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fANOVA application for comparison of companies by the CEO turnover rates

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Abstract. The aim of this study was to analyze the data from the Nasdaq Baltic listed companies' financial statements and to estimate if the CEO changes have a significant influence on the financial performance: profitability, indebtedness and stock price. Data was collected and financial ratios were computed for 34 companies during 2006 to 2021 (2008 to 2022 for stock prices). The companies were divided into 3 groups: ones that had no CEO changes over the period; those that had 1 or 2 and those with 3 or more. Point-wise ANOVA, fANOVA and fMANOVA were conducted. Both point-wise and functional ANOVA indicated that there is a significant difference of at least one group from the others in terms of ROA and EBITDA margin. After conducting two-sample tests, the group with 3 or more CEO changes was identified as having a significantly higher EBITDA margin than the others. Furthermore, a significant positive relationship between the stock price and the CEO turnover was uncovered in the function-on-scalar regression results.

Keywords: profitability; CEO turnover; functional data; fANOVA

AMS Subject Classification: 62P99, 62R10

Introduction

The rate at which the world companies are changing their CEOs is growing each year. Such development would imply that the more frequent turnover should affect the company positively, however, the studies on this subject find contradicting results. The question whether more frequent CEO changes bring value is important not only to the researchers, but also to the boards of directors who make the hiring or firing decisions and need to know what implication the change of CEO has: if it is better to keep the

already experienced employees in this position or to bring new and fresh perspective. This research will test if companies that have more frequent CEO turnover tend to be more profitable and have less debt in their capital structure. Also, the relationship between stock price and CEO turnover frequency will be explored.

1 Literature review

The interest in CEO turnover is not new among the researchers. Many studies focused on estimating the optimal CEO tenure, searched for differences between forced and voluntary turnovers and the impact they have on the firms' profitability or stock prices. Literature review part will summarize and describe what research has already been conducted on the subject.

1.1 CEO Tenure

Generally, the time period of around 10–15 years in the company is considered to be the "Golden Age" for a CEO. It is the time when the general manager knows the company well enough to make the best decisions, but is not yet repetitive or too detached from the market. Looking at the literature, Citrin *et al.* [1] find that the best period for CEO is above 10 years: their performance will only get better. Cutter [3] finds that CEOs between the years 11 to 15 of their tenure are the most beneficial to the companies. Henderson *et al.* [11] argue that different CEO tenures are optimal for companies in different industries – firms in IT industry should have shorter CEO tenure, while the food services industry should have a longer one [11]. Also, Jung [12] finds that public entities, whose CEO was replaced without serving at least 3 years, experienced decline in their performance. Even though exact boundaries of tenure are debatable, most research seems to agree it is somewhere above 10 years. This finding was used when splitting the sample of companies in this research by the amount of CEO changes during the observed 16 years.

1.2 Positive effects of the CEO turnover

The CEO turnover can bring positive change to a company. Xu [16] conducted OLS regression on the Chinese listed companies and found a positive effect of CEO turnover on profitability. Moreover, Gao *et al.* [8] employed a matched sample analysis to conclude that in US, the private companies experience larger increase in profitability after the CEO turnover than the public ones. In addition, Khurana and Nohria [13] found significant positive effects on profitability when CEO change is non-voluntary and a person outside of the company is chosen as a replacement. Furthermore, it was shown that for companies in liquidation, the CEO change can have a positive impact and save the company from being declared bankrupt [4]. Considering the stock prices, Mandagi [15] claimed that the market reaction is positive, only if the CEO resigns voluntarily.

1.3 Negative effects of the CEO turnover

Other studies point-out the negative side of the management change. Garcia *et al.* [9] by the means of fixed effects panel regression found that the firm performance

decreased after the CEO change. Furthermore, Dogan *et al.* [6] detected the same negative effect. Also, Zhang *et al.* [17] uncovered that CEO change affected IT firms negatively. Moreover, according to Khurana and Nohria [13], if the turnover happens voluntarily and an outsider takes the place, it has a negative effect on a company. Also, the market reaction is negative, if the CEO change is forced [15]. In addition, frequent CEO turnover is suggested to decrease the firm's performance (productivity and ROE) [14]. Considering the financing of the companies, forced CEO turnover cause worse borrowing terms which make debt more expensive [5]. Lastly, there is a noticeable stock price volatility increase following a CEO change [7], which is even higher for forced turnover and for voluntary changes, when the successor is an outsider [2].

To summarize, the methods used for estimating the effect of CEO turnover differ from t-tests to panel regression, but none of the articles employed functional data analysis methods. Also, the results indicated by the studies differ, depending on country, industry, entity type, whether the CEO change was forced/voluntary and other factors. There is no consensus about the overall impact that the CEO turnover and it's frequency has on firm's profitability, liquidity and market performance.

2 Data and Exploratory Analysis

The dataset contains the information about Lithuanian, Latvian and Estonian NASDAQ Baltic stock exchange listed companies during the period from 2006 to 2021 for financial data and 2008 to 2022 for stock prices. It was collected from the annual financial statements of the companies on NASDAQ Baltic Shares list https://nasdaqbaltic.com/statistics/en/shares and daily close stock prices were taken from the same source trading information section.

Since the dataset was collected manually, we only picked the variables necessary for our research. The financial variables that were used and their descriptions are presented in Table 1. All of the financial data was collected in thousands of euros annually for 16 years. The stock prices were collected as daily closing prices for 15 years in euros. Figure 1 shows the raw collected data throughout the years (2006–2021 for financial ratios and 2008–2022 for the stock prices). Each curve represents one company's measures.

2.1 Categorical variables and splits

Most of the collected variables, beside the financial ratios, were categorical values, such as Sector, Country, Category. The *CEO_Turnover* and *CEO_Male* variables were marked manually based on the data provided in financial statements. The *Crisis* variable was also added by hand to indicate the periods during the 2008-2009 economic crisis and 2020 for COVID-19 pandemic.

Pivot analysis showed the composition of the dataset split by country – 44% Lithuanian, 24% Latvian and 32% Estonian companies. Split by industry sectors showed top 3 being – 26% Customer cyclical, 20% Consumer defensive, 18% Industrials, with all others being smaller than 10% individually and accounting for the remaining 36%.

Table 1. Dataset variables.

Variable	Description
Corporation	Name of the company.
Category	Categorical variable with 0 if company did not have CEO turnovers, 1 if company had 1 or 2 turnovers and 2 if company had more than 2 turnovers.
Year	The year of the observation.
Country	Country in which the company is listed.
CEO_Name	Name of the chief executive officer.
CEO_Turnover	Categorical variable with 1 indicating that there was a CEO change in that year and 0 indicating that there was not.
Crisis	Categorical variable with 1 indicating that there was a financial crisis in that year; 2 indicating COVID pandemic and 0 indicating no crisis.
Sector	Sector that the company operates in.
Stock	Stock price of the company.
ROA	Return on assets of the company in a certain year.
ROE	Return on equity of the company in a certain year.
EBITDA_Margin	EBITDA margin of the company in a certain year.
Debt_to_Equity	Debt-to-equity ratio of the company in a certain year.
Current_ratio	Current ratio of the company in a certain year.

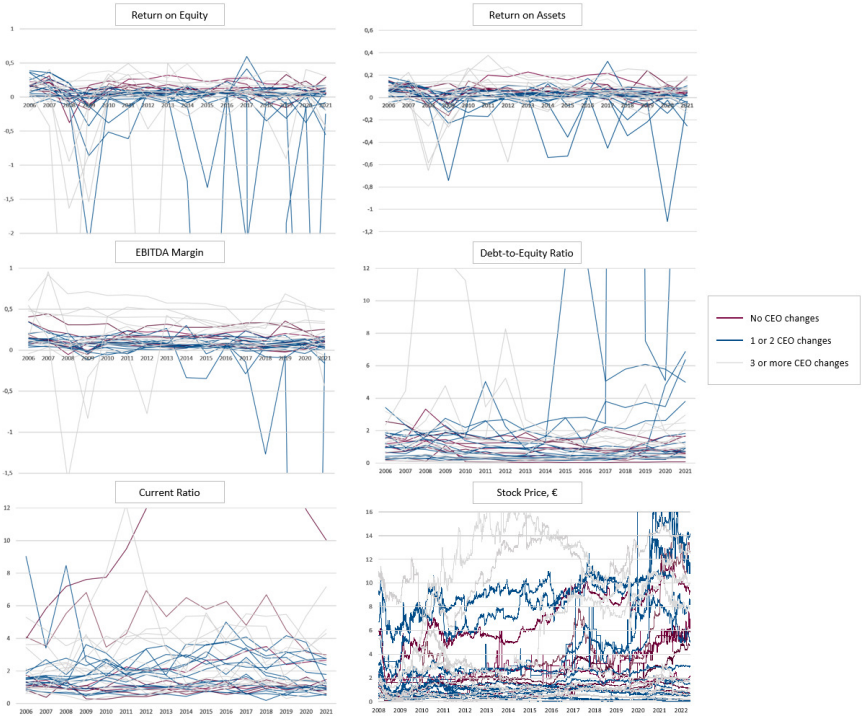

Fig. 1. Raw data.

The companies in the dataset were grouped into 3 buckets based on the frequency of CEO changes:

Group 0 – Having no CEO turnovers (8 companies);
Group 1 – Having 1 or 2 CEO turnovers (14 companies);
Group 2 – Having 3 or more CEO turnovers (12 companies);

2.2 Preprocessing and basis selection for the functional data

All of the variables were a subject for additional transformation: for ROE, ROA and EBITDA margin – minimal value was subtracted and 1 was added to have 1 as the lowest value. Debt to equity, current ratio and stock prices were log transformed. To choose the suitable basis for each of the financial ratios different options were attempted (b-spline and Fourier bases; non parametric smoothing methods; parametric smoothing methods with or without penalty). The chosen best methods for each ratio and stock prices are presented in Table 2. Fourier basis was used for profitability measures which fluctuate more with the economic cycle, whereas the b-spline basis was used for the liquidity measures as well as for the stock prices. The measures in their final functional smoothed form can be seen in Fig. 2 where the time scale for financial ratios (ROE, ROA, EBITDA margin, DtE and current ratio) is 16 annual observations over 2006–2021 years and 3648 daily observations over 2008–2022 for stock price. The respective values are ratios with transformations as described in previous paragraph.

Table 2. Basis selection.

Measure	Number of functions type	Order	Lambda	
ROE	3	Fourier	–	–
ROA	3	Fourier	–	–
EBITDA margin	3	Fourier	–	–
Debt-to-equity	14	B-spline	4	2.66437
Current ratio	12	B-spline	4	0.90882
Stock price	60	B-spline	4	128

2.3 Depth and outliers

Boxplots were created to identify the outlier curves for the variables. Some of the the largest outliers were already removed in the functional data object (Baltika was removed from ROE, Rigas Kugu Buvietava was removed from ROA and EBITDA margin; Arco Vara was removed from EBITDA margin), while the majority of smaller outliers were kept in the dataset.

3 Methodology

This study applies functional data analysis methods including functional ANOVA and MANOVA and function-response regression. R software was used to conduct the analysis, with main packages used: *fda*, *fda.usc*, *fdANOVA*.

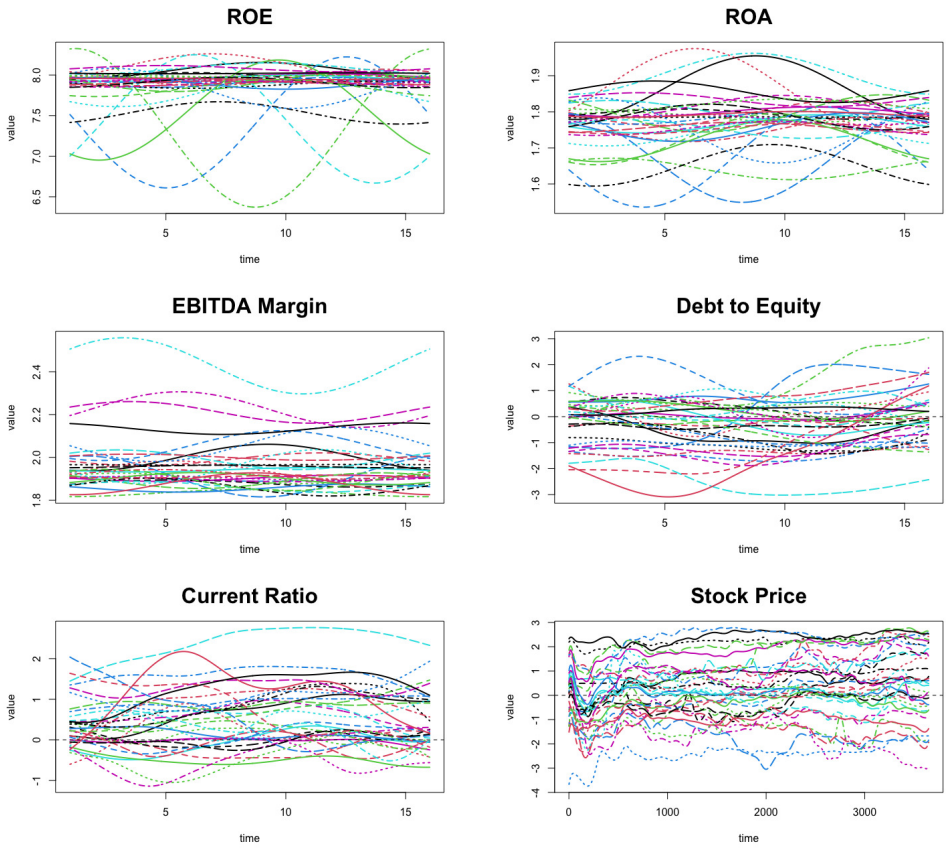

Fig. 2. Data in functional form.

3.1 Hypothesis testing

To clarify the goal and aim of the study the hypotheses were formulated for the analyzed problems. The null hypothesis was formulated as such:

H_0: *There are no significant differences between the companies with different CEO turnover rates.*

The first and second alternative hypotheses covered financial ratios and stock prices respectively:

H_1: *The companies with different amounts of CEO changes are different in terms of profitability and indebtedness.*

H_2: *There is a positive relationship between the CEO turnover and stock price.*

3.2 Two-sample test

The two sample test was conducted as a post-hoc test after the functional ANOVA. The equation for L_2 test:

$$T_N = \int_0^1 \Delta^2(t)\,dt = \frac{nm}{N}\int_0^1 \left[\hat{\mu}(t)_1 - \hat{\mu}_2(t)\right]^2(t)\,dt,$$

where $\hat{\mu}_1$ and $\hat{\mu}_2$ are sample means.

3.3 fANOVA and fMANOVA

To test the mentioned hypotheses functional data analysis of variation model was conducted as it can be used to detect the differences among the groups of functions. The model for fANOVA:

$$X_{ij}(t) = \mu(t) + \alpha_i(t) + \varepsilon_{ij}(t), \quad j = 1, \ldots, n,\ i = 1, \ldots, k$$

after setting each individual mean to be the group mean plus the noise:

$$\mu_i(t) = \mu(t) + \alpha_i(t), \quad i = 1, \ldots, k.$$

Different test were used when conducting fANOVA analysis: FP test, CS test, GPF test and TRP. FP test is a permutation test based on a basis function representation. GFP and Fmax test are F-type tests: GFP is globalizing the pointwise F-test and Fmax is F-statistic maximizing bootstrap test. L2-type test are represented here by CS test – L2-norm-based parametric bootstrap test for heteroscedastic samples. And lastly, the random projections test TRP with $k = 15$ was also used. In practise, obtaining results from more different tests provided a wider outlook on the results and their trustworthiness. R package fdANOVA was used for these calculations and more information about the tests can be found in the vignette of the package [10].

The model for fMANOVA is the same as for fANOVA, except that all of the members are matrices. It also employed multiple tests: Wilk's lambda test, Lawley-Hotelling trace test, Pillai trace test and Roy's maximum root test. All of the mentioned tests are slightly different in their testing of the group mean differences, but are all performed on the random projections of the initial functional data. The pointwise ANOVA was also carried-out. It fixes a time moment and then treats the functions at that point as random variables. Then, the usual ANOVA is conducted.

3.4 Function-on-scalar regression

Function-on-scalar regression assumes a quite standard equation:

$$Y_i(t) = \mu(t) + \rho(t)Z_i + \varepsilon_i(t), \quad t \in [0, 1],$$

where Z_i are scalar regressors and Y_i are dependent functions.

4 Results of the fANOVA

Pointwise ANOVA was performed before conducting the fANOVA. It carries out the test at each fixed time point, treating the observations as a random variable. That provides additional insights about how the groups differ at each time point. However, it does not give a holistic answer, whether the groups are in general different. The results of the pointwise ANOVA in Figs. 3 and 4 show that there is a group different

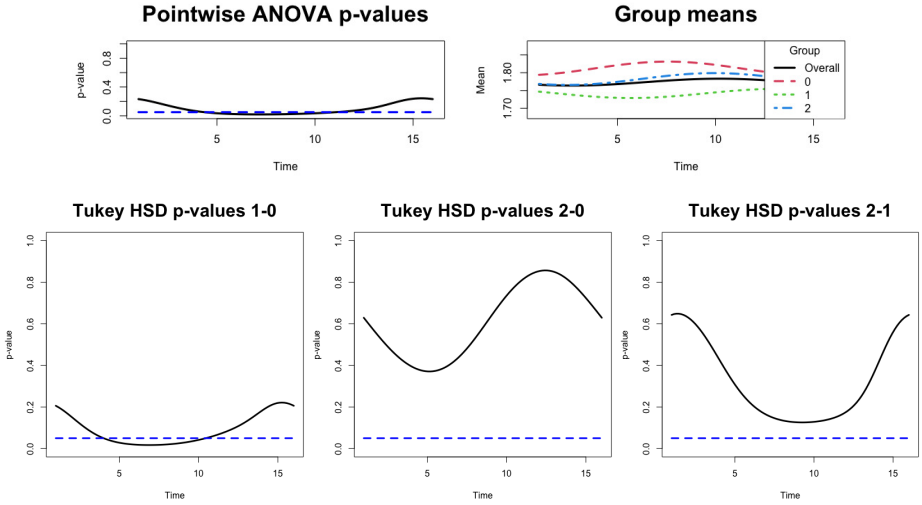

Fig. 3. ROA pointwise ANOVA.

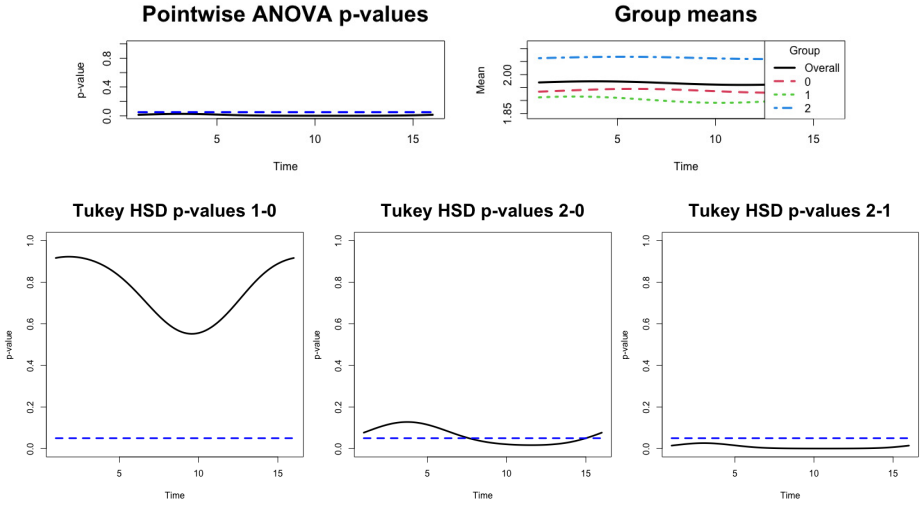

Fig. 4. EBITDA margin pointwise ANOVA.

from the others in terms of the ROA during the 4–10 time period which corresponds to years 2009–2015 and in terms of EBITDA margin for the whole analyzed period. No significant differences among the companies were found during the 2008 and 2020 for the ROA, which indicates that all companies behaved in a similar way during the crisis periods.

Functional ANOVA looks for differences in the group means among the full functions by using integration, not pointwisely. The fANOVA tests were conducted on the data using the previously fitted bases. Also, FP test, CS test, GPF test, Fmaxb test and TRP tests were used. In terms of ROE, DTE, current ratio and stock price no

Table 3. Results of the fANOVA.

Financial measure	fANOVA test	p-value	Financial measure	fANOVA test	p-value
ROE	FP	0.097	Debt-to-equity	FP	0.453
	CS	0.114		CS	0.434
	GPF	0.163		GPF	0.496
	Fmaxb	0.287		Fmaxb	0.265
	TRP ($k = 15$)	0.075		TRP ($k = 15$)	0.447
ROA	FP	0.027*	Current ratio	FP	0.662
	CS	0.018*		CS	0.648
	GPF	0.019*		GPF	0.671
	Fmaxb	0.068		Fmaxb	0.448
	TRP ($k = 15$)	0.034*		TRP ($k = 15$)	0.628
EBITDA margin	FP	0.002*	Stock price	FP	0.505
	CS	0.005*		CS	0.415
	GPF	0.000*		GPF	0.559
	Fmaxb	0.004*		Fmaxb	0.423
	TRP ($k = 15$)	0.000*		TRP ($k = 15$)	0.689

* – significant p-values < 0.05.

tests indicated a significant p-value, as can be seen in Table 3. That means that three groups are not significantly different in the respective measures. Conversely, almost all of the tests (FP, CS, GPF, TRP $k = 15$) indicated significant p-values for ROA and all of them for the EBITDA margin. The conclusion can be drawn that some group is different from others in terms of return on assets and EBITDA margin.

Two-sample t-tests. Even though fANOVA captures the information about a certain group or groups being different, this test does not provide the information on which group it is. To find that out, pairwise t-tests were conducted for the ratios, where significant differences were indicated by the fANOVA. Looking at the results in Table 4, for ROA the difference between the group with zero CEO turnovers and the group with 1–2 CEO turnovers is significant. For EBITDA, the difference between companies with 1–2 CEO turnovers are significantly different from the the companies with 3 or more turnovers according to the L2 test. Because of how data is spilt into groups, it is unexpected to see the difference in only one pair of the groups. To solve this problem, the same analysis for the ROA was conducted after eliminating all of the outlier companies indicated by the functional boxplot. Then, the result indicated no significant differences among the groups in fANOVA. To summarize, the only significant difference among the companies with varying amount of CEO changes is the EBITDA margin.

Table 4. Two-Sample t-test results.

Measure	Groups	Test statistic	p-value
ROA	0–1	2.6645	9.96e−12*
	0–2	0.4952	1
	1–2	1.1366	0.2422
EBITDA margin	0–1	0.6139	0.9953
	0–2	7.5349	0.0228*
	1–2	15.6025	0*

Table 5. Results of the fMANOVA.

Measure group	fMANOVA test	p-value
Profitability (ROE, ROA, EBITDA Margin)	Wilk'slambda test (Wp test)	0.0148*
	Lawley-Hotelling trace test (LHp test)	0.0164*
	Pillai trace test (Pp test)	0.0136*
	Roy's maximum root test (Rp test)	0.0474*
Liquidity (Debt-to-Equity, Current ratio)	Wilk'slambda test (Wp test)	0.7052
	Lawley-Hotelling trace test (LHp test)	0.7078
	Pillai trace test (Pp test)	0.7016
	Roy's maximum root test (Rp test)	0.7714
All (Profitability and liquidity)	Wilk'slambda test (Wp test)	0.2262
	Lawley-Hotelling trace test (LHp test)	0.2246
	Pillai trace test (Pp test)	0.2258
	Roy's maximum root test (Rp test)	0.2288

* – significant p-values < 0.05.

5 Results of the fMANOVA

To obtain a more holistic view, variables were grouped into profitability measures (ROA, ROE and EBITDA margin) and indebtedness ratios (DtE and current ratio) and functional MANOVA was performed. The variables used for this analysis included the outlier companies as well, to have the same amount of companies for each dependent variable in the analysis. The obtained results, as can be seen in Table 5, indicate that there is a difference between some groups in terms of profitability, but not indebtedness. The analysis for all of the ratios at once also indicate that companies with different rates of CEO turnover, in general, are not significantly different.

6 Results of the regression

The data used in the model includes the observations collected from 34 companies during the year 2021. The stock price data consists of daily observations excluding weekends and holidays for these companies in 2021. The sample size of 34 companies for the regression (Table 6) is rather small, so the results should be considered with caution. However, there is an indication that the CEO change during the particular year has an effect on that year's stock price. Penalized flexible functional regression model indicated a quite poor R Squared, but the variables in the regression were all significant. However, more research on a bigger dataset is crucial to confirm it. When the stock price was used as an independent functional variable in scalar-on-function regressions for the financial ratios, it was not significant.

Conclusions

After the study was conducted the following findings and conclusions were summarized. First, that point-wise ANOVA indicated significant differences among the groups in terms of ROA (difference between group 0 and group 1) and EBITDA margin (group 2 different from the other two). Second, fANOVA tests indicated that there is a significant difference among the groups for ROA and EBITDA margin. Two

Table 6. Results of the regression.

Family: gaussian Link function: identity				
Formula: stock_21 CEO_Turnover + ROE				
Constant coefficients:				
	Estimate	Std. Error	t value	Pr(> |t|)
(Intercept)	0.43668	0.01528	28.58	<2e−16***
.....				
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Smooth terms & functional coefficients:				
	edf	Ref.df	F	*p*-value
Intercept(yindex)	2.244	19.000	0.471	0.00338**
CEO_Turnover(yindex)	1.005	1.009	502.549	<e−16***
ROE(yindex)	2.249	2.626	161.417	<2e−16***
.....				
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
R-sq.(adj) = 0.0967, Deviance explained = 9.73% -REML score = 14920, Scale est. = 1.8505, $n = 8636(34 \times 254)$				

sample test showed that there is a difference between Group 2 and other two groups in terms of EBITDA margin. Lastly, fMANOVA indicated significant difference between the groups in terms of profitability ratios.

The findings above show that the first alternative hypothesis can be accepted for EBITDA margin and rejected for the other financial rations and stock price, as companies with different CEO turnover rates appear different in terms of only some of the financial metrics. Moreover, the regression indicated a positive relationship between CEO turnover and stock price, giving the sufficient grounds to reject the null hypothesis and accept the second alternative hypothesis. Since the number of companies in the analysis was not that large (34), the results should be interpreted with caution, and possibly reproduced on another set of companies for validation. Also, observing companies more frequently, for example, quarterly, could also provide new insights in the future research.

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REZIUMĖ

fANOVA taikymas kompanijų su dažnu ir retu generalinio direktoriaus pasikeitimu palyginimui

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Šio tyrimo tikslas buvo išanalizuoti duomenis surinktus iš Nasdaq Baltic listinguojamų kompanijų finansinių ataskaitų, kad patikrinti, ar generalinio(-ės) direktoriaus(-ės) pasikeitimas turi įtakos finansiniams rezultatams, tiksliau, pelningumui, įsiskolinimui ir akcijų kainai. Kompanijų imtis buvo padalinta į tris grupes: kompanijos, kurios neturėjo generalinių vadovų pasikeitimo; tos, kurios turėjo 1–2 pasikeitimus ir tos, kurios turėjo 3 ir daugiau pasikeitimų per nagrinėtą laikotarpį. Funkcinė ANOVA ir ANOVA pataškiui (fANOVA ir poinwise ANOVA) parodė, kad kompanijos su 3 ir daugiau generalinių vadovų pasikeitimų turėjo statistiškai reikšmingai didesnę EBITDA maržą nei kitos dvi

grupės. Daugiamatė funkcinė ANOVA parodė, kad kompanijų grupės statistiškai reikšmingai skiriasi savo pelningumu. Taip pat, naudojant funkcinę regresiją, buvo rastas statistiškai reikšmingas teigiamas ryšys tarp akcijų kainos ir generalinių vadovų pasikeitimo.

Raktiniai žodžiai: pelningumas; generalinių direktorių pasikeitimai; funkciniai duomenys; fANOVA