EMPIRICAL EVIDENCE OF THE EXPECTATION HYPOTHESIS ON THE TERM STRUCTURE OF INTEREST RATES

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An analysis of US dollar LIBOR interbank rates, observed at monthly frequency, for rates spanning the period 1961-2008

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ABSTRACT

The Expectation hypothesis of the term structure of interest rates states that long-term rates are influenced by the expectations that investors have on future short-term rates. To assess the validity of this hypothesis a series of statistical analyses was run. Firstly, a cointegration test between short and long-term interest rates was run. Subsequently, a vector error correction estimate, a Granger causality test, and impulse response analysis were run to verify whether long-term rates anticipate future movements of short rates. This research topic has been extensively explored due to the level of insight that it could provide to central banks. Central banks mostly rely on short-term financial instruments for the implementation of monetary policies. A better understanding of the relations between short and long-term rates could help central banks implement more effective policies. This research aims to empirically confirm this framework of the yield curve through an analysis of US dollar LIBOR interbank rates.

CONTENTS

1 ADF AND COINTEGRATION TEST

M2 and y2 are the main interest rates analysed in this report. M2 refers to the US dollar LIBOR interbank rate with maturity 2 months, whereas y2 refers to a 2-year maturity. As can be seen from figure 1, the yield curve is not inverted since long-term rates tend to lay above short-term ones. This suggests long-term rates have a larger yield due to a risk premium, in line with the expectation hypothesis[1]. Nevertheless, the presence of some outliers is worth noting. For example, during the 2007 financial crisis an inversion of the yield curve occurred, leading to a scenario where short-term investments had higher yields than long-term ones.

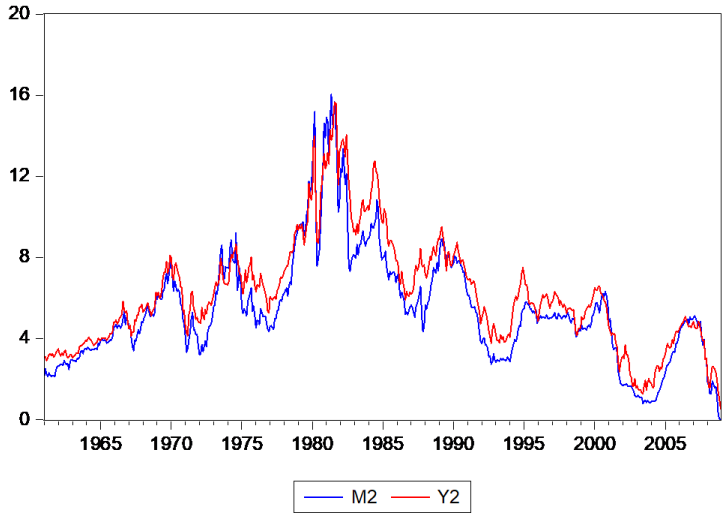


Figure 1: Comparison of long (y2) and short-term (m2) interest rates.

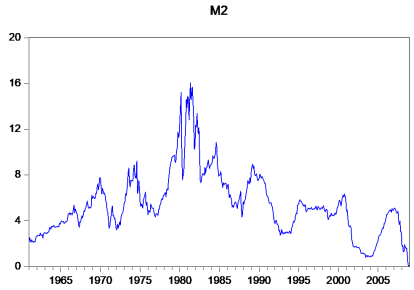
1.1 INTEREST RATES ARE I(1)

Firstly, the short-term interest rate m2 is analysed with the Augmented Dickey-Fuller test.

As can be seen from the ADF test output, the null hypothesis cannot be rejected therefore we have no evidence to say that m2 is I(0). The long term-interest rates are analysed with the same ADF test.

Even in this case, we fail to reject the null hypothesis at 5% confidence level. Therefore there are no reasons to say that y2 is I(0). As previous empirical findings suggest, interest rates are I(1).

1 Shiller R.J., 1979, "The Volatility of Long-Term Interest Rates and Expectations Theories of the Term Structure", Journal of Political Economy, vol. 87, pp. 1190-1219.



(a) m2 plot.

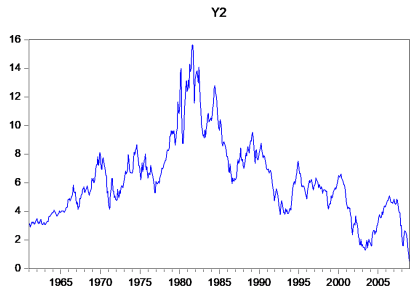
Null Hypothesis: M2 has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=18)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.125743	0.2347
Test critical values:	1% level	-3.441533	
	5% level	-2.866365	
	10% level	-2.569399	

*MacKinnon (1996) one-sided p-values.

(b) ADF test output.

Figure 2: Short-term interest rate.



(a) y2 plot.

Null Hypothesis: Y2 has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=18)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.987172	0.2926
Test critical values:	1% level	-3.441513	
	5% level	-2.866356	
	10% level	-2.569395	

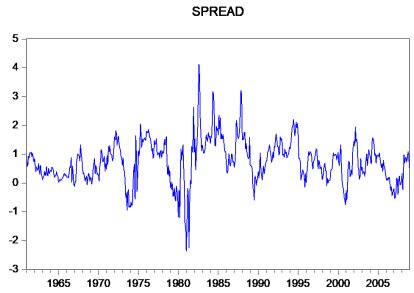
*MacKinnon (1996) one-sided p-values.

(b) ADF test output.

Figure 3: Long-term interest rate.

1.2 THE SPREADS ARE I(0)

Based on the previous findings, the spreads are expected to be I(0). The augmented Dickey-Fuller test was run on the spread between y2 and m2 to verify this hypothesis.



(a) spread plot.

Null Hypothesis: SPREAD has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=18)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.498147	0.0000
Test critical values:	1% level	-3.441493	
	5% level	-2.866348	
	10% level	-2.569390	

*MacKinnon (1996) one-sided p-values.

(b) ADF test output.

Figure 4: Spread between y2 and m2..

The results confirm the literature findings since the null hypothesis is rejected at 5% confidence level. Therefore it can be concluded that the spreads are integrated of order zero. This finding has relevant implications since the spread provides information about the expectations of future rates. In other words, we can derive from the spread whether long-term rates will increase or drop in the future - provided that the expectation theory holds.

1.3 COINTEGRATION TEST

We now proceed to run a cointegration test to confirm that there is a connection between short and long-term interest rates. For this purpose, the Engle and Granger cointegration test was run using y2 as a dependent variable.

Date: 12/04/19 Time: 21:30
Series: M2 Y2
Sample: 1961M01 2008M12
Included observations: 576
Null hypothesis: Series are not cointegrated
Cointegrating equation deterministics: C
Automatic lags specification based on Schwarz criterion (maxlag=18)

Dependent	tau-statistic	Prob.*	z-statistic	Prob.*
M2	-6.508640	0.0000	-78.95937	0.0000
Y2	-6.348921	0.0000	-75.64219	0.0000

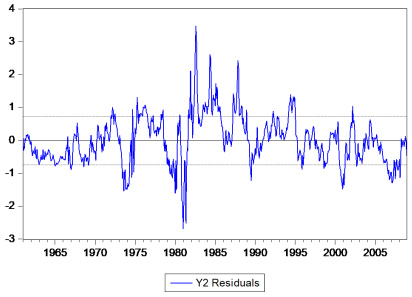
*MacKinnon (1996) p-values.

Figure 5: Cointegration test.

Since 0.00 is smaller than the critical value 0.05 we reject the null hypothesis, concluding that the interest rates are cointegrated which is consistent with literature findings[2].

The cointegration test summarises two steps into a single output which, if it was broken down into its components, it would look as follows:

- based on the ADF test, the two series are I(1)
- their residuals from OLS are I(0).



(a) Residuals plot from OLS.

Null Hypothesis: RESID01 has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=18)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.343344	0.0000
Test critical values:	1% level	-3.441493	
	5% level	-2.866348	
	10% level	-2.569390	

*MacKinnon (1996) one-sided p-values.

(b) ADF test output.

Figure 6: The residuals are I(0).

The residuals are I(0), however we cannot draw conclusions around their stationarity since not all I(0) processes are stationary but all stationary processes are I(0).

2 Hall, A., Anderson, H., Clive W. J. Granger. (1992). A Cointegration Analysis of Treasury Bill Yields. The Review of Economics and Statistics, 74(1), 116-126. doi:10.2307/2109549

2 VEC ESTIMATE, GRANGER CAUSALITY, AND IRF

2.1 LAG LENGTH CRITERIA

Before running the vector error correction estimates and impulse response analysis, the correct lag order is selected based on the Schwarz information criterion.

VAR Lag Order Selection Criteria
Endogenous variables: M2 Y2
Exogenous variables: C
Date: 12/04/19 Time: 22:48
Sample: 1961M01 2008M12
Included observations: 568

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2016.563	NA	4.186494	7.107618	7.122907	7.113584
1	-592.5101	2833.064	0.028203	2.107430	2.153297	2.125329
2	-572.1930	40.27650	0.026628	2.049975	2.126421*	2.079807
3	-565.5809	13.06115	0.026385	2.040778	2.147802	2.082542
4	-556.7284	17.42446	0.025938	2.023692	2.161294	2.077388*
5	-555.3450	2.713303	0.026178	2.032905	2.201086	2.098534
6	-552.5213	5.518112	0.026287	2.037047	2.235806	2.114609
7	-545.5275	13.61821	0.026011	2.026505	2.255843	2.116000
8	-540.3430	10.05862*	0.025903*	2.022335*	2.282250	2.123762

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

Figure 7: Lag length selection.

The SC criterion[1] was chosen because it provides a consistent estimate as opposed to other criteria like the AIC. Our sample size of 568 observations can be considered large enough for the SIC to be a consistent estimate. Therefore, the lag order selected is 2 and this information will be used to tune the VEC model.

2.2 VEC ESTIMATE

Since the variables m2 and y2 are I(1) and cointegrated the vector error correction term has to be included in the VAR. This leads to the following VEC estimates.

1 Schwarz, Gideon. Estimating the Dimension of a Model. Ann. Statist. 6 (1978), no. 2, 461–464. doi:10.1214/aos/1176344136. https://projecteuclid.org/euclid.aos/1176344136

Vector Error Correction Estimates
Date: 12/04/19 Time: 23:04
Sample (adjusted): 1961M04 2008M12
Included observations: 573 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
M2(-1)	1.000000
Y2(-1)	-0.976827 (0.04547) [-21.4807]
C	0.590698 (0.30750) [1.92095]

Error Correction:	D(M2)	D(Y2)
CointEq1	-0.087739 (0.03049) [-2.87753]	0.039020 (0.02633) [1.48179]
D(M2(-1))	0.017703 (0.05883) [0.30090]	0.022539 (0.05081) [0.44359]
D(M2(-2))	-0.022764 (0.05714) [-0.39836]	0.029641 (0.04935) [0.60061]
D(Y2(-1))	0.318272 (0.06794) [4.68472]	0.167330 (0.05867) [2.85187]
D(Y2(-2))	-0.158783 (0.06877) [-2.30893]	-0.129932 (0.05939) [-2.18774]

Figure 8: Vector error correction estimates.

2.3 GRANGER CAUSALITY

The VEC Granger causality test was run between m2 and y2. The test was run on the VEC because the two variables are I(1) and running it on the VEC ensures normality in distribution.
Selecting y2 as a dependent variable, 0.78 is larger than 0.05 therefore m2 can be excluded from the equation of y. Therefore y2 Granger causes m2, which is consistent with the expectation hypothesis. However, m2 does not Granger cause y2.
It is important to point out that Granger causality does not imply mere causality. In fact, this relation has to be interpreted as y2 anticipating future movements of m2.

VEC Granger Causality/Block Exogeneity Wald Tests
Date: 12/09/19 Time: 13:55
Sample: 1961M01 2008M12
Included observations: 573

Dependent variable: D(M2)

Excluded	Chi-sq	df	Prob.
D(Y2)	29.49427	2	0.0000
All	29.49427	2	0.0000

Dependent variable: D(Y2)

Excluded	Chi-sq	df	Prob.
D(M2)	0.490595	2	0.7825
All	0.490595	2	0.7825

Figure 9: Cointegration test.

2.4 IMPULSE RESPONSE

Based on the results of the Vector Error Correction estimates we plot the impulse response function with no degrees of freedom adjustment (Cholesky ordering).
As can be seen from the graph below, short-term mostly responds to itself while the response of long-term to itself decays rapidly.

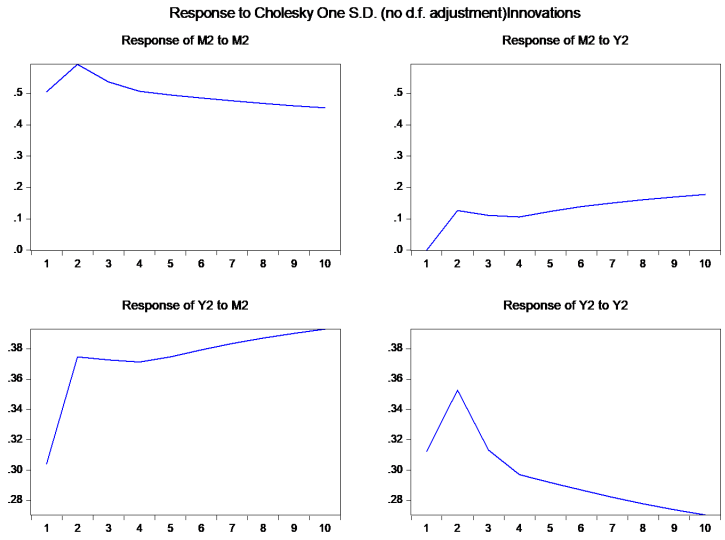


Figure 10: Impulse response function.

M2 responds to y2 in the short run with temporary shocks, while y2 is significantly sensitive to shocks in m2 and the response of y2 does not decay.

These dynamics have important implications for central banks since it shows that shocks in monetary policy - operated through short-

term financial instruments - are eventually transferred into the system, thus impacting long-term rates.

3 CONCLUSIONS

The main findings of this research were interpreted through the theoretical lens of the expectation hypothesis and are as follows:

- US dollar LIBOR interbank rates with maturity 2 months (m2) and 2 years (2y) are I(1)
- the corresponding spread is I(0)
- m2 and y2 are cointegrated
- y2 Granger causes m2 in the sense that the long-term rates anticipate future movements of x2
- y2 keeps responding to m2 while m2's response to y2 is much weaker.

The research outcomes suggest that the Expectation Hypothesis partially holds for the US dollar LIBOR interbank rates m2 and y2. In future studies, more robust measures could be put in place to:

- interpolate periods of strong economic uncertainty since they could provide misleading results
- use variance decomposition to facilitate the interpretation of the fitted VAR model
- test whether the coefficient in the VECM is -1.