Term structure of interest rate and macro economy: an empirical study on selected emerging countries sovereign bond

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Doddy Ariefianto
Accounting Department, School of Accounting-Master Accounting, Bina Nusantara University, Jakarta, Indonesia
Citra Amanda
Bank Indonesia Institute, Bank Indonesia, Central Jakarta, Indonesia, and
Zaafri Ananto Husodo
Management Department, Faculty of Economics and Business, Universitas Indonesia, Jakarta, Indonesia

Abstract

Purpose – To examine the relationship between the term structure of interest rates of sovereign bonds in emerging nations and their macroeconomic indicators, specifically emphasizing its persistence and interaction with inflation, foreign exchange and fiscal conditions.
Design/methodology/approach – Adopting the Mean Group Instrumental Variables (MGIV) technique, as proposed by Cui *et al.* (2020) and Norkute *et al.* (2021), this study analyzes a monthly panel dataset from nine emerging economies spanning January 2010 to October 2021, totaling 1,278 observations.
Findings – The findings reveal significant persistence in both slope and curvature, with a rising yield level linked to the term structure's flattening, while shifts in inflation and exchange rates correlate with its steepening.
Originality/value – Our study is among the few which used an empirically constructed measure of the term structure of interest instead of a theoretical construct. To best our knowledge, we are the first to employ MGIV.

Keywords Term structure of interest, Slope, Curvature, Financial stability, Mean group instrumental variables, Panel econometric
Paper type Research paper

1. Introduction

The term structure of interest (also known as yield curve) of sovereign bonds stands as a key macroeconomic indicator. Prior to the COVID-19 pandemic, the yield curve in most countries was in a normal curve. However, the spread between long-term and short-term government borrowing rates has narrowed, not only in developed countries but also in emerging countries. To tackle soaring inflation, most central banks raise their interest rates, causing a high cost of funds. The inverted yield curve, historically, has been used to predict the onset of recession in an economy. It's widely recognized that the term structure of sovereign bond is used as a pricing benchmark for bank loans and many corporate debt market instruments (Elton *et al.*, 2014). Furthermore, its role

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in asset pricing, portfolio management, capital valuation, and monetary policy can't be understated (Diebold and Rudebusch, 2013). During economic expansions (in a new normal period of COVID-19), the yield curve steepens as governments use low-interest rates to encourage spending and boost economic activity. However, more recently, the two-year yield rose above the 10-year yield, causing investors to worry about the economic slowdown. Therefore, an adequate understanding of term structure behavior is critical for a well-functioning macroeconomy.

Amid these global shifts, what remains underexplored is the term structure's behavior and persistence, particularly in emerging economies. Here lies the novelty of this study: embarking on an empirical exploration of the persistence of slope and curvature in selected emerging countries. Taking cues from prior macro-finance studies (Gadanecz *et al.*, 2018; Byrne *et al.*, 2019; Cepni *et al.*, 2021), the approach uniquely sidesteps the "No Arbitrage" assumption, which, although theoretically sound, conflicts with the preferred habitat theorem (Vayanos and Vila, 2021). In addition, this study uses observable features of term structure, slope, and curvature instead of estimated latent variables. Estimating latent factors requires a complete dataset of yield across tenors, which might not be the case for emerging markets. Moreover, as noted by Cepni *et al.* (2021), the extracted latent factors might not be smooth, which hampers its use for subsequent analysis. Instead of delving into latent variables, this study focuses on observable features, thereby offering a more practical and straightforward interpretation, addressing a significant gap in the yield curve modeling literature.

This study focuses on observable proxies of the term structure, emphasizing the slope and curvature derived from government securities. Generally, the slope is obtained by comparing yields of long-term and short-term papers, while the curvature captures the non-linearity between these rates over different periods. These measures, informed by Gürkaynak and Wright (2012), are pivotal as they help avoid potential distortions inherent in extremely long tenors. This study also incorporates essential macroeconomic variables, such as expected short-term interest rates, foreign exchange movements, and prevailing fiscal conditions.

The main novelty of this study is twofold. First, this study model term structure features (level, slope and curvature) as endogenous to macroeconomic variables which is more appropriate (see the literature section as background). Second, the study uses a recent innovative econometric method: Mean Group Instrumental Variable (MGIV) to address this endogeneity issue. Mean Group instrumental variable (MGIV) developed by Norkutė *et al.* (2021) and Cui *et al.* (2020), brought fresh and promising treatment to the endogeneity issue. Specifically, MGIV has a better estimation fit for panel data with a large time unit-T (Long panel data). Better estimation fit is obtained due to the improvement of estimate consistency and efficiency by exploiting the common factor and unobserved heterogeneity inherent in this type of data structure (Chudik and Pesaran, 2015; Juodis and Sarafidis, 2018). The method extracts common factors as a set of instruments, uses them for consistent estimates of endogenous variables, and handles heterogeneity in cross-section dependency to gain efficiency.

The empirical framework is applied to an expansive monthly panel dataset spanning 9 emerging countries from January 2010 to October 2021 (1,278 observations). This study finds a highly significant persistence of slope and curvature. The level of short-term yield is positively associated with flattening the term structure, indicating a (future) yield reversal mechanism. Inflation and exchange rate change have a significant positive correlation with the steepening of term structure. Moreover, this study unearth intriguing associations between short-term yield levels, inflation, exchange rate changes, and term structure movements, providing fresh insights that can reshape the understanding of post-pandemic economic dynamics in emerging markets.

2. Literature review

The term structure of interest rates, encompassing features like slope and curvature, has been a cornerstone of financial research for decades. Early theoretical development covers, among other expectation hypotheses, preferred habitat theorem and liquidity preference (Malkiel, 2015). Diebold and Rudebusch (2013) emphasize the importance of slope and curvature in assessing the yield curve. Yet, while such foundational works provide a solid background, there remain gaps empirically.

2.1 Theory of term structure of interest rates

The slope measures the first derivative of yield against tenor, i.e. the distance of short-term yield versus long-term yield. The curvature is the second derivative; it measures how the slope changes, i.e. whether the yield curve is flattening or sharpening as it goes from the short to the long end. A more recent approach is macro-finance, which links the yield curve micro-underpinning with a standard macro model (Gürkaynak and Wright, 2012; Cochrane, 2017). Despite having a long and extensive investigation, term structure behavior remains elusive (Crump *et al.*, 2018).

The expectation hypothesis posits that the term structure of interest is the average of expected short-term interest rates. Therefore, assuming no arbitrage, a permanent shift in short-term interest rate will alter the yield in various term structure tenors, resulting in changes in slope and curvature. Short-term interest rates can negatively affect the slope via the mean reversal mechanism (the current rate is too high from the perceived normal). The existence of this process has been modeled by Ross (2015) and Martin and Ross (2019) into the recovery theorem have extended this view, but empirical findings remain inconsistent. This gap, notably the transmission of short-term rates on the yield curve, has been a contentious topic.

The preferred habitat theorem asserts that each tenor has its clientele investors. Therefore, a shock to a tenor does not necessarily transmit to other tenors, i.e. changing the slope or curvature of the yield curve (Vayanos and Vila, 2021). While some scholars (Adrian *et al.*, 2013; Abrahams *et al.*, 2016) found negative correlations, others (Coroneo *et al.*, 2016) and Gadanecz *et al.* (2018) discovered positive ones, as an evidence of increased term premium. Tillmann (2020) found the transmission conditional on monetary policy uncertainty, while Cepni *et al.* (2021) found no empirical support.

Liquidity preference theory (Keynes, 1936) asserts that investors prefer to place their money in short-term instruments for ease of transaction and precautionary reasons. Therefore, they must be compensated to put their money into long-term ones. There are other Keynesian channels, namely investors' psychology and uncertainty, from which short-term interest rates affect the slope and curvature; in this regard, liquidity preference is mixed up with the expectation hypothesis (Akram, 2021). Ornelas and de Almeida Silva (2015), in a study of Brazil's sovereign bond, managed to disentangle the significant liquidity preference effect from the expectation hypothesis. Akram and Das (2019) found empirical support for liquidity preference in the India Government Bond market. Although that research offers some insights, comprehensive empirical evidence across varied economies remains scant.

Furthermore, while canonical theories assert the persistence of slope and curvature (Diebold and Rudebusch, 2013). The persistency of slope and curvature is attributed to serial correlation and non-stationary characteristics (Krippner, 2015). Empirical support for this conjecture has been documented by Härdle and Majer (2016), Levant and Ma (2017), and Cepni *et al.* (2021). Empirical validation, especially for emerging economies, is limited, revealing another gap in existing knowledge.

2.2 Behaviour of the YIELD curve to macroeconomic changes

The term structure's form (slope and curvature) contains information on macroeconomic risks (Christensen, 2018). This hypothesis is a foundation for the macro-finance term structure model-MTSM (Rudebusch and Wu, 2008; Gürkaryanak and Wright, 2012). Nevertheless, this hypothesis has been challenged by studies of Joslin *et al.* (2013, 2014), Coroneo *et al.* (2016). Recently Bauer and Rudebusch (2020) empirically showed the existence of macro risk that is unspanned by the yield curve. However, those studies highlight that much remains undiscovered about how these macroeconomic risks are reflected in yield curves, especially in emerging markets. Combining both views, this study concludes that term structure is at least partially endogenous to macroeconomic variables. Another channel of endogeneity of term structure to macro-economic risks could be attributed to cross-country co-movement due to policy effect spillover and risk compensation (Jotikasthira *et al.*, 2015; Sowmya *et al.*, 2016).

Breach *et al.* (2020), in a study of US sovereign bonds, found that for data before 2008, inflation changed short-term interest rate expectations and positively correlated with slope as a proxy of increased term premium. Currency depreciation can increase the perception of sovereign risk and cause investors to demand higher yields for holding local currency bonds (Gadanecz *et al.*, 2018; Cuchiero *et al.*, 2016). Afonso and Martins (2012), in a study of the US and German sovereign bonds, found that shock in fiscal conditions was initially associated with a negative shift in slope and curvature that eventually died out (hence no effect in the long run). However, there is limited understanding of their long-term impact and interrelation.

3. Data and methodology

Modifying from Gadanecz *et al.* (2018), Bauer and Rudebusch (2020) and Cepni *et al.* (2021), this study proposes two regression models using a similar set of explanatory variables: lag of dependent variable, level of Yield, Interest Expectation, Foreign Exchange Changes, and Fiscal Condition. These models are given by Equations (1) and (2),

$$SLOPE_{it} = \alpha_0 + \alpha_1 SLOPE_{it-1} + \alpha_2 YIELD_{it} + \alpha_3 INT\_EXP_{it} + \alpha_4 FX\_C_{it} + \alpha_5 FIS\_COND_{it} + \varepsilon_{it} \tag{1}$$

$$CURV_{it} = \beta_0 + \beta_1 CURV_{it-1} + \beta_2 YIELD_{it} + \beta_3 INT\_EXP_{it} + \beta_4 FX\_C_{it} + \beta_5 FIS\_COND_{it} + \varepsilon_{it} \tag{2}$$

The previous section has pointed out the endogeneity nature of SLOPE, CURV, YIELD, Int_EXP, FX_C, and FIS_COND; hence, it must resort to instrumental variables for consistent estimation. Finding correct instruments can be daunting; however, recent breakthrough papers by Cui *et al.* (2020) and Norkutė *et al.* (2021) convincingly proposed that factors derived from model variables can be reliable instruments. This study adopts in this paper the operational version developed by Kripfganz and Sarafidis (2021), called the Mean Group Instrumental Variable-MGIV estimator.

Equations (1) and (2) are estimated using a sample panel dataset. The dataset based on monthly frequency comprises 9 (nine) emerging countries: Brazil, China, India, Indonesia, Malaysia, Russia, South Africa, Thailand, and Turkey from January 2010 to October 2021 (1,278 country monthly observations).

The complete list of variables, instruments, their measurement (proxies) and sign hypothesis are described in Table 1. This table presents the definition and calculation of all

Variables/Proxy	Description	Sign hypothesis
Slope (SLOPE)	The difference of Yield 10 year and Yield 1 year (Yield 10 year-Yield 1 year)	Dependent Variable
Curvature (CURV)	The difference of Slope 10–5 Year and Slope 5–1 year: ((Yield 10 Year-Yield 5 year) -(Yield 5 year-yield 1 year))	Dependent Variable
Level of yield (Y1/Y5/Y10)	Generic version of Sovereign Bond: yield of a bond with a tenor of 1 year; Y1, a yield of a bond with a tenor 5-year yield; Y5 and yield of a bond with a tenor of 10 Years; Y10	Positive/ negative
Interest rate expectation, two proxies: (1) Inflation-INF and (2) Central bank policy rate-CBRate	Inflation: Monthly Year on Year (y/y) changes of Consumer Price Index, inflation rate (=log (CPIt/CPIt−1) CBRate: end of month Central Bank policy rate	Positive
Growth (GROWTH)	Monthly Year on Year (y/y) real gross domestic product-GDP change =(log (GDPt/ GDPt−1). GDP is interpolated from quarterly frequency to monthly	Instruments
Foreign exchange rate changes (FX_C)	Monthly (month-on-month changes of the foreign exchange rate (=log (FXt/Fxt−1) where each exchange rate (FX) is expressed as X local currency per USD	Positive
Fiscal condition, two proxies: (1) Fiscal balance-FIS_BAL and (2) Government debt-GOV_DEBT	Fiscal Balance: Fiscal Balance as percentage GDP (Interpolated from annual frequency to monthly using sum match last criteria) Government Debt: Government Debt as a percentage GDP (Interpolated from annual frequency to monthly using sum match last criteria)	Positive
Global uncertainty	Log (Volatility Index-VIX): VIX is implied volatility derived from the price of options on the SP500 index	Instruments

Source(s): Bloomberg, CEIC and IMF. This table describes measurement of all variables used in the study

Table 1. Variables, proxies, and instruments description

variables/proxies used in the study. All yield variables are of generic form. It is the average level of all similar-class sovereign bonds with the closest maturity in each tenor.

It can be noted that this study uses growth and VIXl as "external" instruments inspired by studies by Ozturk (2020) and Cepni *et al.* (2021). Yield-related data (level, slope, and curvature), foreign exchange, and VIX are obtained from Bloomberg; inflation and growth are obtained from CEIC. Fiscal condition (Fiscal Balance and Government Debt) data are obtained from the International Monetary Fund (IMF) Fiscal Monitor dataset. This data is of annual frequency, which then converted to monthly frequency using linear interpolation with a sum that matches the last criteria. This study uses expected short-term interest, foreign exchange changes, and fiscal conditions for the variables of interest.

In this study, the term structure of interest rates, represented by the yield curve, plays a pivotal role. Specifically, this study focuses on three crucial points or tenors on the yield curve: the 1 Year, 5 Year, and 10 Year yields. These tenors are instrumental in understanding the shape and dynamics of the curve.

Slope of the Yield Curve: The slope provides insight into the difference in yields between short-term and long-term bonds. This study calculates the slope using the formula:

Slope = Yield of 10 Year Tenor − Yield of 1 Year Tenor. This calculation gives a measure of the steepness of the yield curve. A positive slope typically indicates that long-term bonds have a higher yield than short-term ones, which is the usual scenario in a growing economy.

Curvature of the Yield Curve: Beyond just the slope, the curvature provides a deeper understanding of how yields evolve over intermediate tenors. It is determined using the formula: Curvature = (Yield of 10 Year Tenor − Yield of 5 Year Tenor) − (Yield of 5 Year Tenor − Yield of 1 Year Tenor); Curvature = (Yield of 10 Year Tenor − Yield of 5 Year Tenor) − (Yield of 5 Year Tenor−Yield of 1 Year Tenor). By capturing how the middle tenor (5 Year) behaves relative to the short (1 Year) and long (10 Year) tenors, the curvature helps in discerning potential inflection points in the yield curve. Based on the guidance from Gürkaynak and Wright (2012), this study opted for the 10 Year yield as the representative long-end of the yield curve. This decision was influenced by the need to sidestep potential perverse downsloping features that might be observed from even longer tenors, a phenomenon attributed to the Jensen Inequality.

The analytical steps can be described as follows. First, we perform descriptive statistics that will give us the data profile and provide early warning of possible obstacles to subsequent analytics. Second, we conduct several preliminary analytics: panel Granger causality and unit root tests. The Granger causality test would serve as a confirmation of the endogeneity structure in the model. Since Granger Causality requires that variables be stationary, a unit root test must be performed first. There are two types of unit root test considering our long panel data. The first is standard unit root test and second is unit root test that accounts for structural breaks.

For standard type unit root test applied on panel variables (Y1, Y5, Y10, SLOPE, CURV, FX_C, GROWTH, INF, CBRATE, FIS_BAL, GOV_DEBT); Pesaran (2007, 2015a, b) proposed the Cross-Sectional Im, Pesaran and Shin (CIPS). According to Pesaran (2015a, b); CIPS is the most appropriate unit root test since long panel data is susceptible to cross section dependence (as verified by Table 4 below). While Augmented Dickey-Fuller (ADF) is applied on time series variables: VIXl. ADF is the most widely used unit root test due to its reliability (Lütkepohl, 2005; Enders, 2014). The null hypothesis of non-Stationary is used for all unit root tests with maximum lag set by following formula: max lag = floor $(T)^{1/3}$ as proposed by Chudik and Pesaran (2015). For unit root test that accounts for possible structural breaks (unknown date assumed) we employ method proposed by Karavias and Tzavalis (2014) for panel variables and Zivot and Andrews (1992) for time series variable.

The presence of endogeneity can lead to biased and inconsistent estimators. This is where the concept of instrumental variables (IV) comes. In the context of this study, where panel data is at play, traditional IV methods might not be sufficient due to the intricate structures, potential heterogeneity, and cross-sectional dependencies. This is where the Mean Group Instrumental Variable (MGIV) method, as advanced by Norkutė *et al.* (2021) and Cui *et al.* (2020), becomes particularly useful. The MGIV method not only provides a remedy for endogeneity but also accommodates unobserved heterogeneity and exploits common factors in panel data. By catering to the idiosyncrasies inherent in long panel data structures, such as the one this study employs, the MGIV offers a robust and consistent estimation strategy.

Third, this study estimates Equations (1) and (2) with 2 Stage Instrumental Variable (2SIV) and MGIV. This study follows closely empirical strategy proposed by Kripfganz and Sarafidis (2021). It has the following objective: 2SIV is used as a complement to MGIV to assess the adequacy of factors used as instruments inferred from overidentifying restriction test (Hansen statistic p-value) and endogenous variables variance explained. The estimation requires instruments in the form of factors extracted from variables in lagged form (at order

2–3). This study employs Principal Component Analysis (PCA) to extract the factors. PCA is applied to variables used in the study: dependent variable, independent variables, and instruments.

Specification of 2SIV requires information on cross-section dependence and slope heterogeneity. The existence of cross-section dependence (cross-section factor loading) will be verified by the ex-ante cross-section dependence test proposed by Pesaran (2015a, b). The slope of regressors (β_i') can be assumed to be heterogenous and are randomly distributed around a common mean. This assumption is subject to further test cross-section slope heterogeneity (Pesaran and Yamagata, 2008; Blomquist and Westerlund, 2013), operationalized by Bersvendsen and Ditzen (2021). If the null hypothesis of the homogenous slope can be rejected, then the mean Group type is appropriate. This study needs to use the pooled version (Pesaran, 2006) as the correct specification. Norkutė *et al.* (2021) show that 2SIV and MGIV are consistent and asymptotically normally distributed as long as N/T is kept around a finite constant.

4. Result and discussion

This study does proper interpolation to fill missing values and winsorizing at 1 and 99 percentiles in data preparation. Table 2 shows the statistical profile of variables used in the study. The statistics calculated are mean, median, standard deviation, minimum, maximum, 1st percentile, 99th percentile, and number of observations. Overall, the variables are reasonably well-behaved. The mean SLOPE of sovereign bonds is 1.535% with a maximum of 8.022% and a minimum -of 7.96%; hence, there are occasions when term structure was inverted. The average of CURV is −0.864, indicating that the shape of the term structure is typically hump shape. Its minimum is −7.96, meaning there are occasions where the shape is parabolic (or triangle with a kink at 5%).

The macroeconomy indicator shows that economic management in sampled country and period is quite good. Average inflation is around 4.9%, with minimum and maximum at −3.4 and 25.24%, respectively. Monthly Exchange rate changes are about −2.29%–0.286%. Monthly growth ranges from −1% to +1% area. The fiscal condition perhaps should be noted since the maximum Government Debt ratio reached 99.8% of GDP while the fiscal deficit reached almost 14%.

Proxies /Statistics	Mean	Median	Std. dev	Min	Max	p1	p99	*N*
Y1	5.509	4.923	3.789	−0.737	25.150	0.406	17.960	1,278
Y5	6.709	6.994	3.436	0.584	25.030	0.853	17.560	1,278
Y10	7.044	7.505	3.263	1.056	20.690	1.412	16.680	1,278
SLOPE	1.535	1.023	1.984	−7.960	8.022	−2.450	7.465	1,278
CURV	−0.864	−0.264	1.803	−9.929	5.290	−7.416	1.203	1,278
INF	4.936	4.310	3.674	−3.440	25.240	−1.270	18.710	1,278
CBRATE	5.988	5.750	3.495	0.500	24.000	0.500	19.000	1,278
FX_C	0.001	0.001	0.097	−2.293	0.286	−0.079	0.118	1,278
GROWTH	0.005	0.003	0.143	−1.036	0.998	−0.540	0.450	1,278
FIS_BAL	−3.850	−3.253	3.214	−13.969	3.414	−13.229	2.674	1,278
GOV_DEBT	46.669	42.581	20.643	9.440	99.801	10.131	97.028	1,278
VIXl	2.858	2.806	0.322	2.252	3.980	2.320	3.760	1,278

Note(s): This table reports descriptive statistics of all variables in the study. Descriptive statistics reported are mean, median, standard deviation, minimum, maximum, percentile 1 and 99 and number of observations
Source(s): Authors' calculation

Table 2. Descriptive statistics

As can be seen from Table 3; unit root condition on variables is quite varied. If we assume at least one structural break occur then following variables: Y1, Y5, Y10, SLOPE, CURV, GROWTH, INF, CBRATE, GROWTH and GOV_DEBT possess stationary processes; and FX_C is the only variable that is non stationary. The structural break assumption is quite supported by the data for some variables. On the other hand if we do not assume any structural break occur than the following variables: SLOPE, CURV, FX_C, GROWTH and INF exhibit stationarity while Y1, Y5, Y10 exhibit non stationary. Therefore, it is not ideal to use Granger Causality since it requires all variables to be stationary. Nevertheless, this study still uses Granger Causality and bear in mind the result of the unit root test.

Table 4 shows that all variables exhibit cross-section dependence. Hence there might be a common factor that influences the movement of variables. Furthermore, from Table 5; we can see that null hypothesis of slope homogeneity of all regression specifications used in the paper is decisively rejected by the data. The presence of both cross-section dependence and slope heterogeneity suggest that MGIV-type estimator is more appropriate for our model.

	Standard unit root test		Unit root test with structural breaks	
Variable	*t*-stat	Conclusion	*t*-stat	Conclusion
Y1	−1.852	Non-Stationary	−17.487***	Stationary (1 structural break; 2018m2)
Y5	−1.783	Non-Stationary	−16.369***	Stationary (1 structural break; 2018m2)
Y10	−1.667	Non-Stationary	−18.499***	Stationary (1 structural break; 2018m4)
SLOPE	−2.921***	Stationary	−16.516	Stationary (1 structural break; 2010m2)
CURV	−4.161***	Stationary	−20.716	Stationary (1 structural break; 2010m2)
FX_C	−6.190***	Stationary	−0.597	Non-Stationary (No structural break)
GROWTH	−5.621***	Stationary	−6.5474***	Stationary (No structural break)
INF	−2.340**	Stationary	−15.666***	Stationary (1 structural break; 2021m6)
CBRATE	−1.367	Non-Stationary	−7.699***	Stationary (1 structural break; 2018m4)
FIS_BAL	−0.965	Non-Stationary	−15.218***	Stationary (1 structural break; 2010m2)
GOV_DEBT	−0.909	Non-Stationary	−47.500***	Stationary (1 structural break; 2010m2)
VIXI	−2.954**	Stationary	−6.331***	Stationary (No structural break)

Note(s): This table reports unit root test of variables used in the study. The significance levels at 0.01, 0.05, and 0.1 are denoted by ***, **, and *, respectively
Source(s): Authors' calculation

Table 3.
Unit root test

Variable	CD-test
Y1	18.690***
Y5	17.650***
Y10	13.980***
SLOPE	11.380***
CURV	2.280**
INF	8.660***
CBRATE	19.960***
GROWTH	22.330***
FX_C	24.140***
VIXI	71.500***
FIS_BAL	39.490***
GOV_DEBT	49.900***

Note(s): This table reports Pesaran (2015a, b) cross section dependence test. The significance levels at 0.01, 0.05, and 0.1 are denoted by ***, **, and *, respectively
Source(s): Authors' calculation

Table 4.
Cross-section dependence test

Specification	Delta	Adj-Delta
SLOPE Y1 INF FX_C GOV-DEBT	18.100***	18.551***
SLOPE Y5 INF FX_C GOV-DEBT	28.195***	28.897***
SLOPE Y10 INF FX_C GOV-DEBT	29.773***	30.515***
SLOPE Y1 INF FX_C FIS_BAL	22.904***	23.474***
SLOPE Y5 INF FX_C FIS_BAL	36.595***	37.506***
SLOPE Y10 INF FX_C FIS_BAL	35.747***	36.638***
CURV Y1 INF FX_C GOV_DEBT	20.439***	20.948***
CURV Y5 INF FX_C GOV_DEBT	24.499***	25.109***
CURV Y10 INF FX_C GOV_DEBT	19.272***	19.752***
CURV Y1 INF FX_C FIS_BAL	11.079***	11.355***
CURV Y5 INF FX_C FIS_BAL	21.653***	22.193***
CURV Y10 INF FX_C FIS_BAL	15.430***	15.814***

Note(s): This table reports slope heterogeneity test (Bersvendsen and Ditzen (2021)). The significance levels at 0.01, 0.05, and 0.1 are denoted by ***, **, and *, respectively
Source(s): Authors' calculation

Table 5. Slope heterogeneity test

The regression specification and instrument construction require at least a raw depiction of endogeneity. Table 6 reported panel VAR Granger Causality [1]; we can see that proposed order of variables endogeneity (from least to the most endogen): FX_C-GROWTH-Y1-CURV-SLOPE is well supported. For example, the null hypothesis of Y1 does not granger cause the

Dep. Var	Expl. Var	X^2	df
SLOPE	Y1	7.113*	3
	CURV	5.55	3
	GROWTH	1.064	3
	FX_C	2.67	3
	ALL	12.916	12
Y1	SLOPE	1.242	3
	CURV	2.574	3
	GROWTH	6.863*	3
	FX_C	3.707	3
	ALL	15.461	12
CURV	SLOPE	3.869	3
	Y1	3.864	3
	GROWTH	4.679	3
	FX_C	3.902	3
	ALL	12.17	12
GROWTH	SLOPE	0.47	3
	Y1	0.348	3
	CURV	1.202	3
	FX_C	0.74	3
	ALL	6.639	12
FX_C	SLOPE	2.439	3
	Y1	2.298	3
	CURV	1.3	3
	GROWTH	2.107*	3
	ALL	14.118	12

Note(s): This table reports panel Granger Cause analysis: Abrigo and Love (2016). The significance levels at 0.01, 0.05, and 0.1 are denoted by ***, **, and *, respectively
Source(s): Authors' calculation

Table 6. Granger causality test

Slope is rejected, while simultaneously, the reverse causality (Slope does not cause granger Yield) is not rejected.

Table 7 shows the result of PCA. Here we can see that three components can be extracted from the covariance matrix. This study uses an eigenvector score 0.2 to classify a variable into a particular factor with discretion. In this case, there is a variable, namely Slope, whose eigenvector score exceeds the threshold. If a variable can be classified into more than 1 component, this study classifies it based on the components with the highest score. This study has three alternative sets of factors to be used as Instruments.

(1) Factor 1 (Y1, INF, CBRATE), Factor 2 (Slope, VIXl), Factor 3 (Growth, FX_C)

(2) Factor 1 (Y1, INF, CBRATE), Factor 2 (Slope), Factor 3 (VIXl, FX_C, GROWTH).

(3) Factor 1 (Y1, INF, CBRATE, SLOPE), Factor 2 (VIXl), Factor 3 (FX_C, GROWTH).

This study employs all three alternative sets as a means of robustness check.

The regression result for the dependent variable SLOPE is reported in Table 8. First, this study observes the persistency of slope as previously found by Härdle and Majer (2016), Levant and Ma (2017), and Cepni *et al.* (2021). It can be seen that estimates for short-term yield (Y1) are all negative and highly significant. This finding supports the mean reversal mechanism for future yields as stipulated by Ross (2015) and Martin and Ross (2019). It corroborates earlier studies by Adrian *et al.* (2013), Abrahams *et al.* (2016), and Shareef and Shijin (2016). As proxied by inflation, interest rate expectation has a positive

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.997	1.049	0.3	0.300
Comp2	1.948	0.774	0.195	0.495
Comp3	1.17S	0.175	0.118	0.612
Comp4	0.999	0.022	0.100	0.712
Comps	0.978	0.077	0.098	0.810
Comp6	0.90	0.34	0.090	0.900
Comp7	0.559	0.364	0.056	0.956
Comp8	0.196	0.037	0.020	0.975
Comp9	0.158	0.069	0.016	0.991
Comp10	0.089		0.009	1.000

Variable	Comp1	Comp2	Comp3	Comp4	Comn5	Unexplained
Yl	0.5445	0.0478	−0.0789	−0.0235	0.024	0.09851
SLOPE	−0.2632	0.2742	0.5496	0.0954	−0.1667	0.255
CURV	−0.357	−0.158	0.0989	0.0417	0.0855	0.5487
INF	0.4788	0.1936	0.2643	0.0225	−0.1138	0.1447
CBRATE	0.4933	0.1595	0.1337	0.021	−0.0402	0.198
GROWTH	−0.002	0.017	−0.1688	0.9296	−0.3115	0.007295
FX_C	0.0589	0.0174	0.2696	0.3426	0.8903	0.01122
FIS_BAL	−0.1594	0.589	−0.2615	−0.0689	0.0903	0.1548
GOV_OEBT	0.064	−0.6727	−0.0903	0.0223	0.0247	0.09537
VIXI	−0.0338	−0.1857	0.6453	−0.0288	−0.2267	0.3892

Note(s): This table reports the Principal Component Analysis of variables used in the main specifications: Y1, SLOPE, CURV, INF, CBRATE, GROWTH, FX_C, FIS_BAL, GOV_DEBT and VIXl. The upper part of the table is used to determine the number of components, while the lower part is used to determine factor grouping
Source(s): Authors' calculation

Table 7.
Principle component analysis

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
L.SLOPE	0.516***	0.256***	0.497***	0.195***	0.511***	0.419
	(0.0693)	(0.0676)	(0.0813)	(0.0600)	(0.0669)	(0.330)
Y1	−0.257***	−0.443***	−0.270***	−0.468***	−0.273***	−0.127
	(0.0453)	(0.0558)	(0.0525)	(0.0472)	(0.0591)	(0.0940)
INF	0.0464**	0.0968***	0.0583**	0.104***	0.0236	−0.0253
	(0.0221)	(0.0129)	(0.0275)	(0.0114)	(0.0335)	(0.0339)
FX_C	2.418***	4.280**	5.286***	9.778***	3.365*	11.43**
	(0.825)	(1.831)	(1.947)	(1.988)	(2.004)	(4.841)
GOV_DEBT	−0.0362	−0.221***	−0.0370	−0.213***	−0.0646	0.415**
	(0.0353)	(0.0460)	(0.0395)	(0.0497)	(0.0707)	(0.208)
Constant	2.936**	13.41***	2.920**	13.18***	4.692*	−17.72*
	(1.276)	(2.766)	(1.415)	(2.609)	(2.434)	(9.601)
Estimator	MGIV	2SIV	MGIV	2SIV	MGIV	2SIV
Observations	1,260	1,260	1,260	1,260	1,260	1,260
Variance explained		0.928		0.918		0.755
No of instruments		6		6		6
No of factors		3		3		1
Hansen test (p value)		0.955		0.907		0.972

Note(s): Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
This table[a] reports mean group instrumental variables (MGIV) and two stages of instrumental variables estimation (2SIV) developed by Kripfganz and Sarafidis (2021) for the Dependent variable: SLOPE. Model 1,3, and 5 are MGIV type and corresponds to instruments set I, II, and III; respectively, model 2,4,6 is of 2 SIV Type. Statistics information presented includes coefficients, standard error (in parentheses), type of estimators, number of observations, variance explained (by factors), number of factors, and Overidentifying restriction test (Hansen test p-value). The level of significance at 0.01, 0.05, and 0.10 are denoted by ***, **, and *, respectively
[a] As recommended by Kripfganz and Sarafidis (2021), we use lagged form (at the order of 2 or 3) of extracted factors for Instrumented variables. In baseline regressions w use 2; while for robustness we use 3. This practice has caused reduction of number of observations used in estimation (to 1,260 for Tables 8 and 9; and 1,251 for Tables 10 and 11
Source(s): Authors' calculation

Table 8.
SLOPE regression

and significant influence on the slope of yield. This finding corroborates earlier findings by Coroneo *et al.* (2016) and Gadanecz *et al.* (2018), Sowmya and Prasanna (2018), Bulíř and Vlček (2022).

Local currency depreciation is associated with an increase in the slope aligned with the risk premium hypothesis. These findings confirm similar findings by Gadanecz *et al.* (2018), Cuchiero *et al.* (2016), and Chernov *et al.* (2019). Factors used (and corresponding instruments) have performed exceptionally well, as shown by the magnitude of endogenous variable explained variance that accounts for more than 90%.

Persistence is also an empirical feature of curve regression (see Table 9). However, unlike slope regression, this study no longer observes a significant role of macroeconomic variables in shaping yield curvature. This finding hence contradicts earlier results by Cepni *et al.* (2021).

Finally, the previous findings generally hold when alternative proxies (robustness check) are performed. As seen in Table 10, a rise in short-term interest expectation still poses a positive relationship with the slope when replacing INF with CBRATE. The central bank rate is also a credible proxy for short-term rate change. This study also still finds an insignificant role in fiscal conditions when replacing Gov_Debt with FIS_BAL (See Table 11).

Variables	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
L.CURV	0.697***	0.646***	0.694***	0.686***	0.697***	0.940***
	(0.0582)	(0.142)	(0.0562)	(0.142)	(0.0538)	(0.0642)
Y1	−0.0414	−0.0354***	−0.0488	−0.0327***	−0.0398	−0.00475
	(0.0314)	(0.00641)	(0.0411)	(0.0106)	(0.0404)	(0.00638)
INF	0.0133	0.0273***	0.0184	0.0223***	0.0140	0.00163
	(0.0248)	(0.00760)	(0.0302)	(0.00746)	(0.0325)	(0.00349)
FX_C	−0.976	0.439	−3.678	0.244	−3.544	−1.511*
	(0.906)	(1.335)	(2.534)	(1.721)	(2.393)	(0.808)
GOV_DEBT	−0.0150	−0.0390**	−0.0304	−0.0290	−0.0102	−0.0152
	(0.0336)	(0.0164)	(0.0423)	(0.0177)	(0.0437)	(0.0173)
Constant	−0.225	1.575	0.382	1.156	−0.682	0.684
	(1.548)	(1.533)	(1.725)	(1.119)	(2.074)	(1.229)
Estimator	2SIV	MGIV	2SIV	MGIV	2SIV	MGIV
Observations	1,260	1,260	1,260	1,260	1,260	1,260
Variance explained		0.609		0.639		0.484
No of instruments		6		6		6
No of factors		2		2		1
Hansen test (p value)		0.973		0.993		0.988

Note(s): Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
This table reports Two stages of instrumental variables estimation (Kripfganz and Sarafidis, 2021) for the Dependent variable: CURV. Statistics information presented includes coefficients, standard error (in parentheses), type of estimators, number of observations, variance explained (by factors), number of factors, and Overidentifying restriction test (Hansen test p-value). The significance levels at 0.01, 0.05, and 0.1 are denoted by ***, **, and *, respectively
Source(s): Authors' calculation

Table 9.
CURV regression

Variables	Model 13	Model 14	Model 15	Model 16
L.SLOPE	0.508***	0.258***	0.447***	0.283***
	(0.0714)	(0.0726)	(0.0670)	(0.0542)
Y1	−0.259***	−0.426***	−0.275***	−0.320***
	(0.0465)	(0.0398)	(0.0616)	(0.0178)
INF	0.0448**	0.0917***	0.0525**	−0.00559
	(0.0191)	(0.0103)	(0.0208)	(0.0177)
CBRATE				
FX_C	2.341***	4.553*	2.198***	1.790
	(0.820)	(2.412)	(0.747)	(2.000)
GOV_DEBT	−0.0322	−0.182***		
	(0.0343)	(0.0448)		
FIS_BAL			0.0438	−0.351***
			(0.113)	(0.0457)
Constant	2.894**	11.49***	1.761***	1.524***
	(1.235)	(3.080)	(0.681)	(0.528)
Estimator	MGIV	2SIV	MGIV	2SIV
Observations	1,251	1,251	1,251	1,251
Variance explained		0.919		0.460
No of instruments	9	9	9	9
No of factors		6		6
Hansen test (p value)		0.954		0.901

Note(s): Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
This table reports first part of robustness check regression. A robustness check is conducted using the Dependent variable, SLOPE but with alternative proxies for Interest Expectation (INF vs CBRATE) and Fiscal condition variables (FIS_BAL vs GOV_DEBT) with instrument set I. Statistics presented are coefficients, standard error (in parentheses), type of estimators, number of observations, variance explained (by factors), number of factors, and the Overidentifying restriction test (Hansen test p-value). The significance levels at 0.01, 0.05, and 0.1 are denoted by ***, **, and *, respectively

Table 10.
Robustness check-Alternative Proxies Part I

Variables	Model 17	Model 18	Model 19	Model 20
L.SLOPE	0.521***	0.340**	0.521***	0.340**
	(0.0721)	(0.134)	(0.0721)	(0.134)
Y1	−0.305***	−0.423***	−0.305***	−0.423***
	(0.0428)	(0.0254)	(0.0428)	(0.0254)
INF				
CBRATE	0.0874**	0.109***	0.0874**	0.109***
	(0.0419)	(0.0295)	(0.0419)	(0.0295)
FX_C	2.286***	0.629	2.286***	0.629
	(0.689)	(3.715)	(0.689)	(3.715)
GOV_DEBT	−0.0104	−0.217***	−0.0104	−0.217***
	(0.0196)	(0.0772)	(0.0196)	(0.0772)
FIS_BAL				
Constant	2.177**	12.81***	2.177**	12.81***
	(0.996)	(4.211)	(0.996)	(4.211)
Estimator	MGIV	2SIV	MGIV	2SIV
Observations	1,251	1,251	1,251	1,251
Variance Explained		0.684		0.684
No of Instruments	9	9	9	9
No of Factors		6		6
Hansen Test (*p* value)		0.951		0.951

Note(s): Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
This table reports the second part of robustness check regression. A robustness check is conducted using the Dependent variable, SLOPE but with alternative proxies for Interest Expectation (INF vs CBRATE) and Fiscal condition variables (FIS_BAL vs GOV_DEBT) with instrument set I. Statistics presented are coefficients, standard error (in parentheses), type of estimators, number of observations, variance explained (by factors), number of factors, and the Overidentifying restriction test (Hansen test *p*-value). The significance levels at 0.01, 0.05, and 0.1 are denoted by ***, **, and *, respectively
Source(s): Authors' calculation

Table 11. Robustness check–alternative proxies part II

5. Conclusion

This research aims to see the relationship of key features: slope and curvature of sovereign bonds from selected emerging countries. Departing from conventional yield curve modeling, this study treats slope and curvature as observable features (calculated from the data). The slope and curvature then regress against macroeconomic variables established in the literature: short-term yield, short-term interest expectation, foreign exchange depreciation, and fiscal condition. This study addresses the endogeneity problem inherent in the model and data structure using a novel econometric: MGIV. The dataset comprises nine emerging countries from January 2010 to October 2021 (1,278 observations).

The study reveals several significant findings. First, this study found slope and curvature to be highly persistent phenomena. Second, short-term yield is found to exert a reversal mechanism. Third, the results support the expectation hypothesis and contradict the preferred habitat and liquidity preference hypothesis. Fourth, local currency depreciation is found to increase term premiums significantly. The result is robust against alternative proxies and specifications.

Nevertheless, this study noted that panel unit root test that yielded mixed order of integration in the variables should serve as a methodological note. The main econometric method: MGIV and its variants are all silent about the implications of mixed order of integration in the variables used. Mixed order of integration is not rare occurrence in empirical works. Hence future works could aim to address this issue.

The study highlights the importance of maintaining financial stability. The empirical findings show that the impact of financial stability variables could be spread across the curve, affecting a broad spectrum of financial activities that could disrupt economic performance.

This study has shown that yield curve modeling can be studied empirically. The model and estimation result can generate sensible and comparable results using a more (constrained) theoretical-based model. This provides a research avenue to an approach that is intriguingly still scarce. Furthermore, the method can be modified to resolve several outstanding questions like the preferred habitat empirics, the role of global uncertainties, and cross-country linkages between yield curves.

Notes

1. We conduct Andrew and Lu (2001) procedure to determine the optimal lag used in the Panel VAR estimation that subsequently used for Granger Cause analysis. The optimal lag selected by Akaike Information Criteria (AIC), Bayesian Information Criteria (BIC) and Handan Quin Information Criteria (HQIC) is 3, results are not reported to save space but available upon request.

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Corresponding author
Doddy Ariefianto can be contacted at: moch.ariefianto@binus.ac.id