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Methodological and Ideological Options

Reconsidering Monetary Policy: An Empirical Examination of the Relationship Between Interest Rates and Nominal GDP Growth in the U.S., U.K., Germany and Japan

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ABSTRACT

The rate of interest – the price of money – is said to be a key policy tool. Economics has in general emphasised prices. This theoretical bias results from the axiomatic-deductive methodology centring on equilibrium. Without equilibrium, quantity constraints are more important than prices in determining market outcomes. In disequilibrium, interest rates should be far less useful as policy variable, and economics should be more concerned with quantities (including resource constraints). To investigate, we test the received belief that lower interest rates result in higher growth and higher rates result in lower growth. Examining the relationship between 3-month and 10-year benchmark rates and nominal GDP growth over half a century in four of the five largest economies we find that interest rates *follow* GDP growth and are consistently *positively* correlated with growth. If policy-makers really aimed at setting rates consistent with a recovery, they would need to *raise* them. We conclude that conventional monetary policy as operated by central banks for the past half-century is fundamentally flawed. Policy-makers had better focus on the quantity variables that cause growth.

1. Introduction

> "*What is it that monetary policy-makers do and how do they do it? The simple answer is that a central banker moves interest rates…*"
>
> Cecchetti (2000).

The policy tool emphasised over the past half-century by conventional economics and central bank publications is the interest rate, also known as the 'price of money'. A vast literature declares the primacy of interest rates and interest policy in macroeconomics. Yet, many ecological economists argue that a debt and interest-based system may be responsible for an unsustainable bias of economies towards harmful growth (Soddy, 1926; Binswanger, 1982, 2012; Daly, 1991; Douthwaite, 2012). Soddy pointed out that debt growing at interest was a social construct pushing the economy towards the boundaries set by finite resources and the laws of physics. The work of such writers is often the basis for the call for a fundamental change of the monetary system, moving away from interest, as well as from a debt-based money supply, to 'full reserve banking' (see Fisher, 1935; Huber and Robertson, 2000; Benes and Kumhof, 2012), which has also been presented as a 'green' banking reform (Dittmer, 2015). However, others are unconvinced, such as Dolenc Dalendina (1997); Horowitz (1996), who defends the focus on 'prices'; Loehr (2012), who advocate negative rates based on Gesell (1916) and Jackson and Victor (2015). The literature review by Aspinall et al. (2015) concluded that there is a need for more empirical work on these and related issues to help us understand the interrelations between finance and sustainable growth.

While these questions are disputed, one related issue seems without debate: All major economic schools of thought, namely classical (e.g. Ricardo, 1817), neoclassical (e.g. Marshall, 1890), Keynesian (Keynes, 1936; Hicks, 1937; Tobin, 1969), monetarist (Brunner and Meltzer, 1971; Friedman, 1970), new classical (Lucas, 1975), 'neo-Wicksellian' (e.g. Woodford, 2003), as well as post-Keynesian (e.g. Lavoie, 1995), Austrian (e.g. Garrison, 1989) and some ecological economics (e.g. Horowitz, 1996; Baum, 2009) claim that *lower rates stimulate economic growth* and vice versa. The same claim is frequently made by central banks. However, there is a paucity of empirical evidence. The present paper for the first time systematically examines the empirical relationship between the *level* of nominal interest rates and economic growth. Knowledge of the empirical relationship between them provides a foundation for the debates in ecological economics and it is also necessary for an effective conduct of monetary and macroeconomic policy.

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2. Theoretical Foundations and Existing Empirical Evidence

Interest rates are the price of money. Since Marshall (1890) and Walras (1874), economics has emphasised prices over quantities. The former gave his name to the 'Marshallian cross' of upward-sloping supply and downward-sloping demand curves, and the latter had constructed the theory that markets are in equilibrium. Equilibrium and optimality are also the analytical framework for many researchers in resource economics (e.g. Clark, 1976).

In an equilibrium setting, prices are key: their movement is said to achieve the postulated equilibrium. Any problem (such as persistent large-scale unemployment) is interpreted as being due to price 'rigidity' that must be remedied. Due to this analytical emphasis on price variables, relatively little research has been produced on the role of quantities in the economy – including resource constraints. Daly (1991) identified the 'microeconomic' excessive focus on prices and lack of recognition of quantity constraints as major problems in standard economics.

The focus on equilibrium and prices is due to the hypothetico-axiomatic method, a.k.a. the *deductive methodology*. The axioms are postulated that people are individualistic and focus on maximising their own satisfaction (named 'utility', in honour of Jeremy Bentham, the first economist to argue for the legalisation of the then banned practice of charging interest; Bentham, 1787). Next, a number of assumptions are made: perfect and symmetric information, complete markets, perfect competition, zero transaction costs, no time constraints, fully flexible and instantaneously adjusting prices. McCloskey (1983) has argued that economics has been using mathematical rhetoric to enhance the impression of operating scientifically. Equilibrium will not obtain, if only one of the axioms and assumptions fails to hold. But their accuracy is not tested. Yet, one can estimate the probability of obtaining equilibrium.

Despite the claims to rigour, the pervasive equilibrium argument and focus on prices reveal a weak grasp of probability mathematics: Since for partial equilibrium in any market, at least the above eight conditions have to be met, if one generously assumed each condition is more likely to hold than not – corresponding to a probability higher than 50%, for instance, 55% – then the probability of equilibrium equals the joint probability of all conditions, which is 0.55 to the power of 8: less than 1%. As the probability of each of the eight conditions being an accurate representation of reality is likely significantly lower than 55% (most having a probability approaching zero themselves), it is apparent that the probability of partial equilibrium in any one market approaches zero (Werner, 2014b). For equilibrium in *all* markets, these very low probabilities have to be multiplied by each other many times. So we know a priori that partial, let alone general equilibrium cannot be expected in reality. Equilibrium is a theoretical construct unlikely to be observed in practice. This demonstrates that reality is instead characterised by rationed markets. These are not determined by prices, but quantities: In disequilibrium, the *short side principle* applies: whichever quantity of supply and demand is smaller can be transacted, and the short side has the power to pick and choose with whom to trade (not rarely abusing this market power by extracting 'rents', see Werner, 2005).[1]

Without equilibrium, quantities become more important than prices. Whether this is also true in the crucial markets for money, with interest as its price, is a testable hypothesis we shall examine in this paper. Specifically, we are testing the oft-repeated claim that lower interest rates will stimulate economic growth, and higher rates will slow it. The number of researchers advocating the use of interest rates as the intermediate monetary policy instrument to move the economy is long (to name a few: Bernanke and Blinder, 1992; Taylor, 1993; Judd and Motley, 1993; Woodford, 2003).

Should it be found empirically that interest rates are not in fact related to economic growth as postulated, this would support the rationing argument, and monetary policy would have to be fundamentally altered. Negative interest rates, demanded by some (Rogoff, 2016), could not be justified.

Werner (1996, 2005) argued that interest rates follow economic growth and are positively correlated with it.[2] In ecological economics, Tisdell (2011) doubts the validity of the proclaimed relationship between the level of interest rates and economic growth and argues that "the market rate of interest can increase or decrease with a rise in aggregate investment and also with an increase in the level of aggregated economic activity." Tisdell also concludes that instead of focusing on prices, greater emphasis should be placed on quantities: "It is the level of aggregate economic activity (particularly, the aggregate level of investment) that is of greatest significance for the depletion of natural resources" (p. 2515).

Concerning the empirical record, no systematic empirical study of the question of how the level of nominal interest rates is related to nominal economic growth exists. This is surprising, especially since researchers have over the years found grounds for doubt concerning the canonical central bank model of lower interest rates resulting in higher growth: Werner (1994) found that in a model of capital flows, price variables (interest rates and interest differentials) had little explanatory power, while quantity variables did (the quantity of credit creation). Melvin (1983) and Leeper and Gordon (1992) found little support for the so-called 'liquidity effect' of interest rates on the money supply. Many studies refer to an observed positive correlation between interest rates and inflation as the 'price puzzle' (first identified by Sims, 1992, see also Hanson, 2004). King and Levine (1993) did not find evidence to support the hypothesized relationship between real interest rates and economic growth in a cross-section of countries. Taylor (1999) found that the link between real interest rates and macroeconomic aggregates such as consumption and investment is tenuous. Kuttner and Mosser (2002) found a positive correlation between real GDP growth and interest rates in the US between 1950 and 2000. Dotsey et al. (2003) examined the behaviour of real interest rates, finding that they are contemporaneously positively correlated with lagged cyclical output. The Department of Commerce has not included interest rates in its list of 'Leading Indicators' nor in its list of 'Coincident Indicators'. Instead, it considers interest rates a *lagging* indicator of economic growth (a fact neglected by proponents of the interest paradigm).[3] Finally, there is the experience of Japan, where interest rates have been falling for over two decades (since 1991, having recently fallen into negative territory), without a clearly identifiable positive effect on growth. This has posed a significant challenge to virtually all schools of thought in macroeconomics (see Werner, 2003b, 2005, 2006).[4]

Milton Friedman claimed already in the 1960s:

> "*As an empirical matter, low interest rates are a sign that monetary policy has been tight – in the sense that the quantity of money has grown slowly; high interest rates are a sign that monetary policy has been easy- in the sense that the quantity of money has grown rapidly. The broadest facts of experience run in precisely the opposite direction from that which the financial community and academic economists have all generally taken for granted*"
>
> (Friedman, 1968, p. 7).

Despite such sporadic indications that interest rates are not 'well-

[1] Some economists have argued for market rationing in the 1960s and 1970s; see, for instance, Malinvaud (1977) and Muellbauer and Portes (1978).

[2] Based on this approach, Werner proposed a focus on the quantity of credit creation for GDP and non-GDP transactions (credit for the 'real economy' determining nominal GDP and credit for financial transactions determining asset prices and financial fragility) for both macroeconomic analysis and policy, i.e. the Quantity Theory of Credit, see Werner (1997, 1992, 2012a, 2013a, 2013b).

[3] An exception is Stock and Watson (1989).

[4] This challenge is not explained by the so-called 'liquidity trap' argument, since this fails to address the question at hand (why interest rate *reductions* have failed to have the proclaimed positive effect on growth).

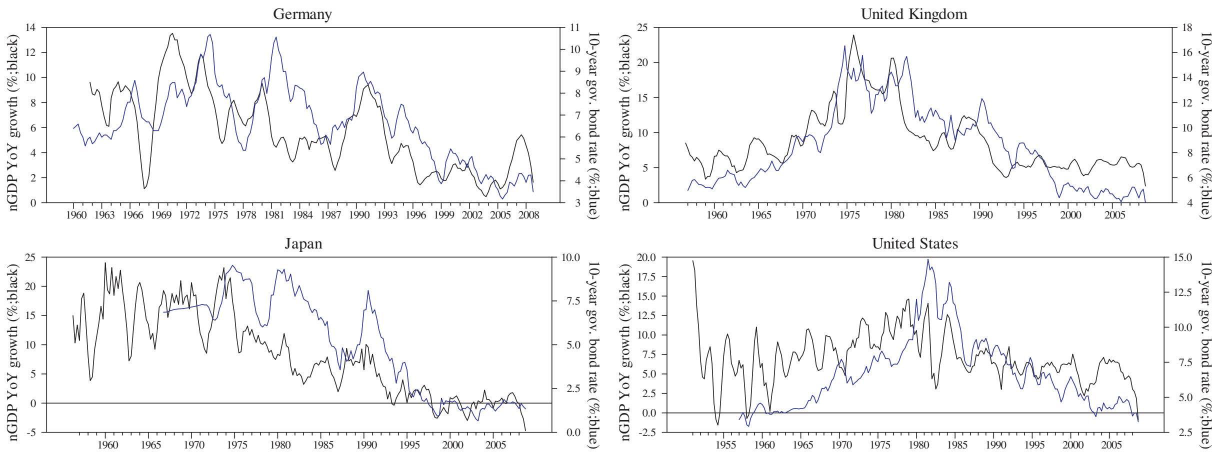

Fig. 1. Nominal GDP growth vs. 10-year government bond rates.

behaved', our paper is the first that is systematically evaluating the relationship between nominal interest rates and nominal GDP growth in several major economies. We use data from top economies on the half-century until 2008. After that, monetary policy arguably shifted away from interest rates to "quantitative easing" (Voutsinas and Werner, 2011; Lyonnet and Werner, 2012; Werner, 2013b).

The choice of the four major economies reflects our interest in industrialised economies, where the mainstream postulate is said to apply most unreservedly. The UK has been a top-5 and top-7 economy, while the remaining three economies have been the top-3 economies for the entire observation period. Moreover, the literature on different 'varieties of capitalism' compares the US/UK-style economic system with the German and Japanese-style economies ('stock market capitalism' vs. 'bank-based capitalism'/'welfare capitalism', see Zysman, 1983; Dore, 2000). We can thus check for robustness across these 'varieties of capitalism'.

Using diverse tests and methods, we analyse correlation and statistical causality. We found no empirical support for the much-asserted negative correlation between interest rates and growth nor any consistent support for statistical causation running from interest rates to economic growth. Instead we found that interest rates follow nominal GDP growth, and are positively correlated (as argued by Werner, 2005). These findings imply that traditional monetary policy is flawed. They also provide a new basis for the debates about interest and resource constraints.

The rest of the paper is structured as follows: Section 3 describes our data. Sections 4 and 5 discuss the empirical methods and results concerning correlation and statistical causation, respectively. Section 6 summarises and concludes.

3. Data

We used quarterly non-seasonally adjusted data on nominal GDP growth, 3-month interest rates and 10-year government yields, covering 52 years (1957Q1 to 2008Q4) for the UK, US and Japan (except for the Japanese 10-year government bond yield series, which begins in 1966Q4 with the issuance of the first government bonds) and 47 years (1961Q4 to 2008Q4) for Germany.[5] In all cases we calculated the year-on-year (YoY) growth rate (equivalent to seasonal log differences).

[5] GDP: US Department of Commerce; UK Office for National Statistics (ONS); Deutsche Bundesbank; Japanese Cabinet Office (combining 68SNA and 93SNA); all countries also from IFS-IMF and OECD (Datastream), which allowed us to adjust the break point at 1991Q1 due to German 'unification'. As US authorities stopped publishing the original, non-seasonally-adjusted nominal GDP series in 2007, we had to use seasonally-adjusted US data for two years (source: Thomson Datastream). The effect of mixing seasonally and non-seasonally adjusted data for these two years is negligible, as correctly undertaken seasonal adjustment should produce similar results.

We examine the link between growth and both short and long-term rates, measured by 3-month Treasury bill rates or money market rates and 10-year government bond yields. Monthly data from International Financial Statistics (IMF) were converted into quarterly data using the geometric average. For data reliability, we also compared data from other sources (the Fed, Bank of England, Eurostat Frankfurt bank rate). The 3-month bill rates from Fed and IMF were found to be identical. The 3-month UK Treasury bill rate from the IFS and Bank of England were identical; the 3-month Japanese rate was identical to Eurostat data. The German 3-month bill rate series was not long enough in the IFS database, so we used the Frankfurt bank middle rate from Datastream, which was very similar for the overlapping period.

4. Correlation Results

4.1. Correlation Between Growth and Long-term Rates

Fig. 1 contrasts the nominal GDP YoY growth rate with the 10-year government bond rates for each country examined. We first estimated constant correlations of nominal GDP YoY growth (at time t) with the 10-year government bond rates (t − 4 to t + 4). Table 1 reports the results. The contemporaneous correlations between economic growth and long-term rates are found to be positive and statistically significant. The correlation between economic growth (t) and interest rates (t + 1 to t + 4) are higher than the correlations between economic growth (t) and interest rate (t − 1 to t − 4). For instance, the German economic growth rate (t) is much more highly and positively correlated to interest rate (t + 4) than interest rate (t − 4): i.e., 0.6906 vs. 0.3907. The same is observed in all other countries. Interest rates appear not to 'lead', but to 'follow' economic growth.

These linear correlations are reliable only if the two time series (available at arbe.org.uk, Table B) are stationary (or co-integrated when non-stationary). We conducted the ADF unit root tests for each of the examined time series and the Engle-Granger co-integration tests for their bilateral relationships (available at arbe.org.uk, Tables C1 and C2). Nominal GDP YoY growth is found to be I(0) in Germany and Japan, but I(1) in the UK and the US. The 10-year government bond yield is I(0) in Japan, and I(1) in all other countries. This implies that there cannot be co-integration between economic growth and the long-term interest rate in Germany and Japan, while such a relation can exist in the UK and the US. We found that residuals from OLS regressions between the two variables can be stationary (i.e., the co-integration relation can be validated) depending on the number of lags included in the regression equations for all of the four countries, even in Germany and Japan (arbe.org.uk, Tables C1 and C2).

The above suggests a non-linear framework may be preferable. We conducted the Tse test (Tse, 2000) and confirmed that the correlation is not linear in all countries examined (arbe.org.uk, Table D).

Table 1
Constant correlations between nominal GDP growth and 10-year government bond rates.

Country	Germany	Japan	United Kingdom	Unites States
Correlation/sample period	1961:4 to 2008:4	1966:4 to 2008:4	1957:1 to 2008:4	1957:1 to 2008:4
nGDP growth rate (t) and 10-year gov. bond rate (t − 4)	0.3907	0.7029	0.7429	0.2590
nGDP growth rate (t) and 10-year gov. bond rate (t − 3)	0.4551	0.7204	0.7603	0.3007
nGDP growth rate (t) and 10-year gov. bond rate (t − 2)	0.5164	0.7424	0.7732	0.3472
nGDP growth rate (t) and 10-year gov. bond rate (t − 1)	0.5698	0.7591	0.7840	0.4062
Contemporaneous correlation	0.6101	0.7755	0.7942	0.4614
nGDP growth rate (t) and 10-year gov. bond rate (t + 1)	0.6344	0.7909	0.8034	0.4911
nGDP growth rate (t) and 10-year gov. bond rate (t + 2)	0.6552	0.7986	0.8174	0.5067
nGDP growth rate (t) and 10-year gov. bond rate (t + 3)	0.6750	0.8073	0.8325	0.5162
nGDP growth rate (t) and 10-year gov. bond rate (t + 4)	0.6906	0.8132	0.8436	0.5119

Notes: Constant correlations of nominal GDP YoY growth at time t with up to 4 quarters leading (t − 4) and 4-quarters lagging (t + 4) 10-year government bond rates. According to the conventional *t*-test statistic, all the correlation coefficients presented in this table are statistically different from zero at the 1% significance level.

Consequently, we estimated conditional, time-varying correlations using DCC-GARCH models (Engle, 2002).

To obtain the best dynamic conditional correlation series, we first estimate DCC-GARCH (*p*,*q*) model specifications by combining *p* (= 1, 2, 3) and *q* (= 1, 2, 3) and considering different options for the mean/variance equations in the model.[6] So for each country, we estimate 3 times 3 times 4 (the latter are the four GARCH model options), i.e. 36 model specifications. We then select the best specification from among the competing models (based on both model convergence and performance measured by general significance of parameter estimates). The latter is identified following the principle of parsimony, so that the model that best fits the data with the least number of parameters is selected.

The DCC-GARCH model is often used to estimate the ARCH/GARCH-type behaviour of each individual variable in a multivariate approach (i.e., resulting from the conditional likelihood function of each individual variable, maximised under the assumption of time-varying covariance and correlation). But we here use it to 'extract' the time-varying correlation that should describe best both the individual and joint behaviours between the variables.

From the 36 model specifications for each country and applying the above model selection criteria, we identified the DCC-GARCH (1, 1, option = 3) as the best model specification, common to all countries examined. For all countries, the model converges and all parameters estimates are significant at 1%, with a few exceptions. This indicates that the DCC-GARCH model fits the individual and joint behaviours of economic growth and interest rates in all countries considered.

The resulting series of dynamic conditional correlation between economic growth and long-term interest are shown in Fig. 2: The time-varying correlation is strongly positive (even close to one) during virtually the entire sample period in Germany, the UK and the US. The same is true in Japan until 1992, significantly 'disturbed' in 1993 (close to 0.50) and in 1999, 2002 and 2008 (close to zero and even slightly negative temporarily). Apart from these short periods of disturbance, the correlation in Japan is 'dynamic' while recording some levels at around 0.50 in the 2000s. Despite the high and close-to-one correlations, the Jarque-Bera statistics (arbe.org.uk, Table 2) confirm the non-normality of the distributions of the estimated DCC series and thus confirm ex post the use of this non-linear approach to describe the correlation behaviour between economic growth and long-term interest.

4.2. Correlation Between Growth and Short-term Rates

Fig. 3 depicts the nominal GDP YoY growth rate and the 3-month interest rate. Again, visual inspection suggests short-term rates follow GDP growth, with higher growth resulting in higher rates and lower growth decreasing rates in all countries examined. Table 2 reports the constant correlations, which are very similar to those with long-term rates: (1) They are all positive and statistically different from zero in all countries examined, and (2) the correlations between economic growth (at time t) and interest rates (t + 1 to t + 4) are higher than the correlations between economic growth (t) and interest rates (t − 1 to t − 4). This supports the idea that short-term interest rates also follow economic growth.

Unit root tests (arbe.org.uk, Table B) and co-integration tests (arbe.org.uk, Tables C3 and C4) suggest that the linear correlations between economic growth and 3-month interest rates can be biased in some cases. Results from the Tse test (arbe.org.uk, Table E) confirm that the correlation between economic growth and the short-term rate is a non-linear process in all countries examined. Consequently, the conditional, time-varying correlations are examined. Table 3 reports descriptive statistics of the estimated DCC-GARCH correlations between growth and short rates. Fig. 4 illustrates them graphically. Again, the results are striking: The time-varying correlations between economic growth and short-term rates are highly positive during the entire sample period in all countries, including Japan. We notice the Japanese DCC series between growth and short-term rates during the 'disturbed' periods (i.e., around 1993, 1999, 2002 and 2008) is more stable and higher than the DCC series between growth and long rates. Again, the Jarque-Bera statistics of the estimated DCC series (Table 3) confirm ex post the validity of the non-linear correlation between economic growth and short-term interest rates. Overall, these DCC series also confirm the key idea that economic growth is not negatively but positively correlated with interest rates.

5. Causation Results

5.1. Causation Between Growth and Long-term Rates

We tested whether there is statistical causation between nominal GDP growth and long-term interest rates by implementing Granger causality tests (Granger, 1969), complemented by bootstrapped *p*-values and GMD tests (Geweke et al., 1982). According to Sims et al. (1990), the Granger causality test may suffer from a non-standard distribution problem (i.e., the F-test statistic does not have a standard asymptotic distribution), especially when the series have unit roots. To check the robustness of our results about the causality between the examined variables that are I(0) or I(1), we complement the Granger causality test by applying the 'bootstrapping technique'.[7] This

[6] Option 1 = no constant term or asymmetric effect in the mean/variance equations; Option 2 = with a constant term (μ) in the mean equation; Option 3 = with asymmetric effects (δ) in the variance equation; Option 4 = with a constant term (μ) in the mean equation and asymmetric effects (δ) in the variance equation.

[7] Applied to our Granger causality tests, the bootstrapping technique consists of 're-sampling' the residuals from the test equations, which allows us to simulate the 'true' or 'ad hoc' asymptotic distribution of the F-test statistic and hence to determine the unbiased significance level corresponding to the test statistic obtained, possibly in the presence of unit roots. For a comprehensive description of bootstrap techniques, see, for instance, Greene (2011).

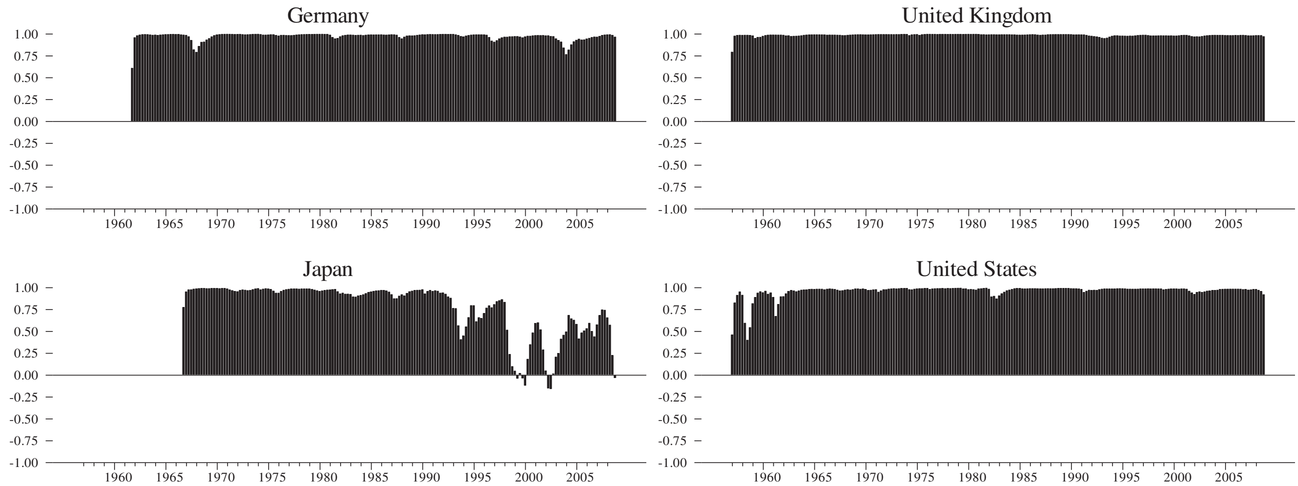

Fig. 2. Estimated DCC between nominal GDP growth and 10-year government bond rates.
Note: The parameter estimates of the selected model for each country are available at arbe.org.uk, Table G.

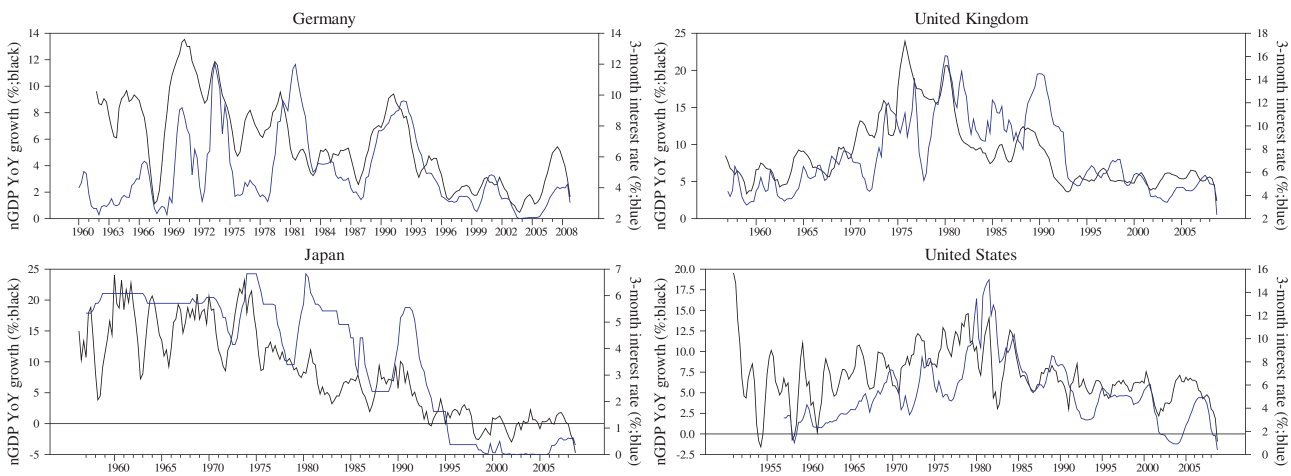

Fig. 3. Nominal GDP growth vs. 3-month interest rate.

Table 2
Constant correlations between nominal GDP growth and 3-month interest rates.

Country	Germany	Japan	United Kingdom	Unites States
Correlation/sample period	1961:4 to 2008:4	1957:1 to 2008:4	1957:1 to 2008:4	1957:1 to 2008:4
nGDP growth rate (t) and 3-month interest rate (t − 4)	0.1722	0.7539	0.4870	0.1868
nGDP growth rate (t) and 3-month interest rate (t − 3)	0.2578	0.7665	0.5272	0.2452
nGDP growth rate (t) and 3-month interest rate (t − 2)	0.3513	0.7812	0.5638	0.3279
nGDP growth rate (t) and 3-month interest rate (t − 1)	0.4373	0.7958	0.5978	0.4330
Contemporaneous correlation	0.5038	0.8093	0.6305	0.5239
nGDP growth rate (t) and 3-month interest rate (t + 1)	0.5381	0.8225	0.6501	0.5678
nGDP growth rate (t) and 3-month interest rate (t + 2)	0.5534	0.8318	0.6689	0.5947
nGDP growth rate (t) and 3-month interest rate (t + 3)	0.5475	0.8364	0.6860	0.6044
nGDP growth rate (t) and 3-month interest rate (t + 4)	0.5297	0.8379	0.6970	0.5965

Notes: Constant correlations of nominal GDP YoY growth at time t with up to 4-quarters leading (t − 4) and 4-quarters lagging (t + 4) 3-month interest rates. According to the conventional *t*-test statistic, all the correlation coefficients presented in this table are statistically different from zero at the 1% significance level. The sample period is from 1961Q4 to 2008Q4 for Germany; from 1966Q4 to 2008Q4 for Japan; and from 1957Q1 to 2008Q4 for the United Kingdom and the United States.

Table 3
Descriptive statistics of the estimated DCC series between nominal GDP YoY growth rates and 3-month interest rates.

Country	Obs.	Mean	Min.	Fract. 5%	Fract. 10%	Median	Fract. 90%	Fract. 95%	Max.	Variance	J.-B. stat.	J.-B. stat. signif.
Germany	189	0.9721	0.5038	0.9148	0.9353	0.9837	0.9948	0.9957	0.9980	0.0021	31,354	0.0000
Japan	169	0.8636	0.2348	0.5542	0.6535	0.9365	0.9892	0.9916	0.9947	0.0221	83	0.0000
United Kingdom	208	0.9783	0.6305	0.9568	0.9635	0.9815	0.9938	0.9948	0.9979	0.0007	160,377	0.0000
United States	208	0.9550	0.5239	0.8311	0.9028	0.9779	0.9902	0.9917	0.9958	0.0041	2606	0.0000

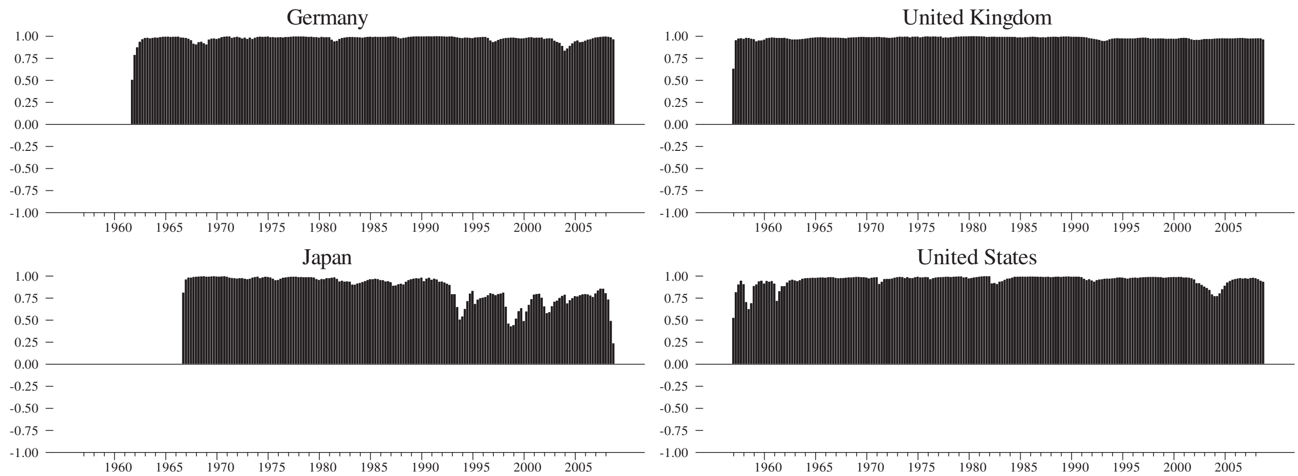

Fig. 4. Estimated DCC between nominal GDP YoY growth rates and 3-month interest rates.
Note: The parameter estimates of the selected model for each country are available at arbe.org.uk, Table G.

Table 4
Granger causality tests from 10-year government bond rates to nominal GDP growth.

	Germany	Japan	United Kingdom	United States
Sample period	1961:4–2008:4	1966:4–2008:4	1957:1–2008:4	1957:1–2008:4
Observations	189	169	208	208
Granger-test statistic F	2.1918	1.0358	0.7201	1.4592
df1;df2 (Granger test)	8; 164	8; 144	8; 183	8; 183
p-Value (Granger test)	0.0305	0.4120	0.6736	0.1749
Bootstrapped *p*-value	0.0363	0.4593	0.6874	0.1942
GMD-test statistic F	2.8067	0.6546	1.6306	1.6927
df1;df2 (GMD test)	4; 155	4; 135	4; 174	4; 174
p-Value (GMD test)	0.0276	0.6247	0.1686	0.1538

Notes: The null hypothesis for the Granger test is that past values of 10-year gov. bond rates do not explain the present value of the nominal GDP YoY growth rate. The 'bootstrapped' *p*-values come from simulated F distributions based on 'resampled' residuals of initial Granger causality test equations. The null hypothesis for the GMD test is that future values of nominal GDP YoY growth rates do not 'explain' the present value of 10-year gov. bond rates.

Table 5
Granger causality tests from nominal GDP growth to 10-year government bond rates.

	Germany	Japan	United Kingdom	United States
Sample period	1961:4–2008:4	1966:4–2008:4	1957:1–2008:4	1957:1–2008:4
Observations	189	169	208	208
Granger-test statistic F	1.9840	2.2880	2.8978	2.8195
df1;df2 (Granger test)	8; 164	8; 144	8; 183	8; 183
p-Value (Granger test)	0.0514	0.0246	0.0046	0.0057
Bootstrapped *p*-value	0.0696	0.0416	0.0056	0.0081
GMD-test statistic F	0.8374	2.5380	0.6658	2.5056
df1;df2 (GMD test)	4; 155	4; 135	4; 174	4; 174
p-Value (GMD test)	0.5034	0.0429	0.6166	0.0439

Notes: The null hypothesis for the Granger test is that past values of the nominal GDP YoY growth rate do not explain the present value of 10-year government bond rates. The 'bootstrapped' *p*-values come from simulated F distributions based on 'resampled' residuals of initial Granger causality test equations. The null hypothesis for the GMD test is that future values of 10-year gov. bond rates do not 'explain' the present value of nominal GDP YoY growth rates.

simulation method allows us to confirm the significance level of the Granger test without any bias that may be due to a non-standard distribution problem.

We also implement the Geweke-Meese-Dent (GMD) test of causality. It is designed to reduce serial correlation of residuals by regressing the present value of X on past, present and future values of Y, as well as on past values of X. We include 8 lags and 4 leads of Y and 8 lags of X. This test allows us to see if future values of Y are significant in the 'explanation' of present values of X. If so, Y can be said to follow X. The Granger test asks if X causes Y by regressing Y on past values of X, while the GMD test asks if Y follows X by regressing X on future values of Y.

Table 4 reports results from all these tests of causality from 10-year yields to nominal GDP growth. Table 5 reports the results for the inverse causality. As shown in the tables, the three tests generate very similar results. This indicates the robustness of our findings.

Table 4 shows that long-term interest rates *do not* Granger-cause economic growth in three countries out of four (except in Germany), which suggests that low (long-term) interest rates have not been stimulating economic growth in most countries examined. In parallel, Table 5 provides strong evidence that economic growth *does* Granger-cause long-term rates in *all* countries without exception. Bond yields (the price of money) *reflect prior* economic growth in Japan, the UK and the US, and not vice versa. In Germany only, we found a two-directional causality, suggesting that economic growth is both leading and lagging the long-term yields.

Overall, we find clear evidence that (1) economic growth is not negatively but positively correlated with the long-term interest rates in all countries and over long time periods (over half a century), and (2) it is economic growth that Granger-causes long-term yields, not vice versa. In other words, the empirical evidence rejects what has been 'declared' repeatedly by economists and central banks as their core 'monetary mantra', that lower rates lead to higher economic growth. They do not. Reality is the opposite in two dimensions (correlation and causation): *higher growth causes higher interest rates*.

5.2. Causation Between Growth and Short-term Rates

Tables 6 and 7 report the results from the three causality tests between economic growth and short-term interest rates. In Japan, causality from economic growth to 3-month rates is confirmed at the 5% significance level by all the three tests (Table 7), while the opposite is clearly rejected (Table 6). Combined with the highly positive correlations, this clear-cut direction of causation – unexpected for proponents of interest rate-based monetary policies in Japan – suggests that the Bank of Japan has been modulating money market or short-term interest rates in line with *past behaviour* of the Japanese nominal GDP growth rate *without influence over the future*. Also in Germany and the UK, no causality is found from the 3-month interest rates to economic growth (Table 6), but the opposite is confirmed at the 10% significance level by the Granger test with bootstrapped *p*-value and at the 5% level by the GMD test (Table 7). These results imply that, also in these two major European countries, the short-term interest rates, determined by their central banks, *follow* economic growth, and not vice versa. Keeping in mind the positive – not negative! – correlations, these results suggest that the Bank of England, the European Central Bank (or Bundesbank) and the Bank of Japan cannot boost growth by lowering rates. Instead, higher rates are consistent with a recovery.

In the US, we found a very strong, two-directional causality (significant at the 1% level in both directions), confirmed by all the three tests implemented. This indicates that economic growth and short-term interest rates do Granger-cause each other in this country. This two-directional causality weakens the conventional central bank view of causality, as it highlights the importance of the *positive correlation*, which strongly suggests that the Federal Reserve System-influenced short-term rate influences, but also follows closely, US nominal GDP growth. In other words, to the extent that we have found interest rates to cause economic growth, the Fed stimulates growth by *raising* rates, while lowering rates causes *weaker* growth. To the extent that we have found growth to cause interest rates, it can be said that rates are being raised, whenever growth has accelerated, and rates are being lowered after growth has decelerated.

6. Conclusions

Our empirical findings on the correlation and statistical causation can be summarised as follows: (1) Nominal GDP growth is highly and *positively* correlated with short and long-term rates in *all* four countries; (2) Nominal GDP growth Granger-causes long-term rates in *all* countries examined, whereas the opposite holds only in one country (Germany, with two-directional causality); (3) Nominal GDP growth Granger-causes short-term rates in *all* four countries, whereas the opposite holds only in one country (the US, where a strong two-directional causality is found).

The data suggests overall that statistical causality runs from economic growth to long-term interest rates. Nominal GDP growth provides information on future interest rates better than interest rates inform us about future nominal GDP growth.

Our empirical findings reject the canonical view that interest rates somehow affect economic growth, and in an inverse manner. To the contrary, long-term and short-term interest rates follow the trend of nominal GDP, in the same direction, in all countries examined. This suggests that markets are not in equilibrium and the third factor driving

Table 6
Granger causality tests from 3-month interest rates to nominal GDP growth.

	Germany	Japan	United Kingdom	United States
Sample period	1961:4–2008:4	1957:1–2008:4	1957:1–2008:4	1957:1–2008:4
Observations	189	208	208	208
Granger-test statistic F	1.1232	0.9821	0.3889	3.4170
df1;df2 (Granger test)	8; 164	8; 183	8; 183	8; 183
p-Value (Granger test)	0.3502	0.4515	0.9256	0.0011
Bootstrapped *p*-value	0.3783	0.4682	0.9303	0.0011
GMD-test statistic F	2.9276	1.0236	0.5166	6.2780
df1;df2 (GMD test)	4; 155	4; 174	4; 174	4; 174
p-Value (GMD test)	0.0228	0.3966	0.7236	0.0001

Notes: The null hypothesis for the Granger test is that past values of 3-month interest rates do not explain the present value of nominal GDP YoY growth rates. The 'bootstrapped' *p*-values come from simulated F distributions based on 'resampled' residuals of initial Granger causality test equations. The null hypothesis for the GMD test is that future values of nominal GDP YoY growth rates do not 'explain' present values of 3-month interest rates.

Table 7
Granger causality tests from nominal GDP growth to 3-month interest rates.

	Germany	Japan	United Kingdom	United States
Sample period	1961:4–2008:4	1957:1–2008:4	1957:1–2008:4	1957:1–2008:4
Observations	189	208	208	208
Granger-test statistic F	1.9444	2.3308	1.9037	3.6276
df1;df2 (Granger test)	8; 164	8; 183	8; 183	8; 183
p-Value (Granger test)	0.0567	0.0209	0.0618	0.0006
Bootstrapped *p*-value	0.0720	0.0262	0.1012	0.0009
GMD-test statistic F	2.5290	3.1240	2.7557	2.6077
df1;df2 (GMD test)	4; 155	4; 174	4; 174	4; 174
p-Value (GMD test)	0.0428	0.0164	0.0295	0.0374

Notes: The null hypothesis for the Granger test is that past values of nominal GDP YoY growth rates do not explain the present value of 3-month interest rates. The 'bootstrapped' *p*-values come from simulated F distributions based on 'resampled' residuals of initial Granger causality test equations. The null hypothesis for the GMD test is that future values of 3-month interest rates do not 'explain' the present value of the nominal GDP YoY growth rate.

GDP growth is a quantity – as shown by Werner (1997, 2012a) in the case of Japan (namely, the quantity of bank credit creation for the real economy - i.e., for GDP transactions, as the Quantity Theory of Credit postulates; Werner, 2013a).

Herman Daly wrote in 1991:

> "Environmental economics, as it is taught in universities and practiced in government agencies and development banks, is overwhelmingly microeconomics. The theoretical focus is on prices, and the big issue is how to internalize external environmental costs so as to arrive at prices that reflect full social marginal opportunity costs. Once prices are right, the environmental problem is 'solved'"
> (Daly, 1991, 255).

In this paper the validity of this focus on prices was put to the test. We examined the central price variable, the interest rate. All schools of equilibrium economics (which is most 19th, 20th and 21st century economics, from classical, Marxist, neoclassical and Keynesian to monetarist, new classical, post-Keynesian, neo-Wicksellian and Austrian, and likely over 95% of all publications in economics) agree that lower interest rates stimulate economic growth, while higher interest rates slow it. This sums up 'the law and the prophets' in equilibrium economics, across the alleged ideological divides. We presented the first serious test of this claim, by carefully examining over half a century of data on four major economies (the US, the UK, Japan and Germany, representing not only much of world GDP during half a century, but also different 'varieties of capitalism'). Out of the ensuing 8 cases (long and short rates in four countries) we found the hypothesis that interest rate levels cause economic growth rejected in 6 out of 8 cases. The alternative hypothesis that economic growth determines interest rate levels is supported in 8 out of 8 cases. Concerning correlation, we found that despite allowing for 2 years of leads and lags, the hypothesis that interest rates are inversely correlated with economic growth is rejected in 8 out of 8 cases. Instead, we found that interest rates are positively correlated with economic growth in 8 of 8 cases.

The central claim that unites the theory-driven deductive equilibrium economics (virtually all of macro-economics as taught at university and commonly discussed in public discourse) is without merit. The alternative view is the notion of pervasive rationing (Muellbauer and Portes, 1978; Werner, 2005), which implies the dominance of quantities over prices (Werner, 2005). That is consistent with the half-century of data examined here.

There are many implications of our findings. If rationing is more frequent than assumed, quantities are of paramount importance in economics, not prices. This paper provides impetus to the research agenda emphasising quantities in general, including resource constraints and therefore the environmental dimension in particular.

If interest rates do not move the economy, what does? If not the price of money, then its quantity? Werner (1997, 2015), Lyonnet and Werner (2012), Ryan-Collins et al. (2016) and Bermejo Carbonell and Werner (2018) have found that nominal GDP growth and interest rates are driven by a common third factor, the quantity of credit creation 'for the real economy', which beats interest rates and standard monetary aggregates in predicting and explaining nominal GDP growth in various empirical tests, including in Japan, Spain and the UK - just as the Quantity Theory of Credit postulates (Werner, 1992, 1997).

Our findings call for policy makers to drop the emphasis on prices and place greater emphasis on the role of quantities, especially the quantity of credit, which is the source of the money supply (Werner, 2005, 2012a, 2014a, 2015). This may include a policy to steepen the yield curve, which makes bank lending attractive for banks (raising short-term rates to create expectations of higher rates in the future; stopping large-scale central bank purchases of bonds and instead selling them, pushing up long-term rates, ensuring the banking sector is structured to deliver bank credit creation for productive purposes, and/or backing fiscal policy with monetary policy by stopping the issuance of government bonds and instead borrowing from banks ('Enhanced Debt Management', Werner, 2014c).

The findings are consistent with Werner's (2005) call for 'green quantitative credit guidance' to induce banks to lend only to environmentally sustainable projects, implemented by the central bank ('window guidance', see Werner, 1998, 2002, 2003a) or in a decentralized fashion through a system of local banks (Werner, 2013c). This would constitute true 'quantitative easing', as originally defined when the concept was proposed (Werner, 1995), and thus can be called 'green QE' (Werner, 2012b).

Finally, the ongoing debate about whether the existence of interest imposes pressure on economies to grow unnecessarily (needlessly depleting finite resources) can now be conducted on a firmer footing.

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