Making decisions on issuing sub-federal bonds: key factors modeling
Part 2

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Initial Data and Main Aim

Name	Indicator
RBV	Regional (sub-federal) bond volume, 1000 rubles
BLP	Budget loan proportion, %
KR	Key rate (refinancing rate), %
ACCI	Average per capita cash income, rubles
DL	Debt level (public debt/volume of tax and non-tax revenues), %
RBS	Regional budget surplus, million rubles
EMPL	Employed, 1000 people

Try to elucidate the process of sub-federal bonds issuing based on panel data on Russia's regions.

Software and Reproducible Research

- Software used: R 3.6.3
- Main packages used:
  - pglm (GLM for panel data);
  - glmmTMB (GL Mixed Models);
  - DHARMa (GLMM diagnostics);
  - bbmle (compare models with AIC);
  - texreg (presentation of model summaries)
- Complete workflow (Jupyter notebook):
  Yakunina_final.ipynb
  https://github.com/alxymitr/regional-bonds-Russia

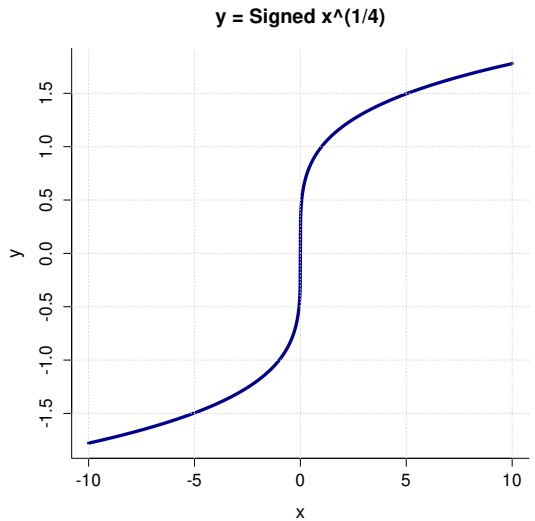
Initial Data Summary

Statistic	N	Min	Median	Mean	St. Dev.	Max
RBV	5,440	0	0	5,803,268.000	11,796,174.000	111,255,238
BLP	5,440	0.000	50.419	51.655	27.962	100.000
KR	5,440	6	9	9.324	2.454	17
ACCI	5,100	5,223.000	26,332.500	29,742.540	12,952.260	150,843.000
DL	5,133	0.000	55.360	55.137	34.171	230.190
RBS	5,097	−67,511.000	303.900	4,782.966	24,254.230	381,541.200
EMPL	5,434	19.130	555.690	849.577	960.401	7,294.200

The data on the response variable – Regional Bond Volume (RBV) includes more than a half of zero values, suggesting the use of a model consisting of two parts: the first one predicting the probability of any non-zero RBV volume, the second one predicting the volume itself provided it is positive.

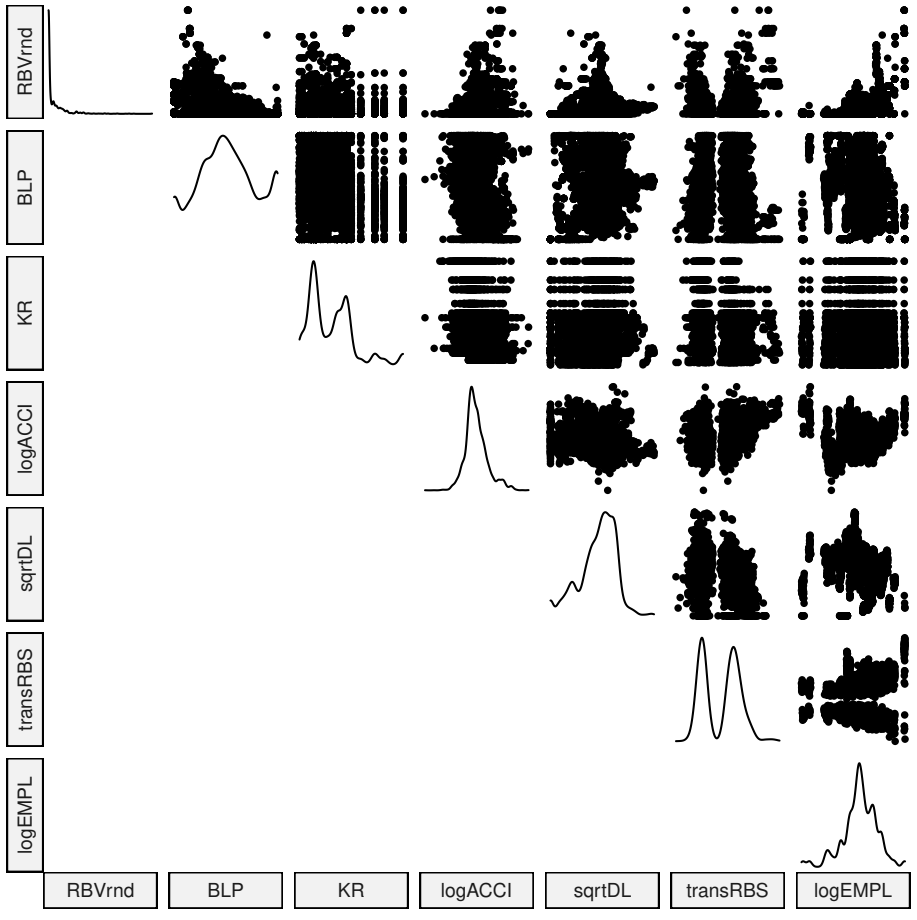
Data Transformations

- RBVrnd = as.integer(round(RBV/1e5))
- RBVnz = as.factor(as.integer(RBVrnd > 0))
- logACCI = log(ACCI)
- sqrtDL = DL^(1/2)
- transRBS = trans_rbs(RBS)



- logEMPL = log(EMPL)

Transformed Data: Pairs Plot



Models 1-4 for RBVnz

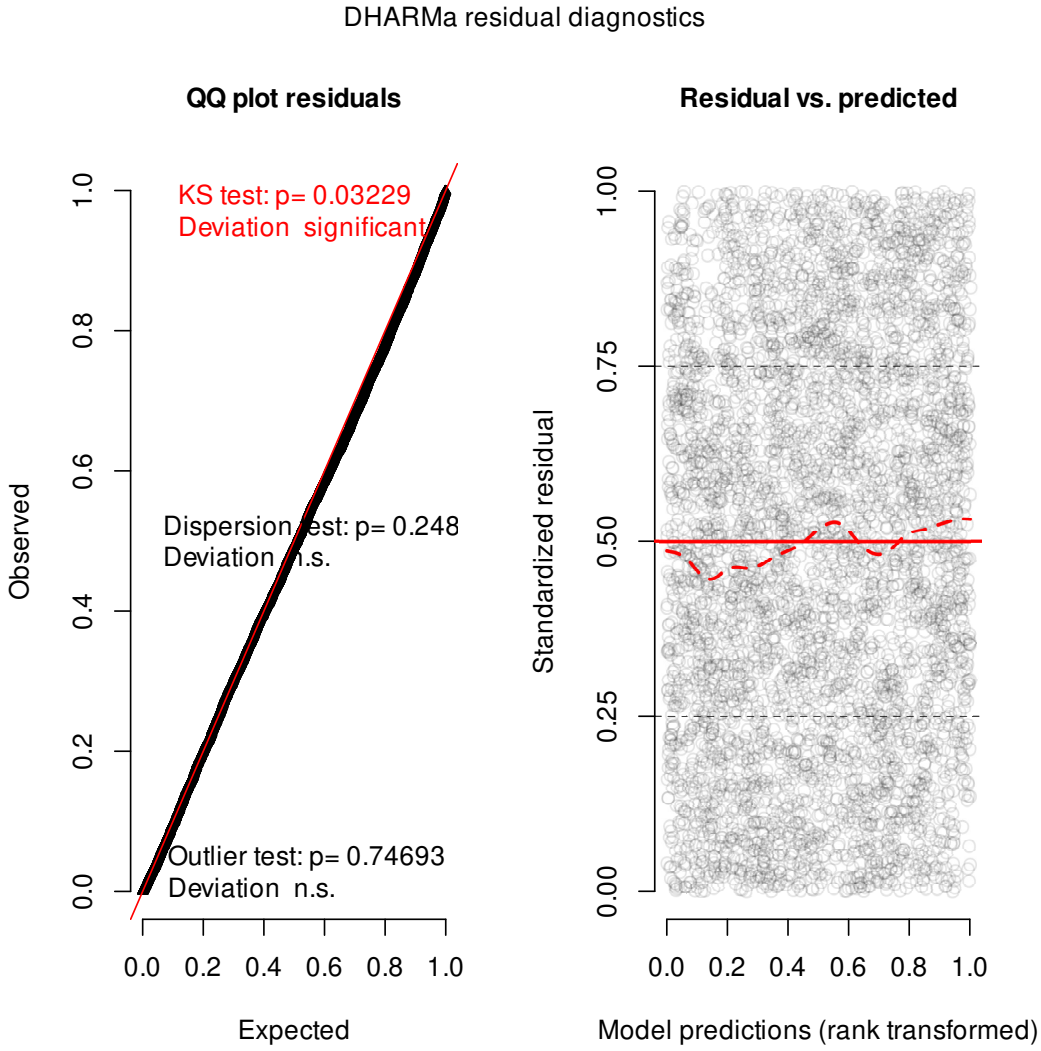
Table 3: Response RBVnz: Models 1, 2 estimated with pgls, Model 3, 4 with glmmTMB

	Model 1	Model 2	Model 3	Model 4
(Intercept)	**−32.057*****	**−27.792*****	**−29.865*****	16.312
	(3.410)	(3.729)	(7.936)	(41.461)
BLP	**−0.069*****	**−0.100*****	**−0.087*****	−0.078
	(0.004)	(0.006)	(0.007)	(0.065)
KR	**−0.478*****	**−0.550*****	**−0.575*****	**−5.231*****
	(0.039)	(0.045)	(0.051)	(1.258)
logACCI	**2.067*****	**1.676*****	0.966	−0.653
	(0.271)	(0.297)	(0.509)	(3.447)
sqrtDL	**0.548*****	**0.873*****	**1.012*****	0.550
	(0.042)	(0.058)	(0.128)	(0.768)
transRBS	0.007	0.011	0.022	−0.115
	(0.012)	(0.013)	(0.015)	(0.160)
logEMPL	**2.296*****	**2.103*****	**3.587*****	1.821
	(0.128)	(0.126)	(0.850)	(1.766)
sigma	**5.748*****	**5.435*****		
	(0.272)	(0.266)		
D201812		**9.527*****	**11.103*****	**37.927*****
		(0.857)	(1.004)	(6.513)
Log-Likelihood	−904.138	−780.307		
Num. obs.	4879	4879	4879	4879
AIC			1505.392	557.189
Log Likelihood			−743.696	−268.594
Num. groups: region			85	85
Var: region (Intercept)			60.844	
Var: region monthmonth2				48909.591
⋮				⋮
Var: region monthmonth60				48909.591

Coefficients with $p < 0.05$ in **bold**.

	dAIC	df
RBVnz_glmm4	0.0	10
RBVnz_glmm2	948.2	9
RBVnz_blogit2	1021.4	9
RBVnz_blogit1	1267.1	8

DHARMa: Model 4 diagnostics



Model 5: Command

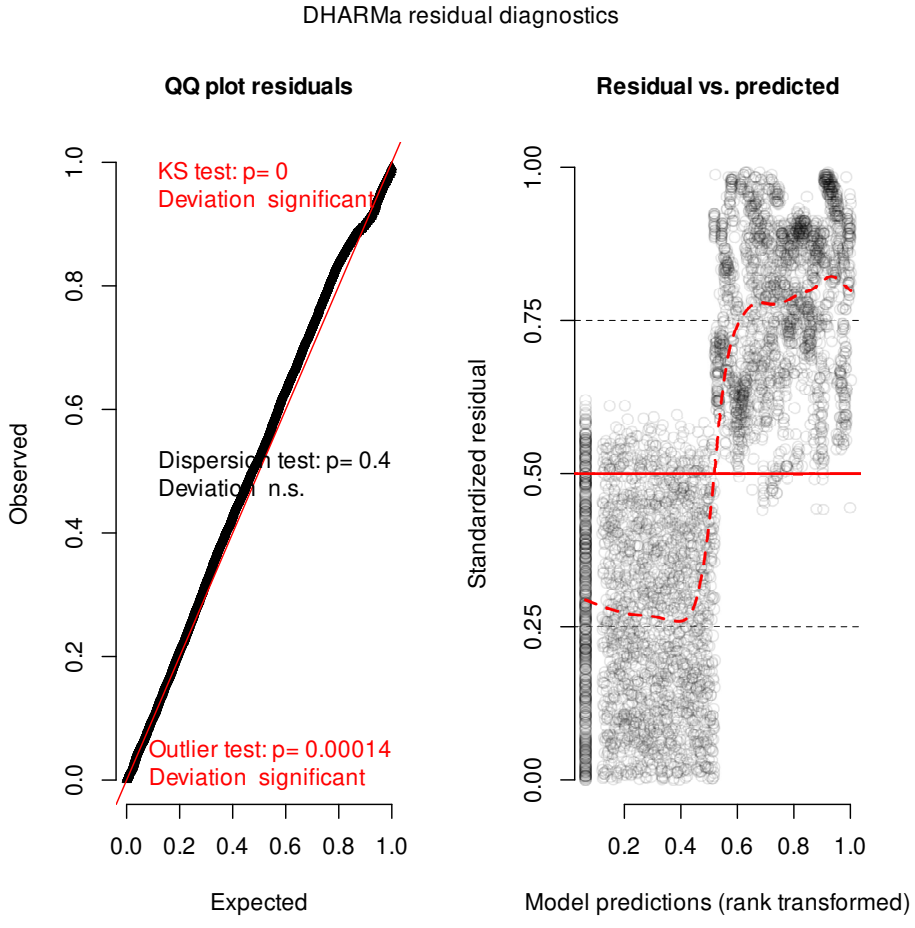
```
# truncated Poisson for RBVrnd
RBVrnd_poisson1 <- glmmTMB(RBVrnd ~ BLP + KR + logACCI + sqrtDL + transRBS + logEMPL + D201812 +
                        ar1(month + 0|region),
                           REML = FALSE,
                        family = "truncated_poisson",
                            ziformula = ~ BLP + KR + logACCI + sqrtDL + transRBS + logEMPL + D201812 +
                        ar1(month + 0|region),
                        data=da,
                        control = glmmTMBControl(optCtrl=list(iter.max=1e5,
                                                              eval.max=1e5)))
```

Model 5: Summary and Diagnostics

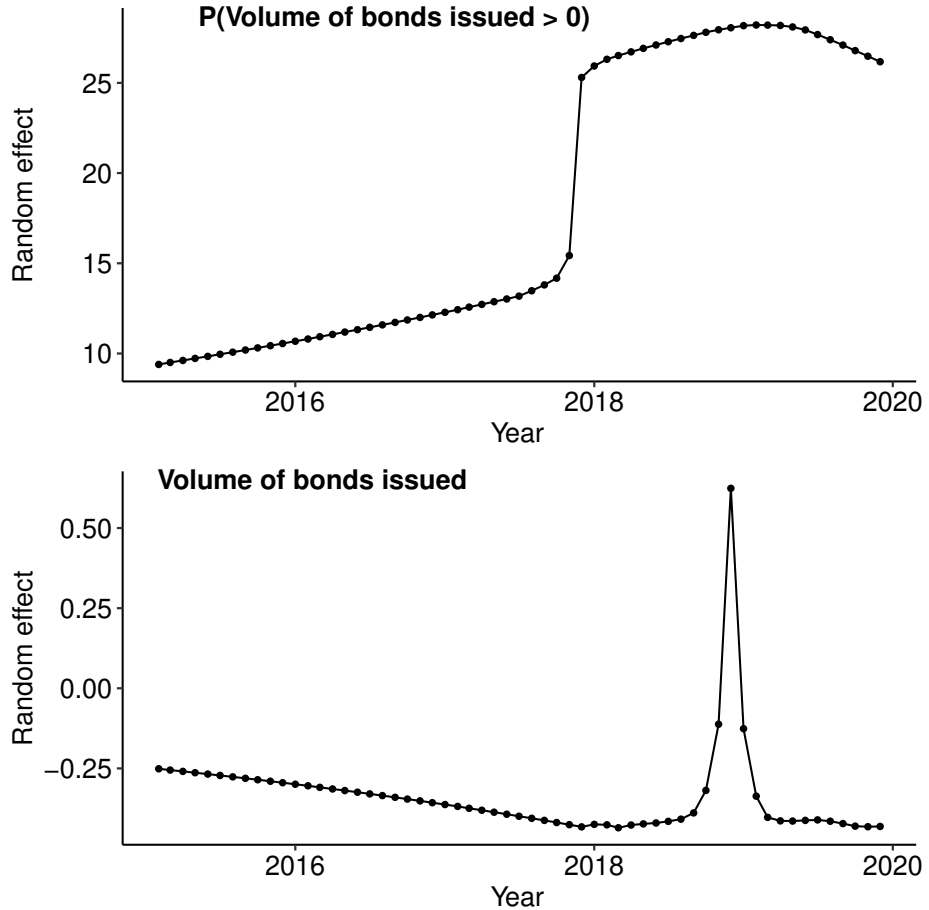
Table 4: Response RBVrnd: Model 5 estimated with glmmTMB

	Model 5
Count model: (Intercept)	0.373
	(0.786)
Count model: BLP	**−0.004*****
	(0.001)
Count model: KR	−0.001
	(0.010)
Count model: logACCI	0.004
	(0.030)
Count model: sqrtDL	0.019
	(0.019)
Count model: transRBS	−0.002
	(0.001)
Count model: logEMPL	**0.564*****
	(0.102)
Count model: D201812	**0.390*****
	(0.029)
Zero model: (Intercept)	−16.318
	(41.462)
Zero model: BLP	0.078
	(0.065)
Zero model: KR	**5.231*****
	(1.258)
Zero model: logACCI	0.653
	(3.448)
Zero model: sqrtDL	−0.550
	(0.768)
Zero model: transRBS	0.115
	(0.160)
Zero model: logEMPL	−1.821
	(1.766)
Zero model: D201812	**−37.928*****
	(6.514)
AIC	20159.511
Log Likelihood	−10059.755
Num. obs.	4879
Num. groups: region	85
Var (count model): region monthmonth2	0.982
Var (count model): region monthmonth60	0.982
Var (zero model): region monthmonth2	48909.636
Var (zero model): region monthmonth60	48909.636

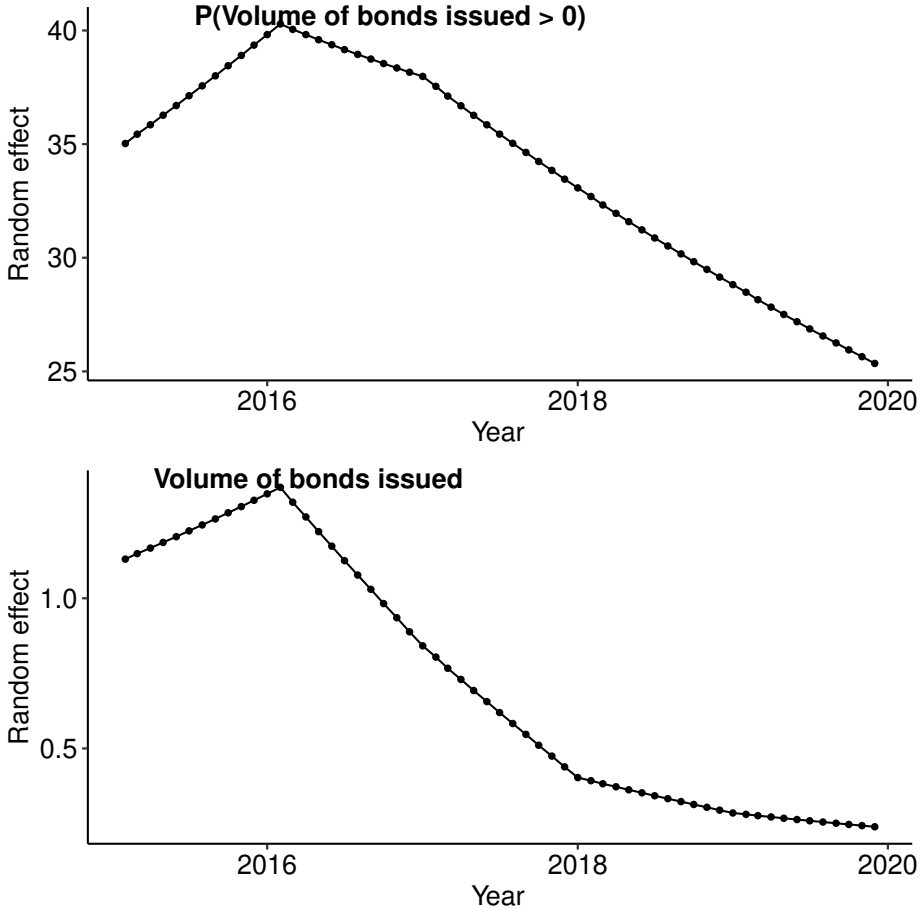
Coefficients with $p < 0.05$ in **bold**.



Model5: Estimates of Random Effects for Saratov Region



Model5: Estimates of Random Effects for Moscow



Conclusions 1

- Ordinary regression analysis (for panel data), trying to predict condition $RBV > 0$ and $RBV|RBV > 0$ using a limited set of predictors, such as Budget loan proportion, Key (Refinancing) rate, Average per capita cash income, Debt level, Regional budget surplus, Employed hardly lets us get closer to the goal. Regression coefficients don't reflect a two-subject (the region's government and the Central Bank of Russia) decision process, leading to the stated RBV.
- We started to consider models with slowly varying (AR(1)) region-specific latent factors.
- glmmTMB package allowed to estimate individual values of these factors. The final Model 5 gave separate estimates of such factors, one predicting condition $RBV > 0$, another predicting $RBV|RBV > 0$. As a result, the set of predictors with significant impact on RBV reduced.

Conclusions 2

- For the non-zero volume of RBV these are Key (Refinancing) Rate of Central Bank of Russia, influencing negatively, and time-specific factor of December 2018, influencing positively.
- For the volume of RBV provided it is positive, these are Budget Loan Proportion (the share of budget loans in the structure of the state debt of the regions) (influencing negatively), the size of region's economy, measured by logarithm of Employed and the same time-specific factor of December 2018 (both positively).
- The negative dependence to issue non-zero volume of regional bonds might reflect the regions incentive to reduce current cost of borrowing.

Conclusions 3

- The hypothesis (1) that the regional budget deficit increase leads to an increase in the volume of sub-federal bonds is not confirmed – weak dependence on RBS both for $RBV > 0$ and $RBV|RBV > 0$.
- The hypothesis (2) that the expectations of a Key rate cut reduce the volume of sub-federal bonds remains unclear; the Key Rate itself influences negatively the condition $RBV > 0$, but not the positive volume of RBV itself.
- The hypothesis (3) that an increase in the share of the federal budget loans issued to the region reduces the volume of the regional bonds is confirmed.
- The hypothesis (4) that an increase in the level of the regional budget debt burden reduces the volume of the regional bonds is not confirmed.
- The hypothesis (5) that the higher the level of the regional economic development, the greater the volume of the regional bonds is confirmed.

Thank you for attention!