

Identifying the Distortions of Market Relationships in Government Bond Markets using ARDL-Models

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The relevance of the study

The government bonds issued in the local currency (GBLCY) in the emerging markets have reached a 30% share in the volume of the world public debt by 2020.

Our research is motivated by identifying new trends after the global financial crisis of 2008 and the regional crises of 2014-2015.

We can assume the presence of market inefficiencies on the BRICS markets:

- Central Bank policy: conducting operations in the market in order to regulate the level of interest rates (India), the exchange rate support policy (China), the policy of stimulating state banks to purchase GBLCY (Russia)
- The barriers that are imposed on the inflow of foreign capital into GBLCY



The purpose of the study and its novelty

The purpose is to analyze the determinants of government bond nominal yields in the large emerging markets (BRICS countries) using the optimal ARDL models.

Our value added (novelty) in the research field:

We develop the methodology for financial market pricing analysis. An own optimal ARDL model with specific variables (lags) is built for every country.

We identify and rank the factors that determine the yields of government bonds issued in the local currency (GBLCY), taking into account the time to maturity. Market inefficiencies are determined

The first group of hypotheses : the impact of country specific factors

Hypotheses	Relevant literature
<p>H1.1. The inflation rate has a significant positive effect on GBLCY yields. An important co-factor is the Central Bank (key rate) policy.</p>	<p>Senga et al. (2018)</p>
<p>H1.2. The depreciation of the local currency relative to the US dollar raises GBLCY yields</p>	<p>Sun et al. (2011)</p>
<p>H1.3. The economic growth has a significant effect on GBLCY yields.</p> <p><i>The effect can be positive or negative.</i></p>	<p>Izadi and Hassan (2018); Capelle-Blancard et al. (2019); Boysen-Hogrefe (2017)</p>
<p>H1.4. The ratio of government debt to GDP significantly effects GBLCY yields.</p> <p><i>The effect can be positive or negative.</i></p>	<p>Boysen-Hogrefe (2017); Senga et al. (2018); Rodionova (2014)</p>



The first group of hypotheses: the impact of country specific factors

Hypotheses	Relevant literature
<p>H1.5. The balance of the state budget (% GDP) significantly effects GBLCY yields.</p> <p><i>The effect can be positive or negative.</i></p>	<p>Boysen-Hogrefe (2017)</p>
<p>H1.6. The greater is the increase in the money supply, the lower are GBLCY yields.</p>	<p>Dua and Raje (2010)</p>



The second group of hypotheses: the impact of global market factors

Hypotheses	Relevant literature
H2.1. The higher is the US market volatility index (VIX), the higher are GBLCY yields in the emerging markets. The VIX growth impacts differently the GBLCY markets of various countries.	Piljak (2013), Silvapulle et al. (2016)
H2.2. The growth of the S&P500 stock index has a significant impact on GBLCY yields in emerging markets. <i>The effect can be positive or negative.</i>	Silvapulle et al. (2016)
H2.3. The oil price has a significant effect on GBLCY yields. <i>The effect can be positive or negative.</i>	Rodionova (2014)

The control variables are yields of 10-year US Treasuries and 3-month US T-Bills (Hartelius et al., 2008).



Methodology

✓We check time series for stationarity (Dickey-Fuller, Phillips-Perron, Elliott-Rothenberg-Stock tests) and implement the first differences approach

✓We test the co-integration between the YTM of GBLCY and inflation rate (ARDL-bounds tests, Johansen)

✓To estimate the long-term relationship between the model variables, the ARDL model is used in the form of error correction:

$$\Delta YTM_{i,t} = \alpha_i + \theta_i t + \sum_{k=1}^{p \in (1:K^*)} a_{i,k} \Delta YTM_{i,t-k} + \sum_{k=1}^{q \in (1:K^*)} b_{i,k} \Delta \pi^e_{t-k} + \gamma_i YTM_{i,t-1} + \mu_i \pi^e_{t-1} + \varepsilon_{i,t}$$

where $YTM_{i,t}$ is the nominal yield to maturity of a GBLCY with i years to maturity ($i = 1, 3, 5, 10$), $\alpha, \gamma, \mu, \theta, a, b$ are model parameters, π^e is inflation rate, K^* is the optimal lag of the model variables.

✓To choose the optimal model, we analyze the models with all possible configurations of $\{p; q\}$. After estimating a model, we test its residuals for the normality (Jacques-Burr test) and for autocorrelation (Brousch-Godfrey test), and compute the Akaike (AIC) and Schwartz (BIC) criteria.

Methodology

✓The following component is used to account for the long-term relationship:

$$ECT_t = \gamma_i YTM_{i,t-1} + \mu \pi^e_{t-1}.$$

It is estimated with the help of the Δ -method (Oehlert, 1992).

✓A complex factorial ARDL model is built:

$$\Delta YTM_{i,t} = c_i + d_i t + \sum_{k=1}^{p' \in (1:K^*)} a_{i,k} \Delta YTM_{i,t-k} + \sum_{j=1}^n \sum_{k=1}^{q_j' \in (1:K^*)} b_{i,k} \Delta X_{j,t-k} + \lambda_i ECT_{i,t-1} + \varepsilon_{i,t}$$

where X is a vector of repressors. The models are built with an individual lag for every explanatory variable of the vector X .

✓The original DEA methodology is used to optimize the model selection procedure. The AIC and BIC criteria are used as inputs in the DEA procedure, and the adjusted R^2 as an output.

✓A variable importance measure (VIM) is estimated for the optimal model. The LMG metric is used to assess the VIM (Lindeman et al., 1980). This metric allows us to estimate the contribution of every variable to the value of the model coefficient of determination R^2 .

✓Also, ARDL models are built on the basis of the shorter subsamples (for different moving time “windows” / periods) to analyze the changes in the factor effect on the YTM.



Model variables

Variable	Description
KeyRate	The Central Bank key rate, %
Inflation	The inflation rate, year on year, %
USD_LCY_Return	A change in the exchange rate of the US dollar to the local currency (per month),%
Budget_to_GDP	The state budget balance,% of GDP
Debt_to_GDP	The government debt,% of GDP
M2_Change	A change in the money supply M2 (per month),%
Output_Change	The industrial production growth rate,%
PMI	Purchasing Managers' Index
SnP_500_Return	S&P 500 Index return (per month),%
CBOE_VIX_Return	VIX index change in the US market (per month),%
BrentReturn	A change in the Brent oil price (per month),%
USA_10Y_YTM	YTM of 10-year US Treasuries,%
USA_3M_YTM	YTM of 3-month US T-Bills,%
Y10_GB_YTM, Y5_GB_YTM, Y3_GB_YTM, Y1_GB_YTM	YTM of 10, 5, 3, 1-year GBLCY,%



The sample

The sample includes 169 monthly observations for each BRICS country starting from January 2007 to January 2021.

To study the **dynamics** of the factors influence, the sample is divided into subsamples (“windows”) of 48 observations in each with an interval between the nearest subsamples that is equal to 4 periods.

Overall we use 31 subsamples (the last subsample includes all observations that remain to the end of the main sample).

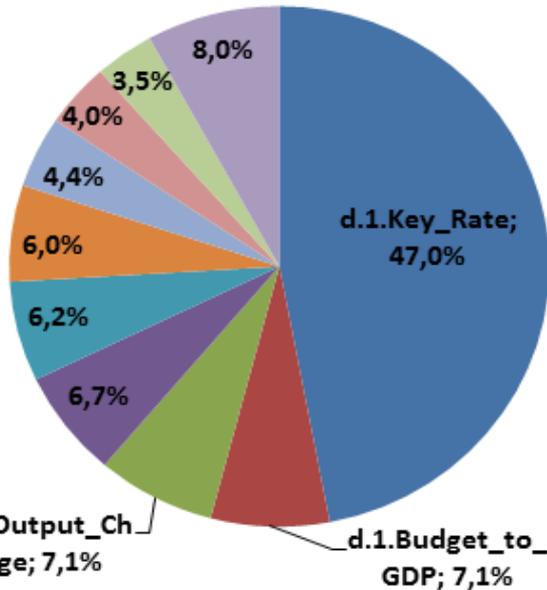
Period	Start date	End date
1	Jan. '07	Dec. '10
2	May. '07	Apr. '11
3	Sep. '07	Aug. '11
4	Jan. '08	Dec. '11
5	May. '08	Apr. '12
6	Sep. '08	Aug. '12
7	Jan. '09	Dec. '12
8	May. '09	Apr. '13
9	Sep. '09	Aug. '13
10	Jan. '10	Dec. '13
11	May. '10	Apr. '14
12	Sep. '10	Aug. '14
13	Jan. '11	Dec. '14
14	May. '11	Apr. '15
15	Sep. '11	Aug. '15
16	Jan. '12	Dec. '15
17	May. '12	Apr. '16
18	Sep. '12	Aug. '16
19	Jan. '13	Dec. '16
20	May. '13	Apr. '17
21	Sep. '13	Aug. '17
22	Jan. '14	Dec. '17
23	May. '14	Apr. '18
24	Sep. '14	Aug. '18
25	Jan. '15	Dec. '18
26	May. '15	Apr. '19
27	Sep. '15	Aug. '19
28	Jan. '16	Dec. '19
29	May. '16	Apr. '20
30	Sep. '16	Aug. '20
31	Jan. '17	Dec. '20



Model results. Russia

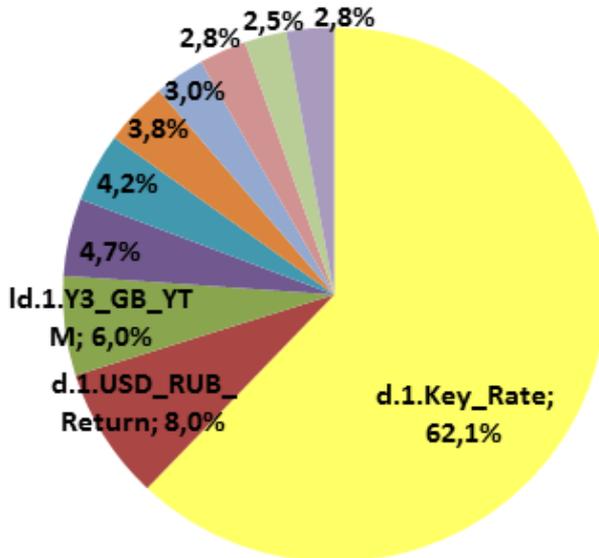
Russia, 10Y

- d.1.Key_Rate
- d.1.Budget_to_GDP
- Id.2.Output_Change
- Id.2.Debt_to_GDP
- Id.8.Key_Rate
- l.1.Y10_GB_YTM
- Id.4.M2_Change
- Id.9.USA_3M_YTM
- Id.5.Debt_to_GDP
- Others



Russia, 3Y

- d.1.Key_Rate
- d.1.USD_RUB_Return
- Id.1.Y3_GB_YTM
- Id.2.Key_Rate
- Id.1.Budget_to_GDP
- Id.10.USA_3M_YTM
- Id.1.Output_Change
- Id.2.USA_10Y_YTM
- l.1.Y3_GB_YTM
- Others



	YTM_Y3	YTM_Y10
(Intercept)	0.198	0.554**
d.1.Budget_to_GDP	0.028*	0.05**
d.1.Debt_to_GDP		-0.093
d.1.Key_Rate	0.534***	0.372***
d.1.M2_Change		0.001
d.1.Output_Change	-0.025	-0.014
d.1.USA_10Y_YTM	0.21	
d.1.USA_3M_YTM	-0.065	0.31
d.1.USD_RUB_Return	0.031***	
l.1.Y10_GB_YTM		-0.059**
l.1.Y3_GB_YTM	-0.027	
Id.1.Budget_to_GDP	0.05**	
Id.1.Output_Change	-0.018	
Id.1.Y3_GB_YTM	0.171***	
Id.2.Debt_to_GDP		0.132*
Id.2.Key_Rate	0.142***	
Id.2.Output_Change		-0.051***
Id.2.USA_10Y_YTM	-0.246	
Id.4.M2_Change		-0.017*
Id.5.Debt_to_GDP		-0.179
Id.6.Debt_to_GDP		-0.109
Id.8.Key_Rate		0.154***
Id.9.USA_3M_YTM		-0.338*
Id.10.USA_3M_YTM	-0.445***	
R ²	0.502	0.6
F-stat	10.289	16.601
Adj. R ²	0.453	0.564

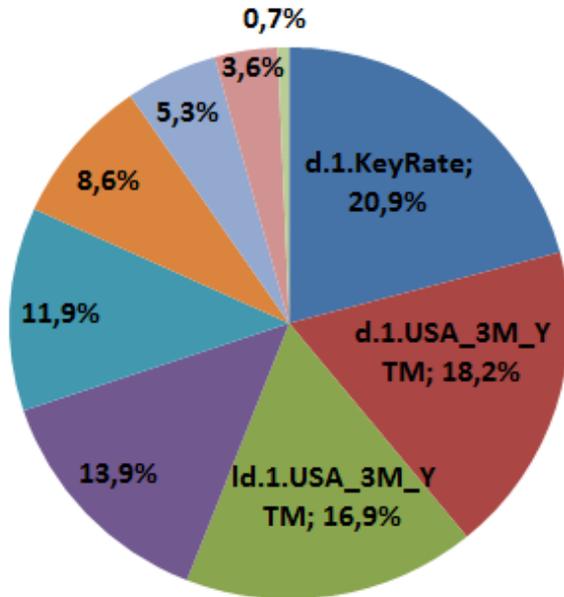


Model results. Russia

- ✓ **The main factor that determines the YTM of long-term and medium-term OFZ is the key rate**
- ✓ **We find a direct relationship between the balance of a state budget and OFZ YTM**
- ✓ **The growth rate of industrial production has a significant negative effect on the YTM of long-term and medium-term OFZ (with a 2-month lag for the YTM of 10-year OFZ, without a lag and with a lag of 1 month for the YTM of 3-year OFZ).**
- ✓ **The higher is the increase in M2, the lower is the YTM for long-term OFZ (a 4-month lag).**

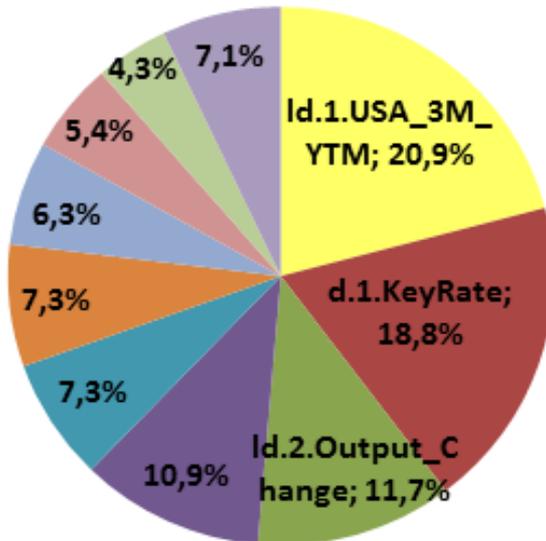
Model results. China

China, 10Y



- d.1.KeyRate
- d.1.USA_3M_YTM
- Id.1.USA_3M_YTM
- Id.1.Y10_GB_YTM
- d.1.USA_10Y_YTM
- Id.4.USA_10Y_YTM
- Id.10.Y10_GB_YTM
- Id.1.SP500_Return
- d.1.SP500_Return

China, 3Y



- Id.1.USA_3M_YTM
- d.1.KeyRate
- Id.2.Output_Change
- Id.1.Y3_GB_YTM
- Id.1.Y3_GB_YTM
- Id.5.Output_Change
- Id.1.USA_10Y_YTM
- d.1.CBOE_VIX_Return
- d.1.USA_10Y_YTM
- Others

	YTM_Y3	YTM_Y10
(Intercept)	0.249***	0.312***
d.1.Budget_to_GDP	-0.034	
d.1.CBOE_VIX_Return	0.001	
d.1.KeyRate	0.408***	0.283***
d.1.Output_Change	0.001	
d.1.SP500_Return		0.0001
d.1.USA_10Y_YTM	0.073	0.077
d.1.USA_3M_YTM	0.032	0.152**
Id.1.Y10_GB_YTM		-0.078***
Id.1.Y3_GB_YTM	-0.072***	
Id.1.KeyRate	0.109	
Id.1.SP500_Return		0.002
Id.1.USA_10Y_YTM	0.085	
Id.1.USA_3M_YTM	0.232***	0.162***
Id.1.Y3_GB_YTM	0.103	
Id.2.Output_Change	0.016**	
Id.4.USA_10Y_YTM		-0.094**
Id.5.Output_Change	-0.014**	
Id.9.Budget_to_GDP	-0.068	
Id.10.Y10_GB_YTM		-0.101
R ²	0.337	0.332
F-stat	6.405	6.881
Adj. R ²	0.285	0.284

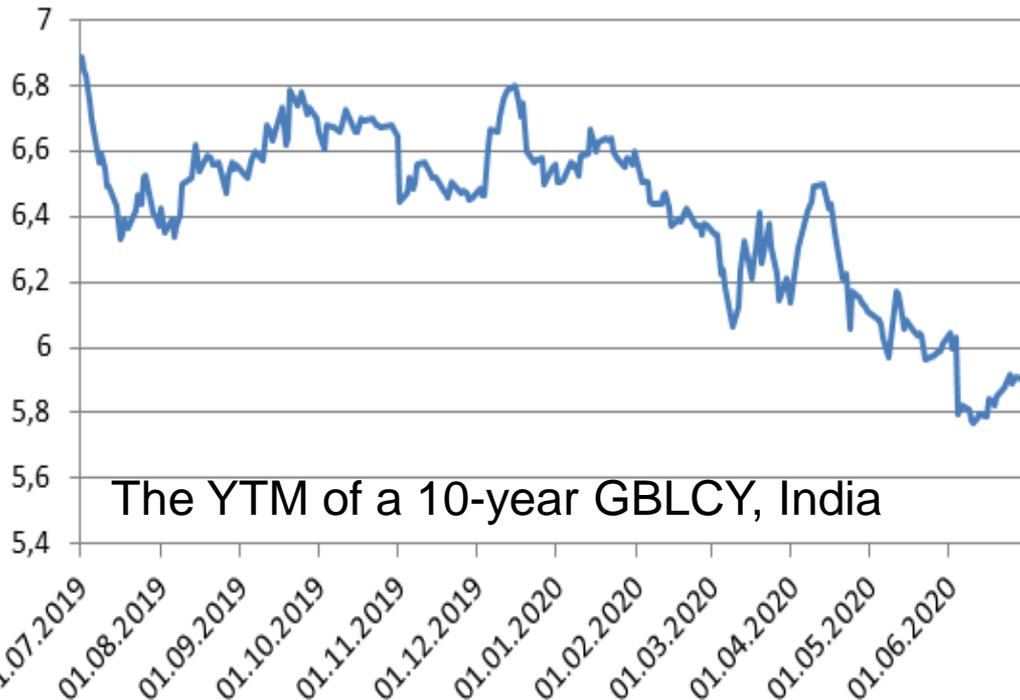
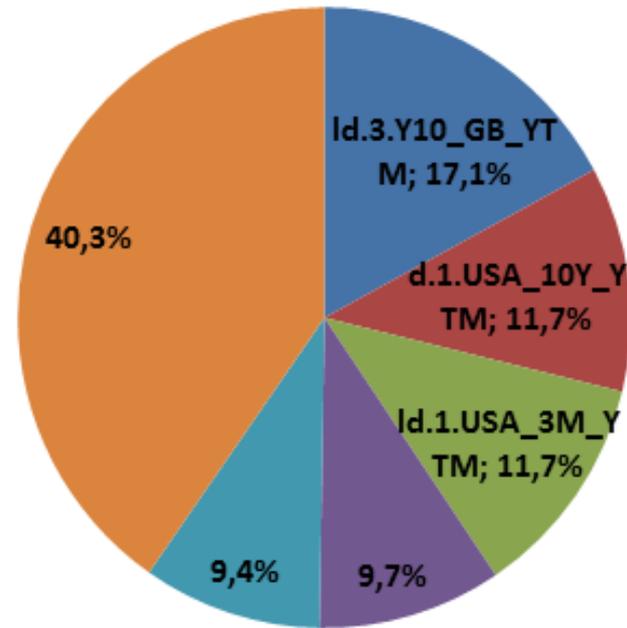
Model results. China/ Summary

- ✓ **One of the most important factors that impacts the YTM of the long and medium-term GBLCY is the key rate.**
- ✓ **The YTM of 10-year and 3-year GBLCY is significantly positively influenced by the YTM of 3-month US T-Bills.**
- ✓ **The YTM of 10-year GBLCY is significantly negatively affected (with a lag of 4 months) by the YTM of 10-year US Treasuries.**
- ✓ **The YTM of 3-year GBLCY is significantly positively influenced by industrial production growth (with a 2-month lag).**
- ✓ **The YTM of 10-year GBLCY is positively influenced by the S&P 500 return (effects of capital flows).**
- ✓ **The higher is the volatility on the US market, the greater is the YTM of 3-year GBLCY.**

Model results. India

India, 10Y

- Id.3.Y10_GB_YTM
- d.1.USA_10Y_YTM
- Id.1.USA_3M_YTM
- l.1.Y10_GB_YTM
- Id.4.Y10_GB_YTM
- Others



	YTM_Y3	YTM_Y10
(Intercept)	0.881***	1.039***
d.1.BrentReturn	0.002	
d.1.Budget_to_GDP	-0.071	0.037
d.1.KeyRate	0.194*	0.3***
d.1.M2_Change		-0.001
d.1.USA_10Y_YTM	0.157*	0.243***
d.1.USA_3M_YTM	0.068	-0.018
l.1.Y10_GB_YTM		-0.118***
l.1.Y3_GB_YTM	-0.098***	
Id.1.USA_10Y_YTM		0.062
Id.1.USA_3M_YTM	0.519***	0.322***
Id.3.Y10_GB_YTM		-0.246***
Id.4.BrentReturn	0.003**	
Id.4.KeyRate	-0.152	-0.174*
Id.4.Y10_GB_YTM		0.211***
Id.7.Budget_to_GDP	0.866***	0.513***
Id.8.M2_Change		0.01**
trendvar	-0.002***	-0.001***
R^2	0.303	0.406
F-stat	6.618	7.085
Adj. R^2	0.257	0.349

Foreign funds reduced their investments in GBLCY 1.5 times in the first two quarters of 2020 (from 1.9 to 1.1 bln Indian rupees, Bloomberg). The budget deficit grew from 5.5% to 10.2% of GDP.

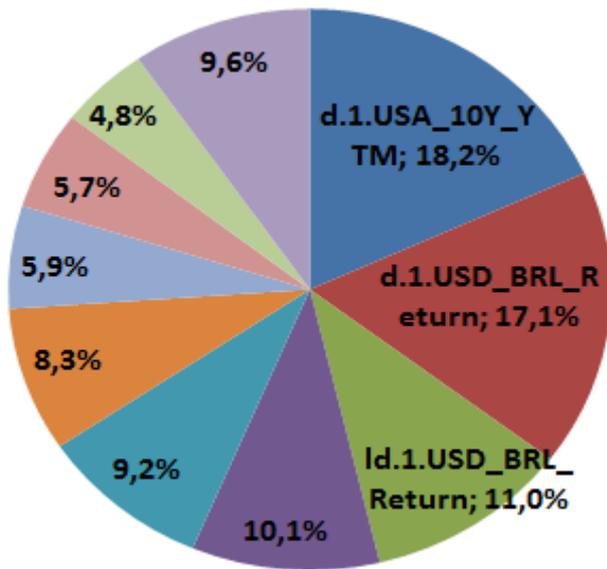
Model results. India/summary

- ✓ **The YTM of 10-year and 3-year GBLCY is significantly influenced by 1, 3 and 4 lags of the dependent variable**
- ✓ **The yield of 10-year US Treasuries and 3-month US T-Bills has a significantly positive effect on the YTM of 10-year and 3-year GBLCY.**
- ✓ **The effect of the key rate on the YTM of 10-year and 3-year GBLCY is significantly positive.**
- ✓ **We highlight that the yield of 3-year GBLCY is positively and significantly influenced by the change in oil prices (with a lag of 4 months) at the 5% confidence level.**
- ✓ **As long as M2 increases, the YTM of 10-year GBLCY does not decrease.**
- ✓ **The balance of state budget (% of GDP) positively effects the YTM of 10-year and 3-year GBLCY.**

Model results. Brazil

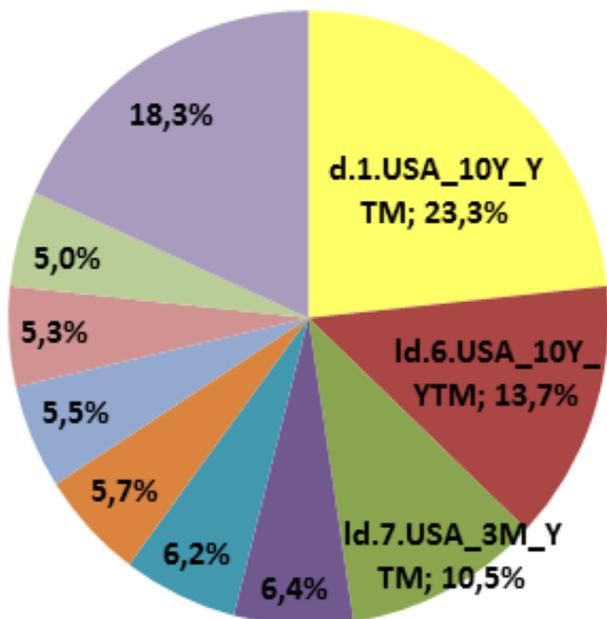
Brazil, 10Y

- d.1.USA_10Y_YTM
- d.1.USD_BRL_Return
- Id.1.USD_BRL_Return
- Id.6.USA_10Y_YTM
- Id.2.Output_Change
- Id.6.M2_Change
- d.1.USA_3M_YTM
- Id.1.USA_10Y_YTM
- d.1.Inflation
- Others



Brazil, 3Y

- d.1.USA_10Y_YTM
- Id.6.USA_10Y_YTM
- Id.7.USA_3M_YTM
- d.1.Inflation
- Id.1.USA_10Y_YTM
- Id.2.Output_Change
- d.1.USD_BRL_Return
- d.1.SnP_500_Return
- Id.1.CBOE_VIX_Return
- Others



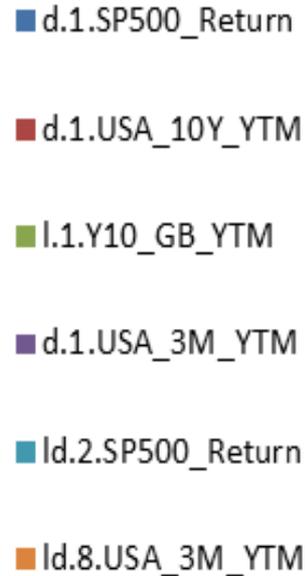
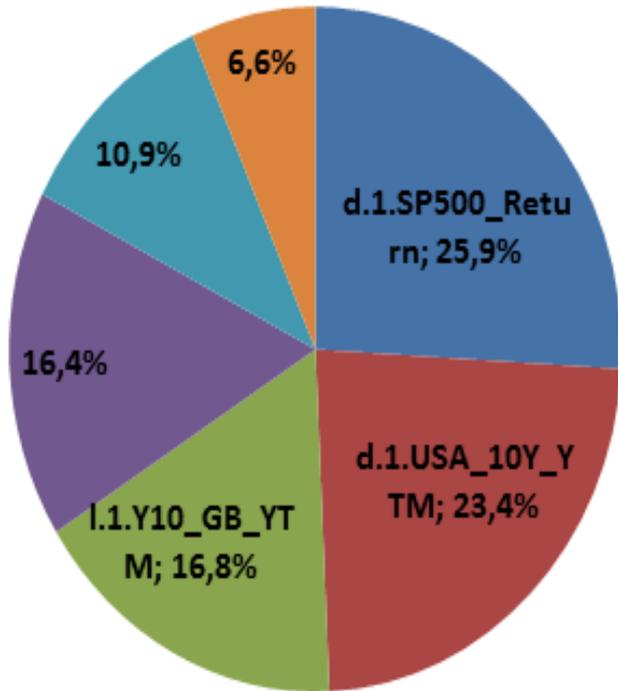
	YTM_Y3	YTM_Y10
(Intercept)	0.488	0.723*
d.1.CBOE_VIX_Return	-0.001	0
d.1.Inflation	0.406*	0.372**
d.1.M2_Change		-0.027
d.1.Output_Change	-0.017	-0.012
d.1.SnP_500_Return	-0.011*	
d.1.USA_10Y_YTM	1.092***	1.035***
d.1.USA_3M_YTM	-0.589**	-0.657***
d.1.USD_BRL_Return	0.016*	0.039***
I.1.Y10_GB_YTM		-0.048*
I.1.Y3_GB_YTM	-0.034	
Id.1.USA_10Y_YTM	0.40**	0.459**
Id.1.USD_BRL_Return		0.031***
Id.2.Output_Change	0.031**	0.037***
Id.3.Y3_GB_YTM	0.018	
Id.6.M2_Change		0.057**
Id.6.USA_10Y_YTM	0.913***	0.744***
Id.7.CBOE_VIX_Return		-0.002
Id.7.USA_3M_YTM	-0.389*	
Id.8.USA_10Y_YTM	-0.214	
R^2	0.452	0.464
F-stat	7.368	8.383
Adj. R^2	0.391	0.409

Model results. Brazil

- ✓ **The YTM of 10-year US Treasuries has the most significant effect on the YTM of 10-year and 3-year GBLCY (positive)**
- ✓ **The impact of 3-month US T-Bills YTM (in the current month) on the YTM of 10-year GBLCY is negative (the effect of capital outflow)**
- ✓ **The depreciation of the Brazil Real against the US dollar leads to an increase in the YTM of 10-year GBLCY (in the current month and with a lag of 1 month)**
- ✓ **An increase in the industrial production growth rate (with a lag of 2 months) leads to an increase in the YTM of 10-year and 3-year GBLCY**
- ✓ **A growth in money supply M2 (with a lag of 6 months) leads to an increase in the YTM of 10-year GBLCY**
- ✓ **An increase in the S&P 500 leads to a decrease in the YTM of 3-year GBLCY, while the influence of the US VIX (with a lag of 1 month) is significantly positive**

Model results. South Africa

S. Africa, 10Y



	YTM_Y10
(Intercept)	0.734**
d.1.SP500_Return	-0.015***
d.1.USA_10Y_YTM	0.487***
d.1.USA_3M_YTM	-0.573***
l.1.Y10_GB_YTM	-0.09**
ld.2.SP500_Return	0.009*
ld.8.USA_3M_YTM	0.257*
R ²	0.279
F-stat	8.395
Adj. R ²	0.246

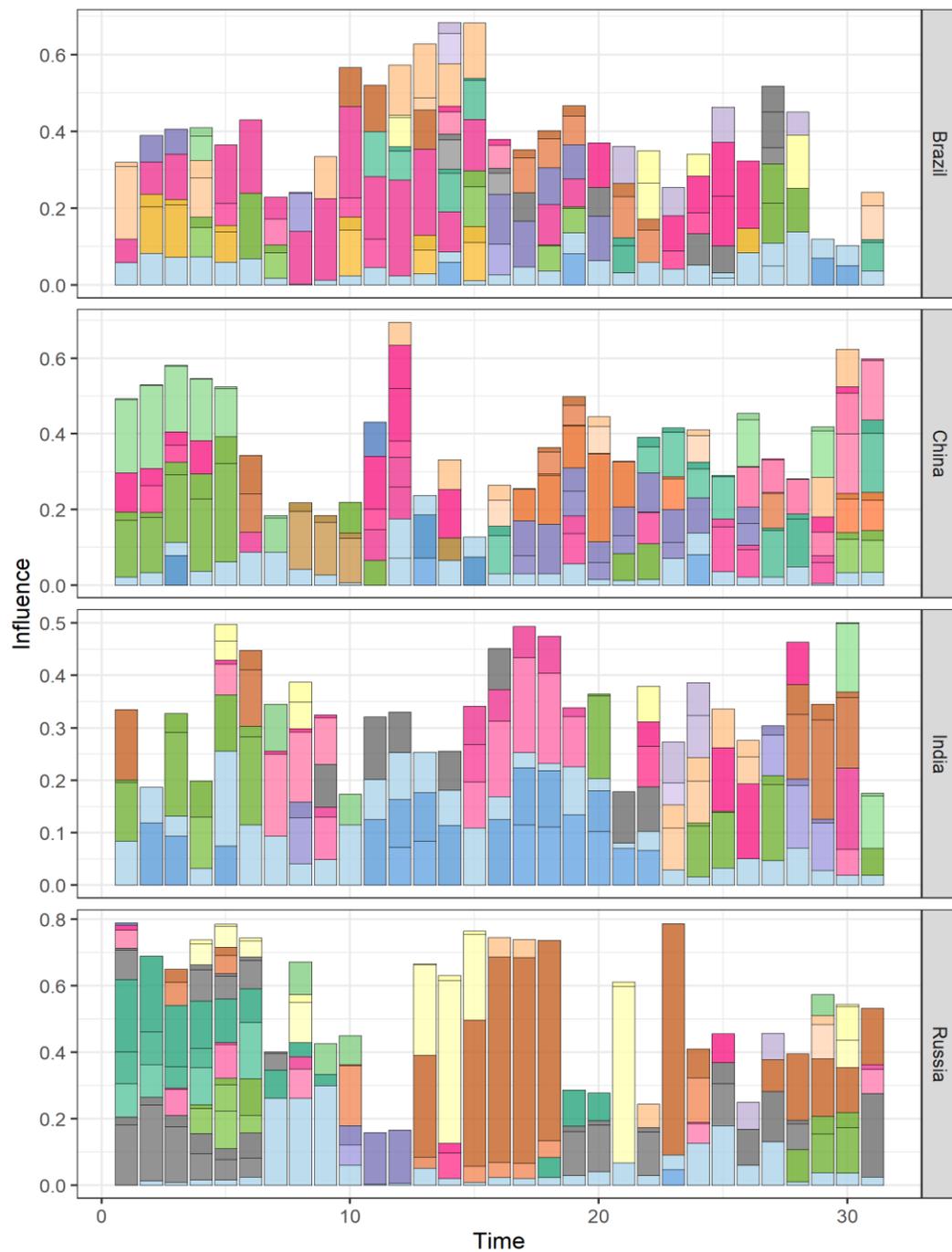
✓ The global market factors are the most important

✓ The growth of the S&P 500 index (in the current month and with a lag of 2 months) leads to a decrease in the YTM of GBLCY

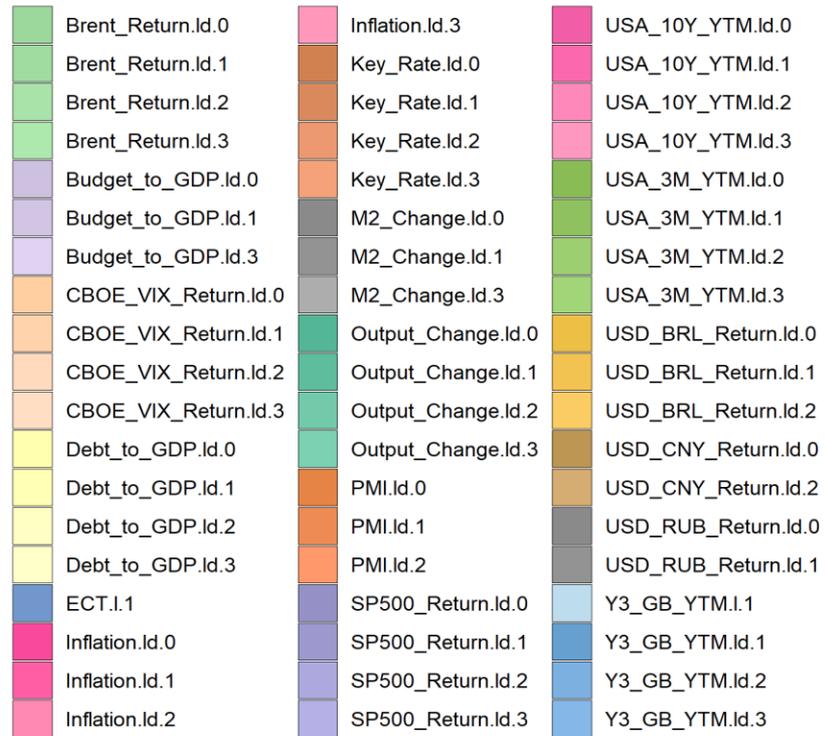
✓ The effect of the 10-year US Treasuries YTM is significantly positive, while the effect of the 3-month US T-Bills YTM is significantly negative

Dynamic factor influence analysis for 3-year government bonds

Factors dynamics for the 3-year GBLCY



mypal





Model results. The factor dynamics for 3-year GBLCY

Russia	Until the III quarter 2014: <ul style="list-style-type: none"> - Exchange rate; - Industrial production growth rate 	Until the III quarter 2016: <ul style="list-style-type: none"> - Key rate 	In 2017-2020: <ul style="list-style-type: none"> - Exchange rate; - Key rate; - The YTM of 3 months US T-Bills
China	Up to IV quarter 2013: <ul style="list-style-type: none"> - The YTM of 3 months US T-Bills and 10-year US Treasuries; - Oil price 	Between 2014 and the I quarter. 2015: <ul style="list-style-type: none"> - The YTM of 10-year US Treasuries In 2016-2017: <ul style="list-style-type: none"> - S&P 500 index return; - Key rate 	In 2018-2020: <ul style="list-style-type: none"> - Industrial production growth rate - The YTM of 3-month US T-Bills and 10-year US Treasuries
India	Until the II quarter 2015: <ul style="list-style-type: none"> - The YTM of 3-month US T-Bills; - The YTM of 3-year GBLCY in the previous periods 	Up to IV quarter 2016: <ul style="list-style-type: none"> - The YTM of 3-year GBLCY in the previous periods; - The YTM of 10-year US Treasuries 	In 2018-III quarter 2020: <ul style="list-style-type: none"> - State budget balance (% of GDP); - Key rate
Brazil	Before 2014: <ul style="list-style-type: none"> - The YTM of 10-year US Treasuries 	In 2014-2015: <ul style="list-style-type: none"> - The YTM of 10-year US Treasuries - VIX USA 	In 2016-2019: <ul style="list-style-type: none"> - The YTM of 10-year US Treasuries In 2020: VIX USA

Thanks

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