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What keeps long-term U.S. interest rates so low?☆

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A B S T R A C T

U.S. government indebtedness and fiscal deficits increased notably following the Global Financial Crisis. Yet long-term interest rates and U.S. Treasury yields have remained remarkably low. What keeps long-term interest rates so low? This paper relies on a simple model, based on John Maynard Keynes' view that the central bank's actions are the key drivers of long-term interest rates, to explain the behavior of long-term interest rates in the U.S. The empirical findings confirm that short-term interest rates are the most important determinants of long-term interest rates in the U.S. Contrary to conventional wisdom, higher government indebtedness has a negative effect on long-term interest rates, particularly on a long run basis. However, in the short run, higher government indebtedness has a positive effect on long-term interest rates. These are relevant for contemporary policy debates and macroeconomic theory.

1. Introduction

U.S. government indebtedness and fiscal deficits increased notably following the Global Financial Crisis. Yet long-term interest rates and U.S. Treasury yields have remained remarkably low. What keeps long-term interest rates so low despite higher government indebtedness and large fiscal deficits? This is an important research and a policy question. It is relevant to contemporary debates on the government debt and deficits, the macro implications of fiscal austerity, monetary transmission mechanism, quantitative easing and monetary policy. Since the onset of the Global Financial Crisis, the Federal Reserve has kept its policy target low, undertook large scale asset purchase programs, and provided forward guidance on the path of the policy rate. This paper examines why long-term interest rates have stayed low, both theoretically and empirically, drawing on a simple, yet intuitive, Keynesian framework.

Keynes (1930) holds that the central bank's actions are the main drivers of long-term interest rates. Following Keynes, a model of long-term interest rates and changes in long-term interest rates is constructed. Next, empirical evidence is provided here to show that the key drivers of long-term interest rates are short-term interest rates that the central bank largely controls. The short-term interest rate, after controlling for changes in other crucial variables (such as the rate of inflation, and the rate of economic activity), is the main driver in setting the long-term interest rate, rather than the government fiscal balance or the government indebtedness ratio.

There is considerable amount of theoretical and empirical work on government bond yields and sovereign bond spreads. However, recent theoretical and empirical work on the determinants of government bonds yields and sovereign bond spreads, such as Baldacci and Kumar (2010), Banerji et al. (2014), Carfi and Musolino (2012), Gruber and Kamin (2012), Lam and Tokuoka (2013), Martineza et al. (2013), Paccagnini (2016), Poghosyan (2014), and Tokuoka (2012), do not consider the Keynesian perspective. Instead the existing models have focused on a wide range of variables and have often stressed government finance variables as the key drivers of interest rates, both on a long run and a short run basis. This paper's contribution lies in presenting a simple, intuitive, and coherent Keynesian model of government bond yields, providing the empirical evidence to support this model, and critically examining the role of government indebtedness on both long run and short run basis.

The paper is organized as follows. Section 2 describes some

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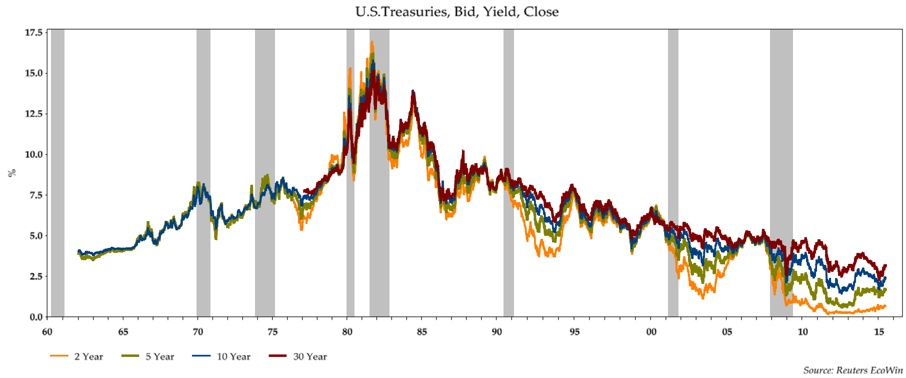

Fig. 1. The evolution of long-term Interest rates in the United States.

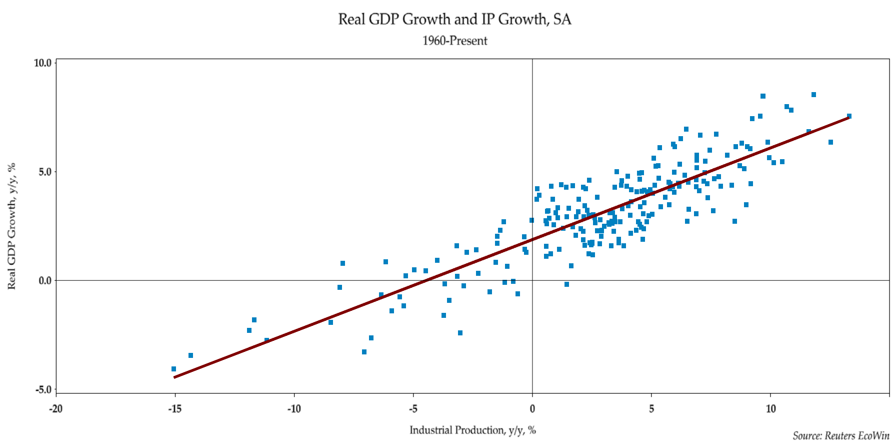

Fig. 2. The pace of industrial production is strongly correlated with real GDP growth.

important stylized facts about the evolution of short-term interest rates, long-term interest rates, and several relevant economic variables in the U.S. Section 3 describes Keynes's views on the main drivers of the long-term interest rate in an uncertain world. Section 4 presents a simple model of long-term interest rates and its changes based on Akram's (2014) and Akram and Das's (2014, 2016) interpretation of Keynes's views. Section 5 describes the data. Section 6 describes the empirical approach undertaken here, reports the findings of several models that are calibrated and interprets these findings from a Keynesian framework. Section 7 concludes.

2. The stylized facts

A look at the evolution of interest rates, inflation, economic activity, and government finance variables provides valuable insights. It can also give useful indicators about the drivers of long-term interest rates and the underlying relationships between the key variables. The shaded areas in the Figures below are recessions, as designated by the National Bureau of Economic Research (NBER).

Fig. 1 shows the evolution of long-term interest rates, as measured by the nominal yields of U.S. Treasury securities of selected tenors, in the U.S.[1] Long-term interest rates generally rose from the early 1960s to early 1980s. Two important features of the evolution of long-term interest rates are apparent from this figure. First, long-term interest rates rose sharply from the early 1960s to the early 1980s but have been on a declining trend since then from the early 1980s to the present. Second, interest rates generally tend to decline during or after a recession.

The evolution of short-term interest rates, as measured by the nominal yields of U.S. Treasury bills of 3 month and 6 month tenors, displays a similar pattern to that of the long-term interest rates. First, short-term interest rates generally rose from the early 1960s to early 1980s but have been on a declining trend since then from the early 1980s to the present. Second, short-term interest rates decline during recessions as the Fed becomes accommodative and usually lowers its policy rate(s) in response to an increased slack in the U.S. economy. Third, short-term interest rates tend to rise before the onset of a recession in response to the Fed's restrictive monetary policy and higher policy rate. Indeed, it is well known that a negatively sloped yield curve, measured by the difference in the nominal yields between a 10-year Treasury note and a three-month Treasury bill, is one of the most reliable and consistently correct forward indicators of the onset of a recession in the U.S.

The evolution of total Personal Consumption Expenditure (PCE) inflation and core Personal Consumption Expenditure (core PCE) inflation reveals certain patterns in these measures of inflation. First, total PCE inflation tends to be more volatile than core PCE inflation. Second, both total and core PCE inflation rose in the 1970s and sharply so from mid-1970s. Third, inflation began to decline after the two recessions in 1980s and finally began to moderate after the recession in the early 1990s. Total CPI and core CPI measures of inflation tend be to respectively higher than total PCE and core PCE measures of inflation. However, CPI measures of inflation also exhibit the same patterns as that of PCE measures of inflation.

Industrial production in the U.S. economy generally tends to grow, except sometimes before recessions and during recessions. Marked decreases in the growth of industrial production and its declines are very useful indicators of the likelihood of a recession and its onset. Fig. 2 reveals that the strong correlation between the growth of

[1] Additional figures are available in the working paper, Akram and Li (2016).

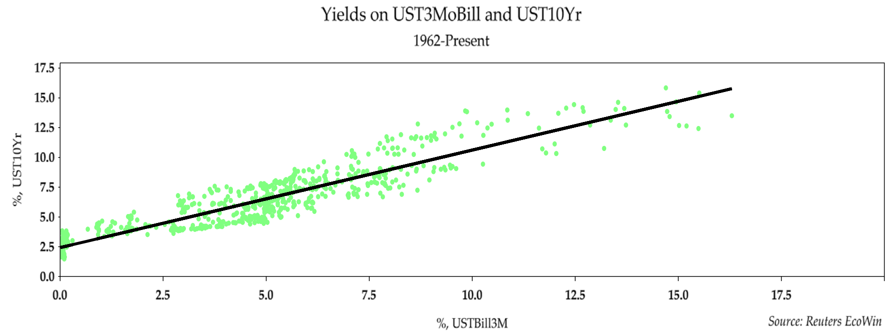

Fig. 3. Scatterplot of the yields of 10-year U.S. treasury securities and 3-month U.S. treasury bills.

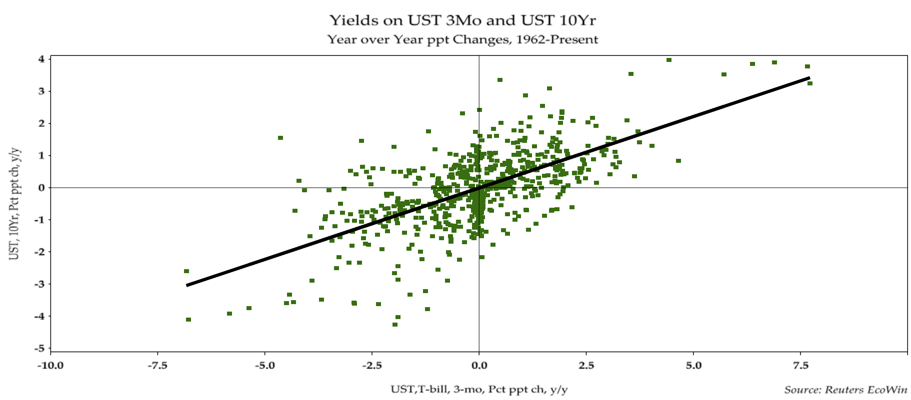

Fig. 4. Scatterplot of the percentage point changes, year over year, in yields of 10-year U.S. treasury securities and 3-month U.S. treasury bills.

Industrial production (IPYOY) and the growth of Real Gross Domestic Production (RGDP) of the U.S. economy. It demonstrates that the growth of industrial production captures the vicissitudes of business cyclical conditions in the U.S. quite well.

Usually the U.S. economy operates with a fiscal deficit. Since the mid-1970s till the mid-1990s, the U.S. usually incurred fiscal deficits of more than 3% of nominal GDP per year but in the mid-1990s fiscal deficits began to decline and the U.S. economy experienced fiscal surpluses until the bust of the tech-bubble and the recession of 2000. Following the recession at the turn of the century, the U.S. got back to its pattern of incurring fiscal deficits, which gradually narrowed with the onset of the housing bubble. However, as the housing bubble ended amid the Global Financial Crisis, the U.S., incurred large fiscal deficits in the ensuring years. In the past couple of years the fiscal deficit has narrowed with the moderate recovery of the U.S. economy.

The ratio of U.S. government debt to nominal GDP stood in the range of 30–40% from the mid-1960s to mid-1980s. It began to gradually creep higher from this range to around 60%. It stayed in the range of around 60% until 2008. After the Global Financial Crisis and the Great Recession, the ratio of government indebtedness rose sharply to over 90%. It remains at these levels as of late 2014.

There is a very strong correlation between the long-term interest rate and the short-term interest rate. There is also fairly strong correlation between the percentage point changes, year over year, of the long-term interest rates, and the percentage point changes, during the same period, of the short-term interest rates. The figures below reveal these strong correlations. Fig. 3 is a scatterplot of the yields of U.S. Treasury securities of a 10-year tenor and 3-month Treasury bills. Fig. 4 is a scatterplot of the percentage point changes, year over year, in the yields of U.S. securities of a 10-year tenor and 3-month Treasury bills.

Table 1
Summary of the data and the variables.

Variable Labels	Data description, date range	Frequency	Sources
Short-term interest rates			
R_ST	Treasury bills, 3 month, bid, yield, %, average; 1Q1960 — 3Q2014	Monthly; converted to quarterly	Federal Reserve; Thomson Reuters EcoWin
Long-term interest rates			
R_LT	Constant maturity yield, 10 year, yield, %, average; 1Q1960 — 3Q2014	Monthly; converted to quarterly	Federal Reserve; Thomson Reuters EcoWin
Inflation			
INF	Price index, Personal consumption expenditure *ex* food and *ex* energy, % change, y/y; 1Q1960 — 3Q2014	Monthly; converted to quarterly	Bureau of Economic Analysis; Thomson Reuters EcoWin
Economic activity			
G	Industrial production, Volume, Total, SA, Index, 2007=100, % change, y/y; 1Q1960 — 3Q2014	Monthly; converted to quarterly	Federal Reserve; Thomson Reuters EcoWin
Government finance			
V	General government net financial liabilities, SA, % of nGDP; 1Q1960 — 3Q2014	Quarterly	OECD Economic Outlook; Thomson Reuters EcoWin

U.S. Treasury securities' nominal yields tend to move in tandem with various measures of the rates of core inflation. This is understandable as investors are usually compensated for inflation or inflationary expectations. Generally nominal interest rates are higher than

Table 2(a)
Unit root tests (level).

Variable		Tests	Statistic	P-value	Obs.
R_ST	Trend	ADF	−1.964	0.6207	218
		PP	−2.263	0.4548	218
	No trend	ADF	−1.439	0.5632	218
		PP	−1.781	0.3900	218
	No trend	ADF	−1.062	0.5467	218
	no constant	PP	−1.189	0.3234	218
R_LT	Trend	ADF	−2.923	0.1549	218
		PP	−1.679	0.7601	218
	No trend	ADF	−0.992	0.7563	218
		PP	−1.299	0.6295	218
	No trend	ADF	−0.646	0.3423	218
	no constant	PP	−0.721	0.4322	218
INF	Trend	ADF	−1.575	0.8020	219
		PP	−2.165	0.5097	219
	No trend	ADF	−1.023	0.7447	219
		PP	−1.746	0.4077	219
	No trend	ADF	−0.71	0.6537	219
	no constant	PP	−1.049	0.3542	219
G	Trend	ADF	−3.857	0.0139	219
		PP	−5.096	0.0001	219
	No trend	ADF	−3.825	0.0027	219
		PP	−5.022	0.0000	219
	No trend	ADF	−3.286	0.0010	219
	no constant	PP	−4.294	0.0000	219
V	Trend	ADF	−0.102	0.9930	215
		PP	−0.63	0.9774	215
	No trend	ADF	1.954	0.9986	215
		PP	0.808	0.9918	215
	No trend	ADF	2.046	0.6350	215
	no constant	PP	1.231	0.3410	215

Note: PP test, ADF test (H0: series has a unit root).

Table 2(b)
Unit root tests (difference).

Variable		Tests	Statistic	P-value	Obs.
Δ(R_ST)	Trend	ADF	−5.880	0.000	217
		PP	−5.035	0.000	217
	No trend	ADF	−5.646	0.000	217
		PP	−4.977	0.000	217
	No trend	ADF	−5.648	0.000	217
	no constant	PP	−4.988	0.000	217
Δ(R_LT)	Trend	ADF	−11.609	0.000	217
		PP	−11.577	0.000	217
	No trend	ADF	−11.536	0.000	217
		PP	−11.523	0.000	217
	No trend	ADF	−11.560	0.000	217
	no constant	PP	−11.548	0.000	217
Δ(INF)	Trend	ADF	−5.198	0.000	218
		PP	−4.733	0.000	218
	No trend	ADF	−4.966	0.000	218
		PP	−4.698	0.000	218
	No trend	ADF	−4.979	0.000	218
	no constant	PP	−4.705	0.000	218
ΔG	Trend	ADF	−5.797	0.000	218
		PP	−4.305	0.000	218
	No trend	ADF	−5.791	0.000	218
		PP	−4.311	0.000	218
	No trend	ADF	−5.803	0.000	218
	no constant	PP	−4.321	0.000	218
ΔV	Trend	ADF	−12.594	0.000	214
		PP	−13.232	0.000	214
	No trend	ADF	−11.844	0.000	214
		PP	−12.571	0.000	214
	No trend	ADF	−11.757	0.000	214
	no constant	PP	−12.491	0.000	214

Note: PP test, ADF test (H0: series has a unit root).

inflation or inflationary expectations.

3. Keynes's view on the drivers of long-term interest rates

Keynes, 2007 recognizes that the ultimate foundation of interest rates lies in human psychology, social convention, and liquidity preference. However, he also maintains that in advanced capitalist countries the central bank is the main driver of both short-term interest rates on Treasury bills and the nominal yields on long-term government bonds. He holds that the central bank influences the long-term interest rates on government bonds mainly through the short-term interest rates and various monetary policy actions (Keynes (1930), p. 353, citied in Kregel (2011), p. 3). The short-term interest rates and the changes in the short-term interest rates are the most important factors in determining the long-term interest rates and the changes in the long-term interest rates. Keynes's analysis of the relationship between short-term interest rates and long-term interest rates drew on Winfried Riefler's (1930) pioneering empirical study of interest rates on U.S. government securities. Keynes (1930), as cited in Kregel (2011, p.4), and Keynes (2007 [1936], pp 152-153) argue that short-term realizations primarily drive the investor's long-term expectations because the investor's often extrapolates the future outlook from the present situation and the past. He holds that the investor cannot estimate the mathematical expectations of the unknown and uncertain future. Thus, the investor has little choice other than inferring from the present condition.

For Keynes liquidity preference, which originates from psychological, social and business incentives to liquidity, creates the foundation for the complex structure of interest rates as reflected on the yield curve for Treasury securities and various other fixed income securities that prevail in the society. Other things held constant, the central bank exerts control on "determinate rate of interest, or more strictly a determinate rate of interest for debts of different maturities" (Keynes, 2007 [1936], p. 204). He notes, in both *Treatise on Money* and *The General Theory*, the close ties between the short-term interest rates and the long-term interest rates. He acknowledges that while "the short-term rate of interest is easily controlled by the monetary authority," that the long-term interest rate might be "more recalcitrant" to the central bank's action, particularly if it has fallen beyond some critical level "which on the basis of past and present expectations of future monetary policy is considered 'unsafe' by representative opinion" (Keynes, 2007 [1936], p. 203). He emphasizes the public confidence on the credibility of the central bank is essential in affecting the long-term interest rates.

Keynes (1930) argues that the uncertainty about future implies that the investor's near term conditions and views color their long-term views. As a result, the factors that affect current conditions and expectations regarding the near term also affect the long-term outlook. This is the key reason why long-term interest rates move largely in tandem with short-term interest rates. Those same factors that alter near term outlook and cause fluctuations in the short-term interest rates also induces similar changes in the investor's long-term outlook, which lead to fluctuations in the long-term interest rates, mostly in accordance with the changes in the short-term interest rates.

Keynes's view is that the key driver of the long-term interest rate is the short-term interest rate, which is primarily set by the central bank's action. His view is concordant with the "chartalist" theory of modern money (Wray, 2003, 2012, Tcherneva, 2011) and the findings of recent mainstream macroeconomics and monetary theory (Sims, 2013, Woodford, 2001).

Table 3
Multi-variate cointegration tests.

Trace Test			Maximum Eigenvalue Test		
Null hypo.	**Test Statistic**	**Critical Value**	**Null hypo.**	**Test Statistic**	**Critical Value**
(R_LT, R_ST)					
r=0	27.1912	20.04	r=0	26.3499	18.63
r#1	0.8414*	6.65	r#1	0.8414	6.65
(R_LT, INF)					
r=0	21.7197	20.04	r=0	16.2729	18.63
r#1	5.4468*	6.65	r#1	5.4468	6.65
(R_LT, V)					
r=0	4.7535*	20.04	r=0	4.4725	18.63
r#1	0.281	6.65	r#1	0.281	6.65
(R_LT, V, INF)					
r=0	24.8691*	35.65	r=0	15.1354	25.52
r#1	9.7337	20.04	r#1	6.6881	18.63
r#2	3.0456	6.65	r#2	3.0456	6.65
(R_LT, R_ST, INF)					
r=0	54.7434	35.65	r=0	37.3605	25.52
r#1	17.3830*	20.04	r#1	13.4271	18.63
r#2	3.9559	6.65	r#2	3.9559	6.65
(R_LT, R_ST, V)					
r=0	60.8477	35.65	r=0	51.8328	25.52
r#1	9.0148*	20.04	r#1	8.5402	18.63
r#2	0.4746	6.65	r#2	0.4746	6.65
(R_LT, R_ST, V, INF)					
r=0	74.2672	54.46	r=0	50.1238	32.24
r#1	24.1434*	35.65	r#1	14.9672	25.52
r#2	9.1761	20.04	r#2	7.3437	18.63
r#3	1.8325	6.65	r#3	1.8325	6.65

Notes:
1. r denotes the number of cointegrated vectors;
2. AIC and SIC are used for the order of VAR model.
* Significance at the 10% level.

In contrast to Keynes's view, the convention wisdom, as expressed in the empirical literature on government bond yields, such as Baldacci and Kumar (2010), Gruber and Kamin (2012), Lam and Tokuoka (2013), Poghosyan (2014), and Tokuoka (2012), is that government financial variables, along with other macroeconomic variables, have a *decisive* influence, both statistically and economically, on government bonds' nominal yields, particularly in the long-term. In the conventional view, increased (decreased) government indebtedness and/or the deterioration (improvement) of government fiscal deficits are associated with higher (lower) government bond nominal yields.

4. A Keynesian model of long-term interest rates and changes in long-term Interest rates

A simple model of long-term interest rate and changes of long-term interest rates is presented here. The model proposed here follows [Keynes, 1930,Keynes, 2007] views as interpreted in Akram (2014) and Akram and Das (2014, 2016) with slight modifications. The crucial institutional assumption in this model is that of monetary sovereignty, as defined in Wray (2012). A country with monetary sovereignty issues its own currency, obtains tax payments in the currency, issues bond in that currency, pays interest payments and redeems its debt in the same currency, and the country's central bank can set the policy rate. The central bank controls the short-term interest rates through setting the policy rate and has the authority to use various other tools of monetary policy. These features of the central banks give it the operational ability to influence long-term interest rates. These characteristics of monetary sovereignty aptly describes the institutional settings of the U.S. government, including the Federal Reserve which has a wide range of tools to set policy rates, influence the short-term interest rates, and, if deemed necessary, even purchases long-term U.S. Treasury securities, agency Mortgage Backed Securities (MBS), and a wide range of fixed income assets from primary dealers in order to influence the long-term interest rates and the interest rate spreads. Moreover, U.S. government debt is issued solely in the U.S.'s own currency, namely, the U.S. dollar.

The main advantage of using the model proposed here are two fold. First, it reflects accurately Keynes's views on the drivers and the dynamics of interest rates on government bonds. Second, it can be readily used to test whether Keynesian's views that the short-term interest rate is the key driver of long-term interest rate is accurate, after controlling for other important variables. The model presented here extends, with slightly modifications, Akram's (2014) and Akram and Das's (2014, 2016) earlier interpretation of Keynes's view. The proposed model is simple, intuitive, and more coherent with the observed behavior of long-term interest rates in comparison with existing models in the empirical literature on government bond yields, such as Lam and Tokuoka (2013) and Tokuoka (2012).

The variables for the model are as follows: the long-term interest rate, r_{LT} ; the short-term interest rate, r_{ST}; the policy rate, r_P; the spread between the short-term interest rate and the policy rate, τ; the forward interest rates, $f_{ST,LT-ST}$; the future short-term interest rate, r_F; the term premium, z; the current inflation rate, π; the expected inflation rate, $\mathbb{E}\pi_F$; the current growth rate, g; the expected growth rate, $\mathbb{E}g_F$; and the government finance variable, V. The model is as qualitatively described below.

The long-term interest rate depends on the short-term interest rate and an appropriate forward rate [Eq. (1)]. Thus, the long-term interest rate is a function of the short-term interest rate and the appropriate forward rate [Eq. (2)]. The forward rate is a function of the future short-term interest rate and the term premium [Eq. (3)]. But the function of the future short-term interest rate and the term premium, in turn, is equal to the function of the expected inflation and the expected growth rate [Eq. (4)].

In a world characterized by rational expectations, the expected rate of inflation and the expected growth rate would respectively amount to the mathematical expectations of the possible growth rates and the possible rates of inflation in various states of the world. However, in a world characterized by ontological uncertainty, the probability of unknown events is incalculable. Hence, under a Keynesian perspective, the investor is forced take cues about the expected rate of inflation and the expected growth rate from the current conditions. The current inflation provides the best guess for the expected inflation [Eq. (5)]. Similarly the current growth provides the best cue for the expected growth rate [Eq. (6)]. The forward rate, thus, is a function of the current inflation rate and the current growth rate [Eq. (7)]. The long-term interest rate depends on the short-term interest rates and the function of the drivers of the forward rate [Eq. (8)]. This implies that the long-term interest rate, under Keynesian assumptions, is a function of short-term interest rate, current inflation, and current growth rate [Eq. (9a)]. This also implies that the change in the long-term interest rate is a function of the change in the short-term interest rate, the change in current inflation, and the change in the growth rate [Eq. (9b)].

If government finance variables are thought to affect long-term interest rates, perhaps through influencing the forward rate, then these factors could be incorporated as well. The long-term interest rate would then be a function of the short-term interest rate, the current inflation, the current growth rate, and the government finance variable [Eq. (10a)]. Similarly the change of the long-term interest rate would be a function of the changes of the above mentioned variables [Eq. (10b)].

The short-term interest rate is the sum of the policy rate set by the

Table 4
Johansen VEC model.

	Model 1	Model 2	Model 3	Model 4	Model 1'	Model 2'	Model 3'	Model 4'
Dummy variables					(82q2,96q1)	(80q3,82q3)	(82q3,05q3)	(80q3,05q3)
Long-run relationship								
R_ST	-0.977***	−0.732***	−1.014***	−0.892***	−0.999***	−0.752***	−0.968***	−0.643***
	[0.07]	[0.08]	[0.06]	[0.09]	[0.08]	[0.07]	[0.04]	[0.06]
INF		−0.339**		−0.135		−0.4***		−0.367***
		[0.12]		[0.11]		[0.1]		[0.08]
V			0.186***	0.136***			0.277***	0.159***
			[0.07]	[0.07]			[0.05]	[0.05]
CONSTANT	−1.67	−1.667	−0.663	−1.014	−0.453	−0.634	0.131	−0.955
Error correction terms								
Δ(R_LT)(−1)	−0.070*	−0.126***	−0.085**	−0.123***	−0.039	−0.104***	−0.076*	−0.212***
	[0.03]	[0.03]	[0.03]	[0.03]	[0.03]	[0.04]	[0.04]	[0.04]
Δ(R_ST)(−1)	0.072	0.026	0.111	0.081	0.142***	0.133**	0.228***	0.039
	[0.04]	[0.05]**	[0.05]	[0.05]	[0.05]	[0.06]	[0.07]	[0.07]
ΔINF(−1)		−0.011		−0.02		0.002		0.029
		[0.02]		[0.02]		[0.02]		[0.03]
Δ(V)(−1)			0.105**	0.075			0.073	0.011
			[0.05]	[0.05]			[0.07]	[0.07]
Diagnostics								
Obs.	217	217	217	217	217	217	217	217
Lags	3	3	6	6	3	3	6	6
AIC	2.935	3.136	5.004	5.19	2.938	3.109	4.995	5.174
Log Likelihood	−303.952	−312.685	−525.9368	−536.116	−305.78	−314.278	−518.969	−526.342
Serial Correlation test	8.8266	17.525	10.508	27.048	8.708	17.956	12.681	22.7
P-value	0.065	0.04	0.311	0.041	0.069	0.036	0.178	0.055
Skewness test	8.383	6.241	12.39	11.874	8.57	8.755	8.484	5.894
P-value	0.015	0.094	0.006	0.018	0.025	0.02	0.037	0.207

*Notes:*1. *, ** and *** imply significance at 1%, 5% and 10%, respectively;2. Test statistics and p-values are presented in respective rows.3. The results of all other long-term interest rates with dummy variables are available upon request.

central bank and a spread [Eq. (11a)]. Likewise the change in the short-term interest rate is the sum of the change in the policy rate and the change in the same spread [Eq. (11b)].

The model is expressed in the following system of equations:

$$(1+r_{LT})^{LT} = (1+r_{ST})(1+f_{ST,LT-ST})^{LT-ST} \quad (1)$$

$$r_{LT} = F^1(r_{ST},\ f_{ST,LT-ST}) \quad (2)$$

$$f_{ST,LT-ST} = F^2(r_F,\ z) \quad (3)$$

$$F^2(r_F,\ z) = F^3(\mathbb{E}\pi_F, \mathbb{E}g_F) \quad (4)$$

$$\mathbb{E}\pi_F = F^4(\pi) \quad (5)$$

$$\mathbb{E}g_F = F^5(g) \quad (6)$$

$$f_{ST,LT-ST} = F^6(\pi,\ g) \quad (7)$$

$$r_{LT} = F^1(r_{ST},\ F^6(\pi,\ g)) \quad (8)$$

$$r_{LT} = F^7(r_{ST},\ \pi,\ g) \quad (9a)$$

$$\Delta r_{LT} = F^8(\Delta r_{ST}, \Delta\pi, \Delta g) \quad (9b)$$

$$r_{LT} = F^9(r_{ST},\ \pi,\ g,\ V) \quad (10a)$$

$$\Delta r_{LT} = F^{10}(\Delta r_{ST}, \Delta\pi, \Delta g, \Delta V) \quad (10b)$$

$$r_{ST} = r_P + \tau \quad (11a)$$

$$\Delta r_{ST} = \Delta r_P + \Delta\tau \quad (11b)$$

5. Data

Time series quarterly data on short-term interest rates, long-term interest rates, the rate of inflation, the pace of economic activity, and government finance variables are used here. Short-term interest rates are obtained from the nominal yields on U.S. Treasury bills of 3-month. Long-term interest rates are obtained from nominal yields of long-term U.S. Treasury Securities of a 10 year-tenor, using constant maturity yield calibrated by the Federal Reserve. Inflation data are based on a measure of core inflation. Core inflation is defined as total inflation minus food and energy inflation. The pace of economic activity is calibrated by the year over year percentage changes in the seasonally adjusted measure of the index of industrial production. Government finance variable is obtained from general government net liabilities as a share of nominal GDP.

Table 1 below summarizes the variables and the data used in the econometric models.[2] The first column gives the variable labels. The second column provides the variable description and the time range for the data. The third column gives the original frequency. It also states if the data have been converted to a lower frequency. The final column lists both the primary sources and the secondary sources.

6. Empirical approach, findings and interpretations

6.1. Model specification

Since the variables in the model are non-stationary, investigating

[2] Additional variables are used in the econometrics models calibrated in the working paper version of the paper.

Table 5
Gregory and Hansen cointegration tests for regime shifts.

	Model 1		Model 2		Model 3		Model 4	
	Test Stat.	Breakpoint	Test Stat.	Breakpoint	Test Stat.	Breakpoint	Test Stat.	Breakpoint
ADF								
Model C	−4.82**	1981q4	−5.08**	1982q4	−5.18**	1982q4	−5.19*	1982q4
Model C/T	−4.83*	1995q4	−6.9***	1981q3	−5.83***	2005q4	−6.78***	1981q3
Model C/S	−6.19***	1986q4	−6.98***	1980q2	−7.05***	1979q4	−7.6***	1985q1
Zt								
Model C	−5.04**	1982q2	−5.51***	1982q3	−5.25**	1982q3	−5.42**	2005q3
Model C/T	−5.37**	1996q1	−6.68***	1980q3	−5.94***	2005q3	−6.52***	1980q3
Model C/S	−6.29***	1985q2	−7.01***	1980q3	−6.99***	1989q4	−7.38***	1985q2
Za								
Model C	−34.89	1982q2	−39.05	1982q3	−43.55*	1982q3	−43.44	2005q3
Model C/T	−40.55	1996q1	−59.34**	1980q3	−56.73**	2005q3	−58.92*	1980q3
Model C/S	−52.88	1985q2	−67.25*	1980q3	−69.88**	1989q4	−78.21*	1985q2

Note:1. *, ** and *** imply significance at 1%, 5% and 10%, respectively; 2. The model specifications are denoted by C-level shift, C/T- level shift with a trend, C/T-regime trend;3. Critical values are taken from Gregory and Hansen (1996).

the relationship under a non-stationary cointegration framework is appropriate to study long run economic relationships, such as the determinants of long-term interest rates. The Vector Error Correction (VEC) model, as developed by Johansen (1988, 1991, 1995), is used here to examine the dynamic relation among the variables—the short-term interest rates (r_{ST}), the long-term interest rates (r_{LT}), the rate of inflation (π_t), economic activity (g_t), and government finance (V_t). Johansen's model has cointegration relations built into the specification so that it restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships, while allowing for short-run adjustment dynamics. This approach is relevant for the questions addressed in this paper.

Following Johansen's procedure, consider a Vector Autoregression (VAR) model, adapted to the VEC model representation, as given below:

$$\Delta Z_t = C + \Gamma_1 \Delta Z_{t-1} + \ldots + \Gamma_{k-t} \Delta Z_{t-k+1} + \Pi Z_{t-k} + e_t \quad (12)$$

where $Z_t = (r_{LT}, r_{ST})'$ (Model 1), or $Z_t = (r_{LT}, r_{ST}, \pi_t)'$ (Model 2), or $Z_t = (r_{LT}, r_{ST}, V_t)'$ (Model 3), or $Z_t = (r_{LT}, r_{ST}, \pi_t, V_t)'$ (Model 4), while $\Gamma_j \Delta Z_{t-j}$ and$\Pi Z_{t-p}$are the vector autoregressive component in first difference and error-correction components, respectively. C is an (n×1) vector of constants, while e_t is an $(n \times 1)$ vector of white noise error terms. Γ_j is an $(n \times n)$ matrix that stands for the short-term adjustment coefficients among variables with $(k-1)$number of lags, and Π is an $(n \times n)$ matrix of parameters. $\Pi = \alpha\beta'$, where α is an $(n \times r)$matrix which represents the speed of adjustment coefficient of the error correction mechanism, while β is an $(n \times r)$ matrix of cointegrating vectors. Under certain conditions, the Z_t process is non-stationary while both the first-differenced process ΔZ_t and the linear combinations $\beta' Z_{t-1}$ are stationary.

6.2. Model estimation

The model estimation process comprises of three parts: (1) testing for a unit root in each series; (2) testing for the number of cointegrating vectors in the system, given that one cannot reject the null hypothesis of a unit root in the variables; and (3) estimating in the framework of a multi-variate VEC model.

6.2.1. Stationarity test

To estimate the VEC model, the first step is to test for stationarity. The stationarity properties in the time series are substantiated by performing the Augmented Dickey–Fuller (ADF) (Dickey and Fuller, 1979, 1981) and Phillips-Perron (PP) (Phillips and Perron, 1988) tests. The tests are conducted on the variables in levels and first differences.

Tables 2a and 2b present the unit root test results of the nominal yields of U.S. Treasury bills of 3 month tenor (r_{ST}), the yields of Treasury Securities of 10 year tenor (r_{LT}) as calibrated on a constant maturity basis, the core PCE inflation (π_t), the growth in the seasonally adjusted measure of the index of industrial production (g_t), and the general government net borrowing/lending as a share of nominal GDP (V_t).[3]

Based on the unit root tests as depicted in Tables 2a and 2b, all unit root tests yield remarkably similar results for variables r_{LT}, r_{ST}, π_t, V_t, which are non-stationary in their levels but become stationary in their first differences. Thus, it can be concluded that those four series are I(1) at the 5% level of significance. However, the application of the ADF and PP tests for g_t revealed that this variable is stationary in both its levels and its first differences.

6.2.2. Cointegration test

Johansen and Juselius's (1990) cointegration method is used for the cointegration analysis. Treating r_{LT}, r_{ST}, π_t, V_t as nonstationary variables, Table 3 presents test statistics for determining whether r_{LT} is cointegrated with any of these variables.

To analyze the cointegration relationships among the variables, seven VAR models are defined. They are-(r_{LT}, r_{ST}),(r_{LT}, π_t),(r_{LT}, V_t),(r_{LT}, π_t, V_t),(r_{LT}, r_{ST}, π_t),(r_{LT}, r_{ST}, V_t), $(r_{LT}, r_{ST}, \pi_t, V_t)$ respectively.[4] The results based on VARs are generally found to be sensitive to the lag length used and ordering of the variables. Thus, before determining the number of cointegrating vectors, lag lengths were chosen by Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC). A sequence of likelihood-ratio test statistics is also used to determine the lag length. The results suggest models with two variables are explained by eight lags, while the other four models with three or four variables are explained by six lags.

[3] The results of the unit root tests on the nominal yields of U.S. Treasury bills of 6 month tenor are consistent with the nominal yields of U.S. Treasury bills of 3 month tenor. The results of the unit root tests on the growth of Real GDP are consistent with the growth in the seasonally adjusted measure of the index of industrial production. The results of the unit root tests on the yields of Treasury Securities of 2 year, 5 year, and 30 year tenors are consistent with the yields of Treasury Securities of 10 year tenor. The results of the unit root tests on PCE inflation, CPI inflation, and core CPI inflation are consistent with core PCE inflation. The results of the unit root tests on federal debt as a share of nominal GDP, federal deficit as a share of nominal GDP, general government gross liabilities as a share of nominal GDP, and general government net liabilities as a share of nominal GDP are consistent with the general government net borrowing/lending as a share of nominal GDP. Those results are provided in Appendix Tables [A1] and [A2] of the working paper and are also available upon requests.

[4] Since g_t is a stationary variable, it is not included in the cointegration test.

Table 6
Chow test and structural change regressions.

	(R_LT, R_ST, INF, V)					
	DUM1980q3			DUM2005q3		
	Chow test_1	Chow test_2	Chow test_3	Chow test_1	Chow test_2	Chow test_3
R_ST	0.802*	0.535*	0.502*	0.856*	0.875*	0.882*
	[0.04]	[0.06]	[0.08]	[0.03]	[0.03]	[0.03]
INF	0.157*	0.291*	0.315*	−0.034	−0.082	−0.086***
	[0.05]	[0.06]	[0.08]	[0.04]	[0.04]	[0.04]
V	−0.165*	−0.222*	−0.18	−0.332*	−0.440*	−0.449*
	[0.03]	[0.06]	[0.1]	[0.03]	[0.04]	[0.04]
CONSTANT	0.701*	1.335*	1.569*	1.065*	0.717*	0.649*
	[0.19]	[0.19]	[0.46]	[0.18]	[0.18]	[0.19]
DUM	0.835*		−0.284	−1.409*		1.87
	[0.15]		[0.51]	[0.2]		[0.98]
DUM*R_ST		0.352*	0.392*		−0.226	−0.209
		[0.07]	[0.1]		[0.13]	[0.13]
DUM*INF		−0.226***	−0.257***		0.331	−0.411
		[0.11]	[0.13]		[0.28]	[0.48]
DUM*V		0.043	−0.006		0.276*	0.356*
		[0.05]	[0.1]		[0.05]	[0.06]
Obs.	219	219	219	219	219	219
Adj R-squared	0.903	0.9143	0.914	0.91	0.9192	0.9202
Chow test statistics	32.99	22.75	17.08	52.16	28.46	22.53
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes:
1. ** imply significance at 5%, respectively;
2. Chow test types: (1) Y=X+DUM; (2) Y=X+DX; (3) Y=X+DUM+DX, where: DUM=Dummy variable (0, 1), takes (0) in first period, and (1) in second period. DX=Cross product of each X_i times in DUM.
3. Chow test statistics and p-values are presented in respective rows.
* Significance at 10%.
*** Significance at 1%.

The Johansen cointegration test uses two statistics tests, namely the trace test and the likelihood eigenvalue test. Both tests are reported in Table 3. The first row ($r = 0$) tests the null hypothesis of no cointegration, the second row ($r = 1$) tests the null hypothesis of one cointegration relation and so on, all against the alternative of full rank of cointegration. The trace test, starts with ($r = 0$) and moves upwards. The process is stopped the first time the null hypothesis cannot be rejected. For instance, in the case of r_{LT}, r_{ST}, the hypothesis of ($r = 0$) is rejected as the computed value of the test statistic (27.1912) is greater than the critical value (20.04). However, in the next step, the null hypothesis of at most one cointegrating vector cannot be rejected at 10 percent level of significance. Thus, there is evidence of one cointegrating vector in the system. The maximum eigenvalue test provides a more conclusive evidence regarding the exact number of cointegrating vectors in the system. These results again confirm that there is one conintegrationg vector (0.8414 < 6.65). Based on these results it can be said that there is one common permanent component driving the entire system of (r_{LT}, r_{ST}). The results for (r_{LT}, π_t),(r_{LT}, r_{ST}, π_t), (r_{LT}, r_{ST}, V_t)and (r_{LT}, r_{ST}, π_t, V_t) also suggest that there are one cointegrating equation, respectively.[5]

6.2.3. Vector error correction model

Given the cointegration results, the next stage in the model estimation process requires the fitting of a multi-variate VEC model where the time series are found to be cointegrated. Table 4 presents the estimation of the corresponding VEC systems for four models: $Z_t = (r_{LT}, r_{ST})'$(Model 1), $Z_t = (r_{LT}, r_{ST}, \pi_t)'$(Model 2), $Z_t = (r_{LT}, r_{ST}, V_t)'$(Model 3), $Z_t = (r_{LT}, r_{ST}, \pi_t, V_t)'$ (Model 4), assuming one cointegrating relationship, respectively.

In Model 1, the long-term interest rates are regressed only on the short-term interest rates. The coefficient is highly significant and suggests that an increase in the short-term interest rates by 1 percentage point increase the long-term interest rates by 97.7 basis points. The addition of the other variables, one by one, leaves the coefficients on the short-term interest rates always highly significant, but its size changes across different models (Models 2–4).

The diagnostic tests are performed to check the signs of misspecification like serial correlation or non-normality. First, the Breusch-Godfrey Lagrange Multiplier test of serial correlation in the residuals show that for Model 2 and Model 4 (with P-values < 0.05), the null hypothesis that there is no autocorrelation is rejected. Second, in the last two rows of Table 4, we compute the skewness statistics to test the null hypothesis that the residuals are normally distributed. At the 10% level, the null hypotheses are rejected for all models (Models 1–4) since all the p-values are less than 0.1. Thus, the results of skewness test do not suggest that the residuals are normally distributed in the four models.

6.2.4. Testing for structural breaks

In the presence of structural breaks, the diagnostic tests will most likely suggest that the estimated model suffers from the non-normality problem. One way to improve the model's goodness of fit is to use dummy variables to capture those structure breaks. Thus, all the models are re-estimated by augmenting the cointegrating equations with dummy variables (Models 1′–4′ in Table 4).

We explore the potential structural breaks with Gregory and Hansen (1996) cointegration test, which extend Engle and Granger's (1987) procedure by allowing a structural break in either the intercept or the intercept and the co-integrating coefficient. This test assumes the null hypothesis of no cointegration against the alternative one of cointegration with one structural break at an unknown time. In Table 5, according to the Gregory and Hansen (1996) approach, we implement three models: Model 1 allows for the level shift only (Model C); Model 2 includes a time trend into shift (Model C/T) and Model 3 includes the regime shift where intercept and slope coefficients change (Model C/S). Each of the models has a dummy variable to allow for a structural break. The dummy variable is set equal to zero before the breakpoint which is determined endogenously. After the breakpoint, the dummy variable takes on the value of one.

The results of Table 5 show that the null hypothesis of no cointegration is rejected by all models (Model C, C/T and C/S). This implies that a structural change is present in the long-run cointegration equation. We also find that there are at least two breakpoints in the cointegration equation of each model. Accordingly, two dummy variables are introduced for each model.[6]

In Model 4, when we apply the modified Chow break test, proposed by Shehata (2011), on two dates (1980q3, 2005q3) separately the results indicate that there is a break for both dates.[7] According to Table 6, for all types of regression, the Chow test statistics are quite large and with p-values near zero. Thus, the Chow break test results reveal that under the null hypothesis of parameter constancy we reject the null hypothesis for both dates specified.[8]

[5] The Johansen cointegration test on various other long-term interest rates produce similar results with the yields of Treasury Securities of 10 year tenor. Those results are provided in Appendix Tables [A3–A9] of the working paper.

[6] The breakpoints are picked according to the Zt* statistics at 5% significance level in model C and C/T. The breakpoints for Model 1: 1982q2, 1996q1; Model 2: 1980q3, 1982q3; Model 3: 1982q3, 2005q3; Model 4: 1980q3, 2005q3.

[7] This methodology provided three types of regression: independent variable(X) with a dummy, X with each X multiplied with a dummy, X with both a dummy and each X multiplied with a dummy. The dummy is zero before a breakpoint and one afterwards.

[8] The Chow break tests on Models 1, 2, and 3 produce similar results.

Table 7
Short-run adjustment coefficients based on Model 4′.

	Coefficients	Std. Error	P-value
ECT	−0.212*	0.04	0.000
ΔR_LT(−1)	0.282**	0.09	0.002
ΔR_LT(−5)	−0.349*	0.09	0.000
ΔR_ST(−2)	−0.141***	0.07	0.030
ΔR_ST(−5)	0.169*	0.06	0.006
ΔINF	−0.421*	0.12	0.000
ΔINF(−3)	0.294***	0.14	0.031
ΔV(−2)	0.131**	0.05	0.005
DUM80q3	0.164	0.09	0.070
DUM05q3	−0.298**	0.11	0.006
CONSTANT	0.079	0.05	0.118

Notes:
1. "ΔX(−1)" represents one lag of the first difference variable; "ΔX(−2)" represents two lags of the first difference variable.
* Significance at 10%.
** Significance at 5%.
*** Significance at 1%.

6.2.5. Interpretation of VEC model results

By augmenting the cointegrating equations in Model 4 with two dummy variables, the null hypothesis that the residuals are normally distributed cannot be rejected (with P-value=0.207). Thus, Model 4′ is treated here as a base-line model for further examination. After normalising on long-term interest rates, the cointegrating vectors associated with the largest eigenvalues yield the following cointegrating relationship:

$$r_{LT} = 0.955 + 0.643 r_{ST} + 0.367\pi - 0.159V \tag{13}$$

The results of Eq. (13) show that there is a significant long-run relationship among short-term interest rates, inflation rates, government finance and long-term interest rates. Both short-term interest rates and inflation rates have positive and significant relationship with the long-term interest rates. Specifically, a 1 percentage point increase in the inflation rates results in a 37 basis points increment in the long-term interest rates in the long run. A 1 percentage point increase in the short-term interest rate causes a 64 basis points rise in the long-term interest rates. Contrary to the conventional wisdom, the results obtained show an increase in government finance impact negatively on long-term interest rates, that is, an increase in government indebtedness leads to a decline in government bond yields. A plausible explanation of this phenomenon is that increase government spending leads to an increase in the amount of banks deposits and/or reserves of the commercial banks as the central bank credits reserves in concordance with the increase government spending (Wray, 2003, pp. 74–96, 2012, pp. 98–109). The rise in the amount of reserves and/or bank deposits in the financial system exerts downward pressures on the effective policy rate and the short-term interest rates, unless the central bank acts defensively to contain this effect. Lower short-term interest rates create downward pressures on the long-term interest rates, provided everything else is unchanged.

The error correction terms presented in the middle panel of Table 4 tell how deviations from the equilibrium are adjusted.[9] The coefficient of error correction term in the long-term interest rates equation has an estimated coefficient of −0.212, which is significant at 1% level, implying that about 21.2% of disequilibrium is corrected within one quarter. The error correction terms for the other three equations are not significant. Thus, the cointegration relation only enters significantly in the long-term interest rates equation.

[9] The lagged error-correction term is derived from the long-term cointegration relationship(s). Hence, the significance of the lagged error correction term(s) will indicate the long-term causal relationship.

The results of Table 7 present the short-run dynamics in the long-term interest rate equation from Model 4′. According to the estimated results of the cointegrating relationship and the short-run dynamics, Model 4′ can be presented as:

$$\begin{aligned} \Delta r_{LT} = {} & 0.281 - 0.212(r_{LT} - 0.643 r_{ST} - 0.367\pi + 0.159V) + 0.282\Delta r_{LT\ t-1} \\ & - 0.349\Delta r_{LT\ t-5} - 0.141\Delta r_{ST\ t-2} + 0.169\Delta r_{ST\ t-5} - 0.421\Delta\pi_{t-1} \\ & + 0.249\Delta\pi_{t-3} + 0.131\Delta V_{t-2} - 0.298 DUM_{05q3} \end{aligned} \tag{14}$$

Eq. (14) shows that lagged variables Δ(R_LT)(−1), ΔR_LT(−5), ΔR_ST(−2), ΔR_ST(−5), ΔINF(−1), ΔINF(−3), ΔV(−2), and DUM(05q3) are statistically significant. The net effect of short-term interest rates and inflation rates on long-term interest rates is ambiguous, while the government finance variable has a positive effect on long-term interest rates in the short run (0.131**), even though only one lag of government finance variable is included in the model with statistically significant coefficient. Additionally, in the short run, a 1 percentage point increases in the dummy variable (2005q3) will result in a 29.8 basis point decrease in the long-term interest rates, which confirms a decreasing trend for the long-term interest rates in the period after the third quarter of 2005 (see Fig. 1).

6.3. Model stability diagnostics

The VEC recursive (sequential) estimation is employed to investigate stability of the estimated coefficients attached to the cointegrating vector and the error correction terms. If the coefficients are constant, one should expect the estimated coefficients to display random fluctuation and noise. We estimate Model 4′ starting with a sub-sample of 100 observations, then sequentially adding one observation at a time, then running the regression until the end of the sample is reached. The results are plotted in Fig. 5.

The top panel in Fig. 5 shows the series of recursive estimated coefficients attached to the error correction terms. The error correction terms of long-term interest rates equation (alpha1) and inflation rates equation (alpha3) set to some fairly constant levels (between −0.1 and −0.2, between 0 and −0.1) through the recursive procedures. The error correction terms of short-term interest rates equation (alpha2) and government finance equation (alpha4) appear unstable at the start of the procedures and as sample size increases, both estimated coefficients settle down.

In the bottom panel of Fig. 5, the series of recursive estimated coefficients of the cointegrating vector are plotted. The estimated coefficients of short-term interest rates (beta2), inflation rates (beta3) and government finance (beta4) are fairly stable, while the recursive intercept (beta5) fluctuates and drops around 2000, and then becomes stable after that. Overall, Fig. 5 provides clear evidence of the stability of most estimates coefficients of Model 4′. The stability condition of Model 4′ is confirmed by the sequence of estimated coefficients using VEC recursive estimation.

The macroeconomic variables employed in base-line model (Model 4′) include the short-term interest rates, the long-term interest rates, the rate of inflation and government finance. Also two dummy variables were introduced to capture structural breaks inherent in the data. Empirical results showed that significant long-run relationship existed among long-term interest rates, short-term interest rates, inflation rates and government finance. Furthermore, the speed of adjustment to the equilibrium long-term interest rates (−0.212***) appear to be relatively moderate. In contrast, the estimated error correction terms in the equations of short-term interest rates, the rate of inflation and government finance do not contribute to the error correction work. Moreover, in the short-run, both short-term interest rates and inflation rates have significant causal link with long-term interest rates, but with ambiguous signs, while the government finance variable has a positive effect on short-term dynamics which is statistically significant and economically meaningful.

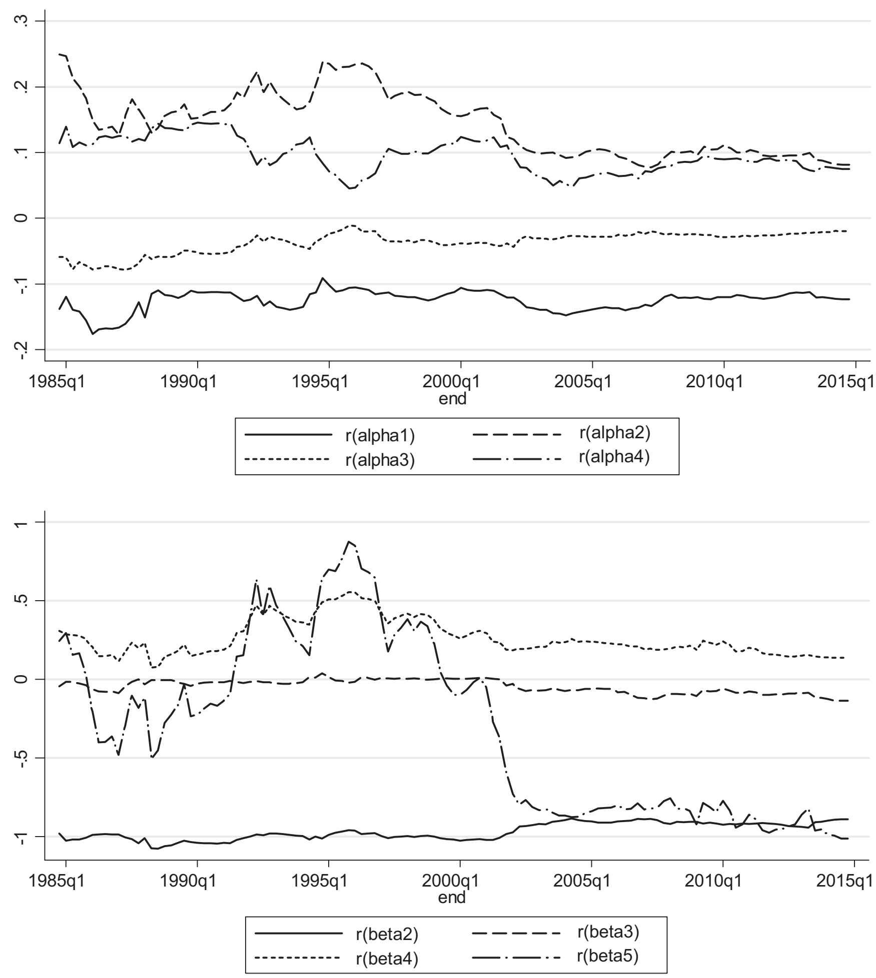

Fig. 5. VEC recursive estimates of the estimated coefficients of Model 4´.

6.4. Model assumptions

The findings of the paper follow from the explicit and implicit model assumptions. In particular, it should be clearly and definitely noted that if a country does *not* have monetary sovereignty then its central bank cannot control short-term interest rates, let alone influence long-term interest rates and the complex structure of interest rates. When a country does not possess or chooses not to exercise monetary sovereignty, Keynes's conjecture that the action of the country's central bank is the decisive determinant of the long-term interest rates would not hold.

7. Conclusion

The empirical findings of this paper support that Keynes, 1930 view that short-term interest rates are the most important determinants of long-term interest rates in the U.S., a country with monetary sovereignty. The long-term interest rates on U.S. Treasury securities are positively associated with the short-term interest rates on U.S. Treasury bills, after controlling for various relevant economic variables, such as the rates of inflation, and government finance variables. The Federal Reserve affects the short-term interest rates through its policy rates and through various other tools of monetary policy. The empirical results show that in the long run an increase in the government indebtedness has a statistically significant and economically meaningful negative effect, while in the short-run effect is statistically significant and economically meaningful positive effect. The long run effect can be explained using a chartalist perspective (Wray, 2012), while the short-run effect can be understood in terms of conventional view that higher government spending and debt may raise the cost of government borrowing.

The findings of this paper are quite relevant to contemporary policy issues, related to fiscal positions (Gruber, 2012) and monetary-fiscal mix in business cycle (Cendejasa et al., 2014, Cuciniello, 2009) and theoretical debates in macroeconomics, such as Gruber and Kamin (2012), Papadamou (2013), Sims (2013), Wray (2012), and Woodford (2001). First, it shows that the central bank exerts a strong influence on long-term interest rates in the U.S. through its control of the policy rate and short-term interest rates in the long run, as Keynes envisioned. Second, it also reveals that higher government indebtedness has a positive effect on government bond yields on the short run, but the effect on the long-run is negative. The short run effect of higher government debt on government bond yields is in concordance with conventional wisdom. However, the long-run effect is at variance with the standard view but it aligns with the post Keynesian and chartalist perspectives on the coordination of Treasury and the central bank, and the role of increased government expenditure in raising the amount of reserves and bank deposits in the financial system. The divergence of the long-run effect and the short run effect is an important result and it should be explored further, theoretically and empirically. A clear implication of the findings of the paper is that the advanced counties may face low long-term interest for a prolonged period. With low or even negative policy rates, low or negative short-term interest rates, low inflation or deflationary threats, long-term interest rates may remain low for a long time, particularly in countries with monetary sovereignty, in spite of elevated and rising government indebtedness in many advanced countries, such as Japan, the United States, and the United Kingdom.

The findings of the paper are largely in concordance with modern "chartalism" (Wray, 2003, 2012), recent developments in macroeconomic theory and understanding of fiat money (Sims, 2013, Woodford, 2001), and the research on the central bank's operational framework (Bindseil, 2004). The Keynesian model of government bond yields and the empirical results presented here provide some additional credence to these approaches to understanding contemporary macroeconomic questions.

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