and INF.

5. Results and discussions

We present the LL relations that can be formed from GDP, INF, and CBI. These are the LL (GDP, CBI), the LL (CBI, INF) and the LL (GDP, INF). We arrange the LL relations so that LL(CBI, X) > 0 if –(minus) CBI is leading GDP or if CBI is leading INF. Thus, positive values show that the central bank is potentially pursuing an active monetary policy.

5.1. Results

The results for the CAEMC region act as a backdrop for the results for each country. High or low values of GDP and INF will generally solicit a response from the central banks in the form of lowering or increasing the CBI, that is, large gaps in output and INF. For both the GDP and the CBI there are defined concepts of "natural" values in the literature (Giammarioli and Valla 2004)[3]. For the GDP, a "natural" growth rate is between 2%yr^{-1} and 6%yr^{-1}. A "natural" inflation rate may be 3% for developing countries (Brunner Meier and Sannikov, 2016).

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[3] In its modern meaning, the natural CBI rate refers to the CBI which is compatible with a production at its potential level (natural GDP) and stable inflation.

5.1.1. Leading-lagging results for the CAEMC countries as a whole

For the CAEMC countries, the GDP growth rate is below 2% in 34% of the time and above 6% in 14% of the time. Low growth rates were common in the period 1990 to 1993 and from 2016 to 2019. The CAEMC target inflation rate is 3%. The INF rate was lower than 3% in 38% of the time and greater than 6% in 10% of the time. However, except for the years 1994-1998, inflation episodes were short and inflation moderate. The CBI in the CAEMC countries decreased systematically from 1990 to 2017 and it stood at 4.5% in 2022. However, the CBI changed more than 2% yr^{-1} in 27% of the time (1994, 2008, 2012 and 2017). Figure 4 shows the LL-relations between the three variables for the whole region. The GDP leads CBI during the first four years, but becomes a lagging variable after that time (Figure 4a, 4b). However, central banks lower their rate to boost the economy as GDP, so it is the negative value of CBI that will lead GDP if the central banks pursue a stabilizing policy. The CBI is a significant leading variable to INF during all years, except the last year (Figure 4c, 4d). GDP was a significant leading variable to INF during the period 2000 to 2012 (Figure 4e, 4f).

5.1.3. Leading-lagging results for each CAEMC country

We have calculated the LL relations for each country separately. We summarize the results for each pair of LL relations as expressed by the LL(x,y) time series. It highlights the variability of the Phillips curve over countries as noted by Leightner (2020).

CMR: The GDP leads CBI during the first three years and in 2011-2012, but was a lagging variable outside that period. The CBI is a significant leading variable to INF during most years, except in 2009 and 2010. GDP lags INF during the first 5 years and becomes a leading variable for the rest of the time.

CAF: The GDP leads CBI over most of the period except for the years 2004 and 2005. The CBI is a leading variable to INF during most of the years, except the years 2000, 2002, 2003, and 2004. GDP is a lagging variable to INF during the half of the period (1990-2006) and becomes a leading variable from 2007 to 2019.

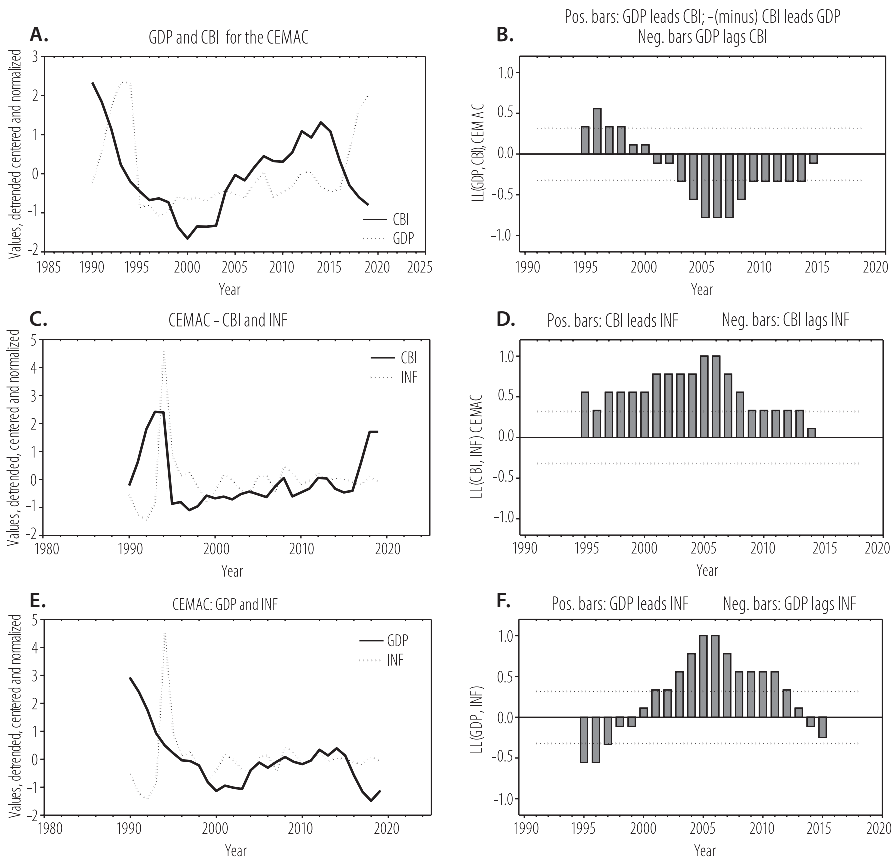
CHA: The GDP leads CBI only during five years, the first four years and in 2006. The rest of the time CBI leads GDP. The CBI is a significant leading variable to INF during all years, except the last two years. GDP is a lagging variable to INF during the first five years and the last two years but was a leading variable between those two periods.

COG: The GDP leads CBI during the first three years, but becomes a lagging variable after that time. The CBI is a significant leading variable to INF during all years. After being a lagging variable for the first year, GDP becomes a leading variable to INF for 8 years and a lagging variable for the next 8 years.

GNQ: The GDP leads CBI during the first four years, but becomes a lagging variable after that time. The CBI is a leading variable to INF during all years, except the years 1999, 2000 and 2001. GDP has alter from been leading and lagging variable to INF during the total period.

GAB: The GDP lags CBI over the most of the period except for the years 1996 and 2010. The CBI is a significant leading variable to INF during all years, except the last four years. GDP is a significant lagging variable to INF during the period 1994-2003 and becomes a leading variable the rest of the time.

Figure 4: Lead-lag relations for CAEMC countries



5.2. Discussion

For the sake of stability of inflation and the targeting rule, the central bank of CEAMC would increase its interest rate when inflation is high or approaches its "optimal" value and as long as the inflation rate remains below or equal to the 3% target, the central bank will manipulate the key interest rate to support or stabilise economic activity. In this case, we would anticipate that the CBI is leading the aggregate GDP and the average INF during the years when the variables are outside their desired target value. This would be in line with the results of Agur (2020). Looking at the results, it clearly appears that there are non-linear relationships between the interest rate, inflation and GDP in the CEAMC zone. There was a unidirectional non-linear causality between interest rate and inflation for the region as a whole. However, comparing the countries we notice that lead-lag directions change during periods. Thus, the probable causality goes both ways. Our results thus agree with those of Aydin et al. (2016) Anidiobu et al., (2018), Shaukat et al., (2019) We discuss the results obtained by comparing the lead-lag patterns of each country to the lead-lag patterns of the CAEMC as a whole in Figure 5. The comparison is made with PCA, and the fit is measured as the Euclidian distance in the PC1/ PC2 plots between the symbols representing the time series for the LL relation and the time series representing years with extreme values. If a country is a preferred country, the two series would be similar and close in the PCA plot, $LL_{CAEMC} \approx LL_{Country\ x}$. We then calculate the "distance" between the points in the PCA loading plot.

With respect to the GDP, the CBI was a lagging variable to GDP in two countries (GNQ and the COG) and in CEAMC as a whole. The two countries (GNQ and COG) showed the most similar LL developments to the development of CAEMC region (distances 0.03, range 0 to 1.0 for GNQ and distance 0.08 for COG) (Table 2). At this level it is the classical and neoclassical theory that seems to be verified. However, in the same period, the countries where the years that CBI had a leading role to GDP corresponded to years where GDP had extreme (low or high) values were GAB (0.19, range ≈ 0.0-1.6) and CHA (0.93) (Figure 5 and Table 3). This indicates that the BEAC's monetary policy has dampen volatility in GDP for those two countries. This corresponds to the Keynesian theories and with the analysis of Agarwal and Baron (2023).

Table 2: Similarity between the lead-lag relations between pairs of the variables GDP, CBI and INF for the CAEMC region as a whole and the LL- relations for each country

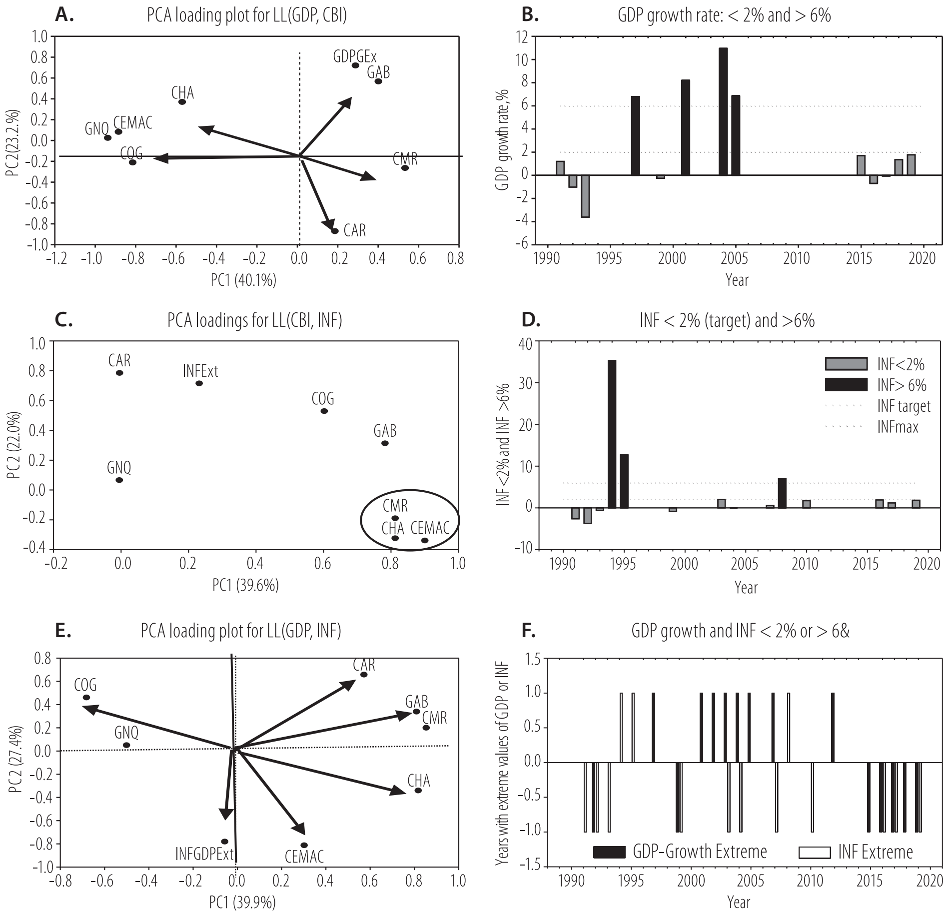
Country	GDP-CBI	CBI-INF	GDP- INF	Average
CMR	0.98	0.11	0.65	0.58
CAR	0.84	0.54	0.80	0.72
CHA	0.39	0.03	0.42	0.28
COG	0.08	0.42	0.94	0.48
GNQ	0.03	0.36	0.69	0.36
GAB	0.94	0.26	0.72	0.64

Table 3: Similarity between the lead-lag relations between pairs of the variables GDP, CBI and INF for each country and the years with Extreme values in GDP and INF

Country	GDP-CBI	CBI-INF	GDP-INF	AVERAGE
CMR	1.015012	1.075447	1.338285	3.428744
CAR	1.594266	0.245952	1.570586	3.410804
CHA	0.926641	1.190413	0.978775	3.095829
COG	1.444034	0.415014	1.390257	3.249305
GNQ	1.40939	0.690849	0.942124	3.042362
GAB	0.190205	0.682059	1.415936	2.288201

There are two caveats when we compare the leading relations LL (GDP, CBI) to the years when the Central Bank should take actions. First, we did not scale the dis-utility of a GDP growth rate between zero and 2% so that it would be comparable to the dis-utility of a positive rate above 6%. The asymmetric response to changes in the Central bank's interest rate was disused in Seip and McNown (2013). We do not know of any scaling measures. Second, in a PCA loading plot for cyclic time series, different positions will indicate that the two series may be displaced relative to each other, not necessarily that they have different developments. Since we examine symbols that are close, we have implicitly assumed that the BEAC react rapidly to non-desirable values and thus CBI would be close to the target value.

Figure 5: PCA loading plot for the LL (x,y) relations for each of the CAEMC countries



With respect to inflation, CHA and CMR are the countries that have the most similar LL relations to the CAEMC region (Distances 0.03-0.11) (Table 2) with CBI leading INF all the years. However, countries where the years that CBI had a leading role to INF best correspond to the years when INF had extreme (low or high) values were CAR (0.23-range 0-1.2) and COG (0.42) despite the relative difference in the development of their inflation patterns (Table 3). The two countries, CMR and CHA, showed similar inflation patterns, but it was different from the average inflation for the CAEMC region. GNQ and GAB showed similar inflation patterns, but the patterns were also different from that of the CAEMC region. Once again, with respect to inflation, classical and Keynesian theories merge in the CEAMC. In some countries, monetary policy had Keynesian overtones (CMR and CHA), while in others it had classical overtones (CAR and COG). But, on the whole, Central bank's interest rate appears to be a significant leading variable to the average inflation of the region meaning that for all the period there was a unidirectional causal relationship between the two variables.

The relation between all countries LL (GDP, INF) relations are shown in Figure 5e. In most cases, INF has had a variable leading and a positive relationship with GDP. This corresponds with the Keynesian theory and contrast with the results obtained by Azam, Khan & Khan (2022) for a panel of 8 North African countries. The CHA is the country that has the most similar LL relations to the CAEMC region (distance 0.42, range 0.4 – 1.0). The countries where the years that GDP had a leading role to INF best correspond to years where INF and GDP had extreme (low or high) values were GNQ (0.94- range 0.0 -1.6) and CHA (0.98) (Figure 5f and Table 3). GNQ and CHA have neither close GDP developments nor close developments in their INF rates. A summary of the comparison results is shown in Table 4. The table shows the countries that respond most similarly to the CAEMC region, and it shows which countries benefit most from the BEAC monetary policy.

Table 4: Comparison of LL- relations

LL-relation	Countries responding most similarly to the CAEMC economy as a whole	Countries where the BEAC policy responds to non-desired values
CBI→GDP	GNQ, COG	GAB
CBI →INF	CMR, CHA	CAR
GDP→INF	CHA	CAEMC

The results obtained have two major implications. One is that although monetary policy in the CAEMC zone has helped to stabilise the economic situation of certain countries from time to time, its priority has always been to stabilise the inflation rate of the whole region. This implies a relative independence of the CAEMC Central Bank (BEAC). This partly corroborates the results of the study carried out by Fouda (1997), despite the many reforms that have been introduced since then.[4] All six countries benefitted from the BEAC monetary policy at one time or another, either with respect to GDP or INF. There are several conjectures set forth that central banks may give favours that are not beneficial to the economies it serves, but that have outside forced (Kilby, 2009; Kersting and Kilby, 2016). Our definition of "benefitting" is that the central bank's policy actually leads to changes in the GDP or the INF in the region (the Central Bank is independent)

[4] See Avom (2006) for institutional reforms made in the BEAC since 1994.

or to changes in particular countries or economies (the Central Bank may be biased towards certain countries or certain economies). However, there may also be valid rationales for why the bank's policy targets particular countries or economies. The other implication is that the CEAMC economies are not synchronised.

6. Conclusion

To our knowledge, this is the first study that examines the relationship between interest rate, inflation and GDP in Central African countries. To identify traits, we use a new lead-lag method. We found that during the period 1990 to 2019 there was a unidirectional non-linear causality between interest rate and inflation for the region as a whole, but with periods for each country where lead-lag relations change direction. It was an extreme peak in inflation during the year 1995 and the experience with this inflation may have dominated the target policy of the central bank from that time until 2008, the year of the recent great depression. The CBI has still been a leading variable to INF, but less persistent. We also found that Gabon and Chad were the countries where the central bank interest rate most clearly was a leading variable to GDP when GDP showed non-desirable values. We see no obvious reason for why these two countries should be emphasized by the BEAC, so we will assume that the leading role of the CBI is just haphazard. Our results suggest a relative independence in the decisions of the central bank.

We do not intend to provide a final analysis on the relationship between interest rate, inflation and GDP in central African countries. Our results have an important implication for the creation of monetary unions and the ability to maintain them. The Central banks should try to synchronise the business cycles of the member countries. However, in view of the results obtained, the economic cycles of the CEAMC countries do not seem to be synchronised. Both the monetary and administrative authorities would therefore do well to work on mechanisms to help their economies converge.

References

1. Agarwal, I. & Baron, M. (2023). Inflation and Disintermediation Available at SSRN: https://ssrn.com/abstract=3399553
2. Agoba, A. M., Abor, J., Osei, K. A., & Sa-Aadu, J., (2017). Central bank independence and inflation in Africa: The role of financial systems and institutional quality. *Central Bank Review* 17(4): 131-146.
3. Agur, I., (2020). Central bank independence and low inflation: who leads the dance? *Applied Economics Letters*, 1–5. doi:10.1080/13504851.2020.1761525
4. Alley, R. B., Brook, E. J., & Anandakrishnan, S., (2002). A northern lead in the orbital band: north-south phasing of Ice-Age events. *Quaternary Science Reviews*, 21(1-3): 431-441.
5. Anidiobu, G., Okolie, P. I. P. & Oleka, D. C. (2018). Analysis of Inflation and Its Effect on Economic Growth in Nigeria. *Journal of Economics and Finance*, 9: 28–36.
6. Avom, D. (2006). La BEAC en marche vers son indépendance : des évolutions institutionnelles remarquables, in *Economies de l'Afrique centrale*, Maison Neuve, Paris, pp. 137-144.
7. Aydin, C., Esen, O., & Bayrak, M. (2016). Inflation and economic growth: A dynamic panel threshold analysis for Turkish Republics in transition process. *Procedia- Social Bahavioral Sciences*, 229, 196-205. https://doi.org/10.1016/j.sbspro.2016.07.129
8. Azam, M., Khan, R. & Khan, S. (2022). Does Phillips Curve Exist? Evidence from the Middle East and North African Countries, *Journal of Central Banking Theory and Practice*, 3:59-78.
9. Ball, L., Mankiw, N. G., & Romer, D. (1988). The New Keynesian Economics and the Output-Inflation Trade-Off. Brookings Papers on Economic Activity, 1988(1), 1–82.
10. Bernanke, B.S., Laubach, T., Mishkin, F. S. and Posen, A. S. (1999). Inflation targeting : lessons from the international experience. Princeton University Press, https://doi.org/10.2307/j.ctv301gdr
11. Bibow, J. (2002). What Has Happened to Monetarism? An Investigation into the Keynesian roots of Milton Friedman's Monetary Thought and its Apparent Monetarist Legacies. Working Paper, No. 347.
12. Bjornland, H. C., Brubakk, L. & Jore, A., (2008). Forecasting inflation with an uncertain output gap. *Empirical Economics*, 35(3): 413-436.
13. Brunnermeier, M. K., & Sannikov, Y. (2016). On the Optimal Inflation Rate. *American Economic Review*, 106 (5): 484-89.

14. Cai, W. J., Ng, B., Geng, T., Wu, L. X., Santoso, A. & McPhaden, M. J. (2020). Butterfly effect and a self-modulating El Nino response to global warming. *Nature*, 585(7823)
15. Cristini, A., and Ferri P., (2021). Nonlinear models of the Phillips curve. *J. Evolut. Econ.*, 31 (4), 1129-1155, 10.1007/s00191-021-00736-5
16. Davcev, L, Hourvouliades, N. & Komic, J. (2018). Impact of interest rate and inflation on GDP in Bulgaria, Romania and FYROM. *Journal of Balkan and Near Eastern Studies*, 20: 131–47
17. Ellner, S. P. & Turchin, P. (2005). When can noise induce chaos and why does it matter: a critique. *OIKOS* 111(3): 620-631.
18. Estrella, A. & Hardouvelis, G. A. (1991). The Term Structure as a Predictor of Real Economic Activity. *Journal of Finance*, 46(2): 555-576.
19. Fama, E. & Schwert, G. (1977). Asset returns and inflation. *Journal of Financial Economics*, 5, 115-146.
20. Fisher, S., (1993), "The Role of Macroeconomic Factors in Growth", *Journal of Monetary Economics*, 32, pp. 485-512
21. Fouda, S.M. (1997). Political monetary cycles and independence of the Central Bank in a Monetary union: an empirical test for a BEAC Franc Zone Member Country. *Journal of African Economies*, 6(1), 112-32
22. Bank of France (1995). Rapport annuel de la Zone Franc.
23. Friedman, M. (1961). The lag in effect of monetary policy. *Journal of Political Economy*, 69: 447–66
24. Giammarioli, N. & Valla, N. (2004). The natural real interest rate and monetary policy: a review. *Journal of Policy Modeling*, 26(5): 641-660.
25. Ghosh, A., & Phillips, S. (1998). Warning: Inflation May Be Harmful to Your Growth. *IMF Staff*, 45, 672-710. https://doi.org/10.2307/3867589
26. Gocer, I. & Ongan, S. (2020). The Relationship between Inflation and Interest Rates in the UK: The Nonlinear ARDL Approach. *Journal of Central Banking Theory and Practice*, 3: 77-86
27. Gokal, V., & Hanif, S. (2004). Relationship between Inflation and Economic Growth. Working Paper No. 2004/04, Suva: Economics Department, Reserve Bank of Fiji.
28. Gross M., and Semmler W., (2019). Mind the output gap: the disconnect of growth and inflation during recessions and convex Phillips curves in the Euro Area. *Oxf. Bull. Econ. Stat.*, 81 (4), 817-848, 10.1111/obes.12291
29. Gul, E. & Ekinci, A. (2006). The causal relationship between nominal interest rates and inflation: The case of turkey. *Scientific Journal of Administrative Development*, 4, 2006, 54–69.
30. Hamilton, J. D. (2018). Why You Should Never Use the Hodrick-Prescott Filter. *Review of Economics and Statistics*, 100(5): 831-843.
31. Hayek, F.A., 1933. The Trend of Economic Thinking. *Economica* 40, 121–137

32. Hayat, M. A., Ghulam, H., Batool, M., Naeem, M. Z., Ejaz, A., Spulbar, C. & Birau R. (2021). Investigating the Causal Linkages among Inflation, Interest Rate, and Economic Growth in Pakistan under the Influence of COVID-19 Pandemic: A Wavelet Transformation Approach. *Journal of Risk and Financial Management* 14: 277. https://doi.org/10.3390/jrfm14060277
33. Huang, N. E., Z. Shen, S. R. Long, M. L. C. Wu, H. H. Shih, Q. N. Zheng, N. C. Yen, C. C. Tung and H. H. Liu (1998). "The empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary time series analysis." *Proceedings of the Royal Society a-Mathematical Physical and Engineering Sciences* 454(1971): 903-995.
34. Jones, C. I., (2016). Life and Growth. *Journal of Political Economy*, 124, Number 2
35. Kersting, E. K. and Kilby C. (2016). "With a little help from my friends: Global electioneering and World Bank lending." *Journal of Development Economics*, 121: 153-165.
36. Keynes, J. M. (1936). The General Theory of Employment, Interest, and Money, Palgrave Mac-millan, London.
37. Kestin, T. S., Karoly, D. J., Yang, J. I., & Rayner, N. A., (1998). Time-frequency variability of ENSO and stochastic simulations. *Journal of Climate*, 11(9): 2258-2272.
38. Khan M. S. and Senhadji, A. S., (2001). "Threshold Effects in the Relationship Between Inflation and Growth," IMF Staff Papers, Palgrave Macmillan, 48(1), 1-21.
39. Kilby, C. (2009). "The political economy of conditionality: An empirical analysis of World Bank loan disbursements." *Journal of Development Economics* 89(1): 51-61.
40. Kumar, V., Acharya, S. & Ho, L.T.H.. (2020). Does Monetary Policy Influence the Profitability of Banks in New Zealand? *International Journal of Financial Studies*, 8: 35.
41. Kusumatrisna, A. L., Sugema, I. and Pasaribu, S. H. (2022) "Threshold effect in the relationship betweeb inflation rate and economic growth in Indonesia," *Bulletin of Monetary Economics and Banking*, 25(1), 14. DOI:https://doi.org/10.21098/bemp.v25i1.1045
42. Leightner, J. E. (2020). Estimates of the Inflation versus Unemployment Tradeoff that are not Model Dependent, *Journal of Central Banking Theory and Practice*, 1: 5-21
43. Machamer, P. and Wolters, G. (2007). Causality in economics. Thinking about causes. From Greek philosophy to modern physics. Pittsburgh, University of Pittsburgh press: 284- 296
44. McKinnon, R. I. 1973 Money and Capital in Economic Development. Brookings Institution Press,. http://www.jstor.org/stable/10.7864/jj.17497055.

45. Mallik, G. and Chowdhury, A. (2001) Inflation and Economic Growth: Evidence from Four South Asian Countries. *Asia-Pacific Development Journal*, 8, 123-135
46. Mishkin, F. S. (1989). International Experiences with Different Monetary Policy. National Bureau of Economic Research.
47. Mohsin S. K. & Abdelhak S. S., (2001). "Threshold Effects in the Relationship Between Inflation and Growth," IMF Staff Papers, Palgrave Macmillan, vol. 48(1), pages 1-1.
48. Omay, T., and Kan E. Ö., (2010). Re-examining the threshold effects in the inflation–growth nexus with cross-sectionally dependent non-linear panel: Evidence from six industrialized economies, *Economic Modelling*, 27(5), 996-1005,
49. Ramlan, H., & Suhaimi, M. (2017). The relationship between interest rate and inflation toward the economic growth in Malaysia. *Journal of Humanities, Language, Culture and Business (HLCB)*, 1(1), 55-63.
50. Seip, K. L. & Grøn, Ø. (2016). Leading the Game, Losing the Competition: Identifying Leaders and Followers in a Repeated Game. *Plos One* 11(3).
51. Seip, K. L. & Grøn, Ø. (2017). On the statistical nature of distinct cycles in global warming variables. *Climate dynamics*.
52. Seip, K. L. & McNown, R. (2007). The timing and accuracy of leading and lagging business cycle indicators: a new approach. *International journal of forecasting*, 22: 277-287.
53. Seip, K. L. & McNown, R. (2013). Monetary policy and stability during six periods in US economic history: 1959-2008: a novel, nonlinear monetary policy rule. *Journal of policy modeling*, 35(2): 307-325.
54. Seip, K. L., Yilmaz, Y. & Schroder, M. (2019). Comparing Sentiment- and Behavioral-Based Leading Indexes for Industrial Production: When Does Each Fail? *Economies*, 7(4).
55. Seip, K. L. & Zhang, D. (2024). Scoring Six Detrending Methods on Timing, Lead-Lag Relations, and Cycle Periods: An Empirical Study of US and UK Recessions 1977–2020. *Computational Economics*. https://doi.org/10.1007/s10614-024-10548-x
56. Shaukat, B., Zhu, Q. & Khan, M.I. (2019). Real interest rate and economic growth: A statistical exploration for transitory economies," Physica A: Statistical Mechanics and its Applications, *Elsevier*, vol. 534(C). DOI: 10.1016/j.physa.
57. Shaw, E.S. (1973). *Financial Deepening in Economic Development*, Oxford University Press, New York.
58. Stips, A., Macias, D., Coughlan, C., Garcia-Gorriz, E., and San Liang X. (2016). "On the causal structure between CO2 and global temperature." Scientific Reports 6.

59. Sugihara, G., May, R., Ye, H., Hsieh, C. H., Deyle, E., Fogarty, M. & Munch, S. (2012). Detecting Causality in Complex Ecosystems. *Science*, 338(6106): 496-500.
60. Taderera, C., Runganga, R., Mhaka, S., & Mishi, S. (2021). Inflation, Interest Rate and Economic Growth Nexuses in SACU Countries, MPRA Paper No. 105419.
61. Taylor, J.B., 1993. Discretion versus Policy Rules in Practice. Carnegie-Rochester Conference Series on Public Policy 39, December, 195-214.
62. Tobin, J. (1969) A General Equilibrium Approach to Monetary Theory. *Journal of Money, Credit & Banking*, 1, 15-29. https://doi.org/10.2307/1991374
63. Umoru, D. & Oseme, A. S., (2013). Inflation Expectations and Interest Rate Variation in Nigeria: An Econometric Assessment of the Evidence. *International Journal of Development and Economic Sustainability*, 1(2), 1-12.
64. Vinayagathasan, T., (2013). Inflation and economic growth: A dynamic panel threshold analysis for Asian economies. *Journal of Asian Economics*, 26, 31-41.
65. Westerlund, J., (2008). Panel cointegration tests of the fisher effect. *Journal of Applied Econometrics*, 23 (2), 193–23