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Web usage analysis of Pillar 3 disclosed information by deposit customers in turbulent times

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ABSTRACT

Market discipline has been a scrutinized area since the last financial crisis in 2008. Regulators strengthened their role particularly through Pillar 3 in Basel III. However, there are still some aspects of market discipline that deserve special attention to avoid future failures. This study focuses on the analysis of the interest and behaviour of deposit stakeholders based on website data dedicated to disclosures of commercial bank in Slovakia during and after turbulent times (period 2009–2012). The data consists of log files, and web mining techniques were applied (the modelling of web user behaviour in dependence on time - based on the proposals of the authors). The results show that also in turbulent times, stakeholders' interest in Pillar 3 disclosures is low (in line with (Munk, Pilkova, Benko, & Blažeková, 2017)) and the highest interest was identified for the Pricing List category. After turbulent times, Pillar 3 categories (Pillar 3 related information and Pillar 3 disclosures) have weak interest, with peaks at the beginning of the year, and the highest increase was in the Business Conditions category. The results suggest that the enhancement of interest of key stakeholders in disclosures inevitably requires changes to deliver sufficient disclosure data structures and to design a disclosure policy that fulfils regulatory expectations.

1. Introduction

Currently, we live in a world of fast changes in products, technologies, companies, markets and industries etc. These changes are sources of economic turbulence which banking sectors also cannot avoid. The last financial crisis proved and highlighted the weaknesses of the global financial regulatory system which was not able to avoid the failures and losses generated by turbulence in the banking industry. Regulators, policy makers, and academics learnt many lessons from this period and tried to fix identified weaknesses. Market discipline is also one of the areas on which regulators have focused. In regulation, it has been included since Basel II's introduction as a Pillar 3 component. Pillar 3 complements the minimum risk-based capital requirements and the other quantitative requirements (Pillar 1), and the supervisory review process (Pillar 2). It aims to promote market discipline by providing meaningful regulatory information to market participants consistently and to be able to assess banks' risk appetite, risk exposure, and level of risk management. Market discipline, in its broadest terms, can be understood as a mechanism via which market participants monitor, assess, and discipline risk-taking by financial institutions. In the studies of Bliss and Flannery (Bliss & Flannery, 2002), a market discipline is defined by its two distinguishing aspects into market monitoring – market participants' assessment of banks' conditions, which are to be reflected in banks' security prices and deposit rates; market influence – banks' reaction brought on by market monitoring or to counteract adverse changes in banks' conditions.

Pillar 3 has been discussed and reviewed by key market participants and concluded with the obligatory regulatory standards for information disclosure for banks. The first obligatory standard for information disclosure for banks was launched as a revised version of the Pillar 3

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framework in December 2015, which is a background to promote market discipline through regulatory disclosure requirements. This document has been reviewed several times in consultation processes. Firstly, the Pillar 3 review and the Pillar disclosure requirements consultative document was disclosed in March 2016, and available for comment until March 2017. Consequently, the Basel Committee on Banking Supervision (BCBS) issued the Pillar 3 disclosure requirements - updated the single Pillar 3 framework in February 2018 (available for comment until May 2018). Moreover, the European Banking Authority (EBA) also published the final guidelines on regulatory disclosure requirements in December 2016, the goal of which is the consistency and comparability of institutions' disclosures and to ensure market discipline. It is important to note that changes and updates to the regulatory disclosure documents should reflect the requirements of key market participants, which is the objective of regulation and also of its consultation processes. Therefore, the complexity of the finalisation process of the disclosure standards, and the very high amount of changes in the disclosed forms suggest that the goal of the standard has not been reached during the implementation of its versions (enhancement of market discipline), also from the regulator's point of view (BCBS - Basel Committee on Banking Supervision, 2015; BCBS - Basel Committee on Banking Supervision, 2016; BCBS - Basel Committee on Banking Supervision, 2018; 2016; 2017). Consequently, the standard and its forms (disclosure tables) should cover the interests of key market participants on the information disclosed based on their behaviour.

All of these discovered and confirmed processes covering requirements of key market participants required changes to find the most effective structure of information. It also has been found that the incentive to monitor the risk that a bank takes is higher for depositors' investments, which are neither guaranteed by deposit insurance nor by other government regulation (Fonseca & González, 2010; Nier & Baumann, 2006). Therefore, in terms of enhancement of market discipline, one specific group of stakeholders is uninsured depositors, who are the source of market discipline in monitoring the bank's risk. Moreover, depositors in Europe actively monitor the riskiness (interest rate on deposits) of banks and prefer safer banks, which can repay deposits anytime and pay higher interest rates (Fueda & Konishi, 2007; Hori, Ito, & Murata, 2009; Martinez Peria & Schmukler, 2001). However, the Guillemin study (Guillemin, 2017) focusing on the effects of disclosure on depositors' behaviour suggests that disclosures negatively influence deposit levels in European banks. Furthermore, according to Bourgain, Pieretti, and Zanaj (2012), disclosures in the European Union (EU) have a positive impact on deposit levels in Middle Eastern and North African (MENA) countries and also in Russia (Wu & Bowe, 2012). Nevertheless, different behaviours among depositors in Europe serve as the background for our research together with a lack of research in the field of analysis of the behaviour of key stakeholders to disclosures in Central and Eastern European (CEE) countries.

1.1. Motivation and research objectives

Commercial banks in CEE countries have numerous specifics. Among them, the most important is prevailing ownership by large international groups and focus on deposit collection. Their depositors represent a very important group of stakeholders; however, empirical studies on their behaviour and interests in using Pillar 3 disclosures are missing. Regulators do not know to what extent existing disclosure rules are meaningful and add value for this type of users and help avoid market discipline failure similar to during the last financial crisis. However, it is crucial for the regulators' goal achievement that market discipline mechanism should be effective and used according to the regulators' expectations. In CEE countries, there is a lack of studies assessing Pillar 3 information disclosures based on the content relevancy to key commercial banks' stakeholders.

Therefore, our study analyses the interest in information disclosures aimed at a specific type of stakeholders (uninsured depositors) in foreign-owned bank not traded on capital markets. The importance of this group is further supported by the fact that nearly half of the deposits in bank accounts in Slovakia are uninsured deposits, and a similar status can be expected in other CEE countries. Moreover, we agree with Kuranchie-Pong, Bokpin, and Andoh (2016) that stakeholders are expected to contribute to effective risk management in the banking industry through market discipline, and they need a sufficient disclosure of risk-related information to assess the risk profiles of banks. In terms of disclosing information, Goldstein and Leitner (2015) stress the necessity of disclosures in preventing market breakdown but they also point out that in terms of sufficient disclosures, there is a potential threat in disclosing too much information. However, according to Bouaiss, Refait-Alexandre, and Alexandre (2017), an increase in disclosure enhances transparency and efficient market discipline by supervising excessive risk-taking and also improves stockholders' monitoring and sensitivity to risk-taking (Goldstein & Sapra, 2014). On the other hand, transparency can have a positive impact on bank performance and stability but only up to a certain point (Iren, Reichert, & Gramlich, 2014). This is due to its conflicting effects: more transparency decreases efficient liquidity, increases rollover risk, and has a negative impact on banks' stock (Bouvard, Chaigneau, & de Motta, 2015). Moreover, Andrievskaya & Semenova conclude that the concentration of the markets is lower with stricter public disclosure requirements, and there is a reduction of competition due to stricter disclosure requirements, which depends on bank credit risks (Andrievskaya & Semenova, 2016). Additionally, they also highlight the marginal positive effects of additional regulation, mostly in developed countries, where regulation is high. These are general findings derived mostly from developed countries. It is important to take into consideration all these factors in the process of designing an optimal disclosure policy.

To sum up, based on the findings stated above, the main goal of this study is twofold: Firstly, to assess the behaviour and interest of the key stakeholders (primarily depositors) in a foreign-owned commercial bank (not traded on capital markets) on disclosed information during and after turbulent times in a country that belongs to the CEE region and subsequently, based on website data analysis during and after crises to identify the key types of information, which are in the particular interest of the key stakeholders as a component for the design of optimal disclosure policy. This study is also aims to contribute to fulfilling a significant research gap in the area of the content relevancy of Pillar 3 disclosures to web users of commercial banks in CEE countries.

The structure of this study is as follows: The first section contains an introduction and the main goal of the study, followed by a section that offers the current status of empirical research and theories connected with market discipline and web usage analysis. The methodology of the modelling of web user behaviour dependent on time, and research results are included in the third and fourth sections. The last section is the discussion and conclusion.

2. Related work

The theory of market discipline is related to the efficient markets hypothesis (Fama, 1970) and explains that depositors (and similar money instruments investors) can rein in the risk taken by banks through market-based mechanisms (Garten, 1986). The theory of market discipline has been scrutinised in the years following the last financial crisis in 2008. Common outcomes of the numerous studies on why market discipline failed during the crisis are twofold (Min, 2015): a/ market discipline very much relies on investors in money instruments who are relatively insensitive to the risk and b/ neglect very risk-sensitive investors who might encourage even greater risk. However, even before the last financial crisis, some authors dispute the ability of, in particular, retail depositors to monitor and change the risky behaviour of banks (Nagarajan & Sealey, 1997; Garten, 1986). The reason, why retail depositors are unsophisticated, poorly equipped to receive risk-related information about their banks and are likely to misinterpret

such information lies in a lack of financial literacy (Semenova, 2012). Nevertheless, post-crisis regulators' efforts tend to enhance market discipline. Enhancement of market discipline as an issue is connected to factors, which support or discourage disciplined behaviour. These factors are studied by researchers from different perspectives. One of these perspectives is the effectiveness of market discipline and disclosure is regarded as one of the most effective tools for the enhancement of market discipline (Fonseca & González, 2010). According to Hamid and Yunus (Hamid & Yunus, 2017), disclosures are effective market discipline tools when the market is more concentrated. On the other hand, Andrievskaya and Semenova (2016) conclude that the concentration of markets is lower with stricter public disclosure requirements and that increased levels of banking disclosures stimulate banks' competition and positively affect banks' market share by attracting more retail deposits (Andrievskaya & Raschupkin, 2015). However, Guillemin (2017) states that depositors in EU countries actively monitor banks and the decline of the deposit base is connected with higher levels of disclosure, which is the case for more transparent banks. Moreover, Hamid's research showed that foreign banks are subject to market disciplining effects when disclosure is taken into account. This enhances the supervisory need to impose stricter disclosure requirements in a more pertinent and timely manner.

However, what about commercial banks for which customers are retail depositors who are risk insensitive? Several studies are focused on the impact of the increase of information disclosures on these banks. According to Bouaiss et al. (2017), the increase in disclosure levels enhances transparency and efficient market discipline to supervise excessive risk-taking. Moreover, according to Guillemin and Semenova (2018), broader and more transparent disclosures increase the ability to attract interbank funding, while the larger and riskier banks (179 largest Russian banks in 2004–2013) tend to have broader and more transparent disclosures. Moreover, increases in banks' disclosures positively influence investor's attitude to bank's risk profiles, actively increase bank's value (Zer, 2015), boosts depositors' sensitivity to equity levels (Kozłowski, 2016), and improve stockholders' monitoring and sensitivity to risk-taking (Goldstein & Sapra, 2014). On the other hand, Goldstein and Leitner (2015) stress the necessity of disclosing information in preventing market breakdown but also point out the potential threat of disclosing too much information, which destroys risk-sharing opportunities.

Nevertheless, an increase in disclosures, which is also connected with an increase in transparency, is outlined by interpretability, availability of information disclosures, and improvement of information transition mechanisms in the stimulation of market discipline. However, studies are lacking which would analyse the behaviour of customers of commercial banks as far as the usage of disclosed information during and after a period of crisis. Therefore, we focus on this issue to explore sufficient disclosures and transparency to enhance commercial bank depositors' incentives to monitor banks, which is an issue in market discipline practice.

Improving transparency is a component of post-crisis regulators' efforts to enhance market discipline (Min, 2015). Researchers appreciated transparency as an effective factor in incentives to market disciplinary effects that lead to greater market efficiency (Gandrud & Hallerberg, 2014). These authors point out that even from a regulatory point of view current EU bank transparency is insufficient. Furthermore, Moreno and Takalo (2016) suggest that only an intermediate level of transparency is socially optimal and effective (Bouvard et al., 2015) to balance its conflicting effects: more transparency decreases efficient liquidity and increases rollover risk. Parwada, Lau, and Ruenzi (2015) also support this view claiming that the increases in transparency by reporting Pillar 3 and its disclosures have a negative impact on banks' stock and the cost of trading corporate bonds decreased, which is in conjunction with Iren et al. (2014) stating that broader and greater disclosures increase bank performance and stability only up to a certain point.

Referring to market discipline theory failures due to the risk-insensitive behaviour of depositors, we studied papers in which authors concentrate on the analysis of depositors' behaviours in connection with the timing of market turbulences (Li, Liu, Siganos, & Zhou, 2016; Arnold, Größl, & Koziol, 2015; Li & Wang, 2014). Arnold et al. (2015) state that strong market discipline is observed during and after turbulent times (sample of German depositors in 2003–2012) and it strengthened after the crisis, with no exemptions for banks with government support (Antzoulatos & Karanastasis, 2016). This is in line with Kaffenberger's study (Kaffenberger, 2015), which states that market discipline has increased and is stronger in the European Union (decrease in deposit growth rates) for fiscally weak countries in the aftermath of the Cypriot bail out. According to Andrievskaya and Semenova (2016), the timing of market turbulence influences the behaviour of depositors, who prefer more sensitive, less risky, and more reliable banks (with strong capital adequacy and liquidity) connected with higher growth in the volume and the share of deposits.

Those results provide evidence that the timing of market turbulence influences the behaviour of depositors and their perception of banks' risk. Depositors in Europe show different disciplining behaviour in terms of transparency and disclosures, and research in this field is rather rare. Nahar, Azim, and Anne Jubb (2016) also conclude that disclosure in general offers lower costs of capital and helps investors to maintain information about the bank's risk and its management. This is valid for an investor in securities or capital instruments, whose risk behaviour, and according to Min (2015), was neglected even before the 2008 financial crisis. The lower risk disclosure occurs in the case of high performing banks, and it generates ambiguity for potential stakeholders. At this point, we have to agree with those authors who point out that further research is needed and inevitable as far as studying the behaviour of different stakeholders' groups of commercial banks. Our study contributes to cover the existing literature gap in depositors' behaviour towards information disclosure during and after turbulent times in the CEE region. Our intent is also to contribute to design and optimise disclosure policy that would prevent future market discipline failures. Moreover, the analysis of interest in disclosed information by depositors' behaviour helps regulators and other interested parties to assess the effectiveness of the implementation of the regulations and their goals, which are enhancements to an effective market disciplining mechanism, relevant, meaningful, and sufficient disclosures.

2.1. *Weekly-based web usage analysis literature review*

The use of web portals is mainly represented by time data. The variable time occurs often only when extracting sequential rules but only when determining the order of visited web parts. There is no time-based modelling of website users' behaviour in the application area. Nevertheless, several authors tried to track behaviour in other ways. Arbelaitz et al. (2013) focused on analysing and creating navigational profiles of visitors to tourist web portal. They designed a system that can achieve profiles that correspond to real visitors' search sequences with a success rate of 60%. The authors aimed to use navigational profiles to better personalize the web portal for visitors. They used basic principles of the Cross-Industry Standard Process for Data Mining (CRISP-DM) methodology to create segments of users with common interests. Other authors (Anitha, 2010; Bhawsar, Pathak, & Patidar, 2012; Vojíř, Zeman, Kuchař, & Kliegr, 2018; Yin & Guo, 2013) also focused on the effort to detect, respectively, to predict the next step of visitors to the web portal. Makkar, Gulati, and Sharma (2010) used Petri Nets with information obtained from the log file and the structure of the web portal to predict the behaviour of users on the web portal. Carmona et al. (2012) focused on developing a methodology for e-commerce web portals using Google Analytics, not sequentially accessing the data. Subsequently, the extracted data was processed by aggregation, association analysis, and subgroup discovery. Based on the results, they identified recommendations and problematic areas of the surveyed web portal for the portal

management team. Van Nguyen, Zhou, Chong, Li, and Pu (2019) dealt with a data mining prediction approach in their paper. The authors aimed to obtain a prediction model for remanufactured products and described the non-linear effect of online market factors as predictors of customer demands. The results of the research showed that the most accurate results were obtained for the ensemble regression tree model.

Inspired by a time-based weekly survey of site users, similar research from other areas will be analysed. Dabrowska-Zielinska, Kogan, Ciolkosz, Gruszczynska, and Kowalik (2002) focused on the development of a model for studying the conditions of crops in various regions of Poland, where the remote exploration of the Earth was used. Based on satellite imagery, they calculated two indices for each week for 14 years. Then they monitored the measured values each week and evaluated the most suitable planting and cropping period during the year. All the results were supported by meteorological observations. The authors used regression analysis relating to yield deviation from the mean. The model was used for yield prediction for the year 1998, where the results of the prediction were compared with results published by the Central Statistical Office. Raffi et al. (2006) focused on examining the impact of the application of antiretroviral treatment to the twelfth week of the disease and the prediction of treatment over the next few weeks. To model the results of the critical weeks of treatment 24, 48, and 96, they used a prediction based on the observed treatment effects during the first twelve weeks. Logistic regression analysis was used to compare patients. The 12 week border was used as a baseline and was compared with the following critical weeks. On the basis of the results, after twelve weeks of treatment, the patient may be advised to continue or discontinue the treatment. The long-term predictive value of early treatment was analysed and the results of continuous treatment validated the assumptions of the authors. Even in the modelling of river basins, Verdhen, Chahar, and Sharma (2014) made predictions focusing on the Himalayan snow melting pattern during the spring. In their research, they used data from 2008 to create a prediction model for the years 2003 and 1983 back-to-back years, examined weekly during the spring periods of those years. The authors focused on the Nash and Sutcliffe efficiency coefficient and the linear regression coefficient to verify the efficiency of computations concerning the observed data. The variability in prediction from temperature index or energy balance models with observations was evaluated. The accuracy of temperature index or energy balance algorithms was determined in terms of probability. In addition to the research results, they also found that their input data was not reliable enough to achieve an effective simulation coefficient for the year 1983. They want to remove this in future research by adding additional parameters to help them to improve the simulation quality.

3. Materials and methods

In this paper, data related to Pillar 3 were gathered from bank web server log files (Munk, Pilková, Drlík, Kapusta, & Švec, 2012). The log files contain information about visitors. This information can be used for further analysis of visitors' behaviour. However, on the other hand, the web server log file also contains irrelevant and unnecessary data as well as inaccurate and incomplete information. Therefore, it is necessary to pre-process the data obtained from the web server log files. Data preparation of the log files consists of data cleaning, session identification, and path completion (Kapusta, Munk, Svec, & Pilkova, 2014; Kapusta, Pilková, Munk, & Švec, 2013). Data preparation was completed according to (Kapusta et al., 2014; Kapusta et al., 2013), where it was needed to pre-process log files from multiple servers that are used as load balancers. After data preparation, the data sample comprised 2 071 235 accesses. Subsequently, the variables were created. The dependent variable *category* was created from URL address, and its levels represent the examined web categories of the web portal (*Pricing List, Reputation, Business Conditions, Pillar3 related, Pillar3 disclosure requirements,* and *We support*). The timestamp served to create the independent variables-predictors *week* (0–53) and *crisis* (0: 2011–2012, 1: 2009–2010), that define the time and period of the access to the examined web categories of the web portal. The dummy variable *internal* (0, 1) was created from the IP address, and it divides the accesses from inside and outside of the organization network. Modelling the probabilities of the accesses to the examined web categories of the web portal of the bank depending on time was done using the multinomial logit model, which is a part of generalized linear models. The estimation of the models' parameters was done by maximizing the logarithm of the multinomial likelihood function. Subsequently, the logits were estimated and used to estimate the probabilities of accesses to the examined web portal categories. The models were evaluated by comparing the observed and expected values at the level of frequencies, probabilities and logits. The created research methodology was inspired by Munk, Benko, Gangur, and Turčáni (2015), Munk et al. (2017), Munk and Drlk (2014), Munk, Kapusta, and Švec (2010) and Munk, Kapusta, Švec, and Turčáni (2010).

4. Results

The probabilities of the accesses to the examined web portal categories were modelled (*category*) based on time, where time was represented by the variable week (*week*). The web server log file from multiple servers was used as load balancers. The source data came from a domestic significant commercial bank operating in Slovakia. The experiment was conducted on the sample of 2 071 235 log accesses obtained after data pre-processing, which is comprised of data cleaning, session identification, and path completion. Web users' behaviour was monitored over several years (2009–2012). The influence of other factors was also analysed, whether it was significant to distinguish the internal and external accesses (*internal*) and whether it was significant to distinguish the years of financial crisis and years after the financial crisis (*crisis*). In the case of the dummy variable *internal,* a trivial degree of dependency with the variable *category* (*Contingency coefficient* $C = 0.077$; *Cramer* $V = 0.077$) was identified. The contingency coefficient can have values from 0 (represents no dependence between variables) to 1 (represents the perfect dependence between variables).

In the case of the dummy variable *crisis,* a small degree of dependency with the variable *category* (*Chi-square* = 81 455.210; $df = 5$; $p = 0.000$; *Contingency coefficient* $C = 0.224$; *Cramer* $V = 0.230$) was identified. The contingency coefficient is statistically significant.

Based on these results, a model for all accesses was created (the internal and external accesses were not distinguished), and a dummy variable *crisis* was implemented into the model as a predictor.

Although the methodology was based on the research of Munk, Drlik, and Vrabelova (2011), it was not clear, by week, whether the model would be a polynomial model of the second, third or fourth degree. Using the Likelihood-ratio (LR) test (Tables 1–3), it was possible to compare estimates of the theoretical counts of accesses with the empirical counts of accesses. On the other hand, the disadvantage of the LR test is in the case of not sufficiently large expected counts where the condition of the LR test usage is violated. In that case, alternative techniques such as visualization of the difference in empirical and theoretical counts, and extreme values identification are used. The results of the LR test for all three polynomial models (second, third and fourth-degree) showed that the value of the LR test is small, so all models can be taken as appropriate. The value of the Pearson Chi-square is roughly equal to 1, which also indicates the suitability of the models.

The maximum of the logarithm of the likelihood function was appropriate for a comparison of the models. The smaller the value, the

Table 1
Evaluation of the second-degree polynomial model.

	df	Stat	Stat/df
Deviance	7,684,410	4,529,670	0.589462
Pearson Chi-square	7,684,410	7,794,534	1.014331
Log-likelihood		−2264835	

Table 2
Evaluation of the third-degree polynomial model.

	df	Stat	Stat/df
Deviance	7,684,405	4,510,212	0.586931
Pearson Chi-square	7,684,405	7,784,416	1.013015
Log-likelihood		−2255106	

Table 3
Evaluation of the fourth-degree polynomial model.

	df	Stat	Stat/df
Deviance	7,684,400	4,503,695	0.586083
Pearson Chi-square	7,684,400	7,829,313	1.018858
Log-likelihood		−2251847	

more appropriate the model. The highest value of log-likelihood (Tables 1–3) was identified for the fourth-degree polynomial model that is not in favour of this model. However, further evaluation of the model by visualizing empirical and theoretical logits allowed us to choose the appropriate degree of the polynomial for the examined model.

Parameter estimation for individual data was done using *STATISTICA Generalized Linear/Nonlinear Models*. The significance of the parameters was tested using the Wald test. The probability of access to the web portal categories was modelled depending on the time-week of access and crisis period. Time was represented by the variable *week* and its transformation based on the degree of the polynomial (*week*^{2}, *week*^{3}, and *week*^{4}) and the dummy variable *crisis* that represents the years of the financial crisis.

Based on the results of the test of all effects (Table 4) for the third-degree polynomial model, the parameters of the model are statistically significant. In the created model the years of the crisis and after the crisis represent a statistically significant sign that is represented by the dummy variable *crisis*. The weeks of the year represented by the variables *week* and its transformation based on the degree of polynomial also showed statistically significant signs.

The estimated parameters for almost all categories (except the category *Pricing List*) were significantly dependent on the week of the access and also for its transformations (Table 5). The values of logits were significantly affected by the period of the crisis. The logit model provides a probability estimate of the output. The absolute size of the parameters reflects predictors with the highest influence on the examined variable. A high absolute value of the parameter refers to a large dependency. A negative value refers to indirectly proportional dependence.

Using the estimated parameters, it was possible to calculate the logits for each category j in time i. The third-degree polynomial model

$$\widehat{\eta}_{ij} = \alpha_j + \beta_{1j} week_i + \beta_{2j} week_i^2 + \beta_{3j} week_i^3 + \gamma_j crisis_i, j = 1, 2, \cdots, J-1, \; i = 0, 1, 2, \cdots, 53$$

The parameters were analogically estimated for the polynomial models of the second and fourth-degree.

Calculated logits were used to estimate the probability for the referential category. The estimate calculation was denoted by $\widehat{\pi}_{iJ} = \frac{1}{1+\sum_{j=1}^{J-1} e^{\widehat{\eta}_{ij}}}$, where $\widehat{\eta}_{ij}$ are the logits for the web category j in time i. Based

Table 4
Test of all effects for the third-degree polynomial model.

	df	Wald Stat	p
Intercept	5	52325.51	0.0000
week	5	10800.15	0.0000
week^2	5	18259.02	0.0000
week^3	5	18995.98	0.0000
crisis	5	68622.95	0.0000

Table 5
Parameter estimation of the third-degree polynomial model.

	Category	Estimate	Std Dev	Wald Stat	p
week	Pricing List	0.0233	0.0025	84.7536	0.0000
week^2	Pricing List	0.0001	0.0001	1.3018	0.2539
week^3	Pricing List	0.0000	0.0000	0.3505	0.5538
crisis	Pricing List	−1.1730	0.0087	18003.3166	0.0000
week	Reputation	0.0507	0.0030	291.4300	0.0000
week^2	Reputation	−0.0023	0.0001	267.4115	0.0000
week^3	Reputation	0.0000	0.0000	305.2583	0.0000
crisis	Reputation	−0.9237	0.0101	8362.0226	0.0000
week	Business Conditions	−0.0623	0.0028	494.4624	0.0000
week^2	Business Conditions	0.0056	0.0001	1814.5684	0.0000
week^3	Business Conditions	−0.0001	0.0000	1721.9480	0.0000
crisis	Business Conditions	−2.0717	0.0095	47714.1908	0.0000
week	Pillar3 related	0.0655	0.0027	574.4090	0.0000
week^2	Pillar3 related	−0.0024	0.0001	343.8587	0.0000
week^3	Pillar3 related	0.0000	0.0000	301.2951	0.0000
crisis	Pillar3 related	−0.8455	0.0093	8189.3534	0.0000
week	Pillar3 disclosure requirements	0.1703	0.0030	3182.4843	0.0000
week^2	Pillar3 disclosure requirements	−0.0074	0.0001	2640.8711	0.0000
week^3	Pillar3 disclosure requirements	0.0001	0.0000	2284.0930	0.0000
crisis	Pillar3 disclosure requirements	−0.9935	0.0100	9890.9264	0.0000

on the estimate of the probability of access to the referential web category and estimated logits, it was possible to estimate the probabilities of accesses to the other web categories $\widehat{\pi}_{ij} = e^{\widehat{\eta}_{ij}} \widehat{\pi}_{iJ}, j = 1, 2, \cdots, J-1$, where $\widehat{\eta}_{ij}$ are the logit estimates of the web category j in time i and $\widehat{\pi}_{iJ}$ is the estimate of the probability of access to the referential web category J in time i.

To find the most suitable model, it was necessary to evaluate the results for each of the models and to visualize the probabilities of access to web categories during the weeks of the year. The evaluation of the model was conducted on three levels – firstly, the counts of accesses, then the probabilities, and finally, the logits. We used contingency tables to define empirical counts of accesses y_{ij} for the web category j in the time i. Based on the estimated probabilities of accesses of the visitors on the examined web categories, it was possible to estimate theoretical counts of accesses $\widehat{y}_{ij} = \widehat{\pi}_{ij} \sum_j y_{ij}$, where $\widehat{\pi}_{ij}$ are the estimates of probabilities of accesses and y_{ij} are empirical counts of accesses to the web category j in time i. Problematic parts in counts were identified using the visualization of differences of empirical and theoretical counts $d_{ij} = y_{ij} - \widehat{y}_{ij}$, where the extreme values are identified based on rule 2σ.

The comparison of differences in counts for each model allowed us to determine the most suitable model. Calculated differences were similar for each model. The most considerable difference was identified for the category *Business Conditions* for the model of the second-degree polynomial (Fig. 1) in the 31st week (second-degree polynomial: 14 445.715; third-degree polynomial: 14 020.797; fourth-degree polynomial: 13 548.354). The plot (Fig. 1) visualizes the differences in empirical and theoretical counts of accesses of visitors in the years of the crisis. After applying rules, 2σ extreme values were identified. For the category *Business Conditions* in the case of the 31st week, the prediction was undervalued. All three models contained a similar count of extreme values and represent 5.55% of all cases.

The next step was to evaluate the probabilities. Based on the observed counts, the empirical relative counts of accesses $p_{ij} = \frac{y_{ij}}{\sum_j y_{ij}}$ can be calculated. Following that, the distributions of the probabilities of empirical relative counts of accesses and the estimated probabilities of the selected web category j in time i were compared. The zero hypothesis was tested using the Wilcoxon pair test. The distribution of the pairs was symmetrical around zero $r_{ij} = p_{ij} - \pi_{ij}$, H0: $F(-r) = 1 - F(r)$. Only two

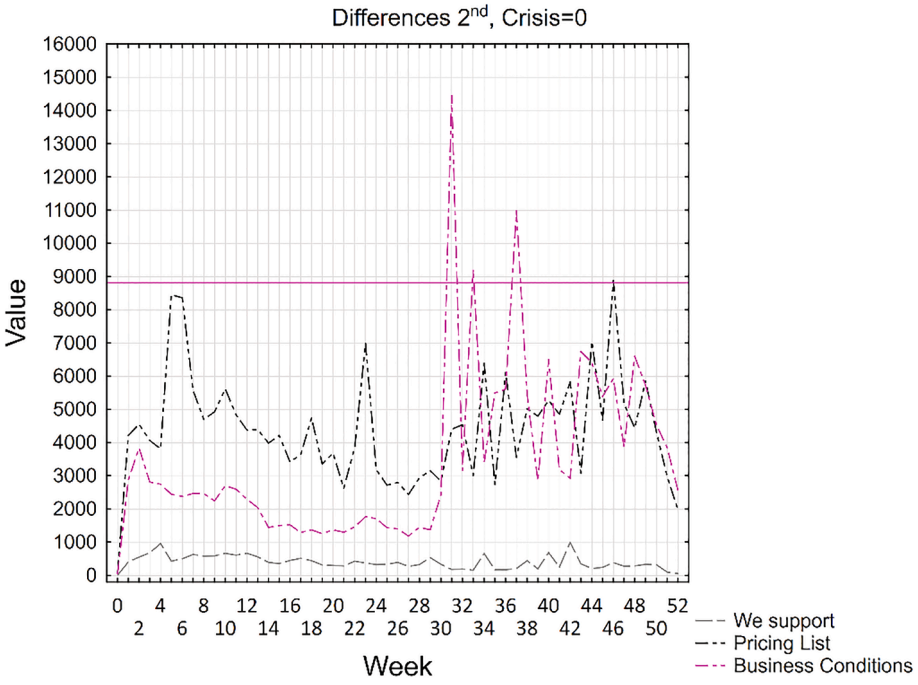

Fig. 1. Differences of counts of the second-degree polynomial model.

categories showed issues (Table 6). It was not clear which degree of the polynomial is the best for the model. During the years of crisis, an issue for the category *We support* (second-degree polynomial: $p = 0.000320$ was identified; third-degree polynomial: $p = 0.000299$; fourth-degree polynomial: $p = 0.000342$). In the case of years after the crisis, the category *Business Conditions* was discovered by the evaluation of differences of counts of accesses.

The last option, to decide which degree of the polynomial is the most suitable, was to evaluate theoretical and empirical logits. In this case, it was analysed whether the estimated theoretical logits fit (model) the empirical logits calculated from the empirical relative counts of accesses $h_{ij} = \ln\left(\frac{p_{ij}}{p_{iJ}}\right), j = 1,2,\cdots,J-1$, where p_{ij} is the empirical relative count of access to the web category j in time i and p_{iJ} is the empirical relative count of access to the referential web category J in time i. The visualization of empirical and theoretical logits of each of the examined web categories (except the referential web category) can show how the theoretical logits model the empirical logits. Based on the visualization, it was seen that all the theoretical logits fit the empirical logits. However, in the case of the second-degree polynomial model (Fig. 2), it was observed that the theoretical logits were more similar to a linear function in the case of some categories, rather than quadratic. In the case of the theoretical logits, the third (Fig. 3) and fourth (Fig. 4) degree polynomials better fitted the empirical logits. However, the fourth-degree polynomial model (Fig. 4) captured the course of the empirical logits in too much detail. On the other hand, the third-degree polynomial model (Fig. 3) offered the same fitting but did not adjust to the data at the expense of the trend. The suitability of the choice of the polynomial degree is shown on plots of the web category *Pillar3 related* (Figs. 2–4).

Table 6
Probability distribution for the third-degree polynomial.

Category	Crisis	N	T	Z	p-value
We support	1	53	307.0000	3.6164	0.0002
Pricing List	1	53	570.0000	1.2881	0.1977
Reputation	1	53	678.0000	0.3320	0.7399
Business Conditions	1	53	621.0000	0.8366	0.4028
Pillar3 related	1	53	659.0000	0.5002	0.6169
Pillar3 disclosure requirements	1	53	686.0000	0.2612	0.7940
We support	0	53	691.0000	0.2169	0.8283
Pricing List	0	53	696.0000	0.1726	0.8629
Reputation	0	53	597.0000	1.0490	0.2942
Business Conditions	0	53	456.0000	2.2973	0.0216
Pillar3 related	0	53	564.0000	1.3412	0.1799
Pillar3 disclosure requirements	0	53	698.0000	0.1549	0.8769

The plots (Figs. 5 and 6) show the visualization of probabilities of access to each of the examined web categories during the years of the financial crisis. The highest access during the crisis was estimated for the web category *Pricing List*, where the highest access probability was during the weeks at the end of the year (the 50th week has the value of 0.481). The lowest estimated values were identified for the weeks at the beginning of the year (the 10th week has a value of 0.381). The second most accessed web category for almost half the year was the web category *Pillar3 related*, where the highest visit rate for this web category was achieved during the first quarter of the year (the 10th week has the value of 0.214). In the second half of the year, access to this web category decreased but significantly increased again in the last four weeks of the year. From the 33rd week to the 50th week of the year, the web category *Business Conditions* was, based on the estimate of the probability of access, the second most visited web category. The highest value of 0.210 was identified in the 42nd week of the year. On the other hand, in the first half of the year, the web category *Business Conditions* was the least visited web category where the lowest value of 0.053 was identified in the 10th week. The probabilities of access to the other web categories are around the value of 0.10. The small rise in the probability of access to the web category *Pillar3 disclosure requirements* is also interesting with the highest value of 0.145 in the 14th week but which afterwards decreases to a value of under 0.10.

The plots (Figs. 7 and 8) show the probabilities of accesses to each examined web category during the years after the financial crisis. The highest access rate was estimated for the web category *Pricing List* in the period of years after the financial crisis. Except for the period of the 36th – 46th week where the web category *Business Conditions* had the highest probability of access. The biggest difference in comparison to the years

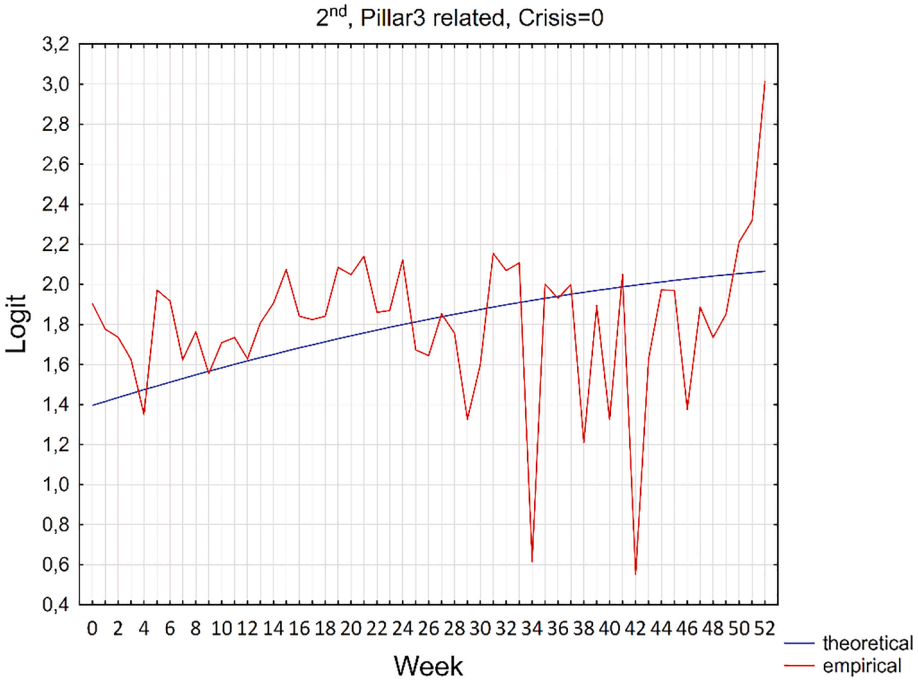

Fig. 2. Logit visualisation of the second-degree polynomial model of the Pillar3 related category.

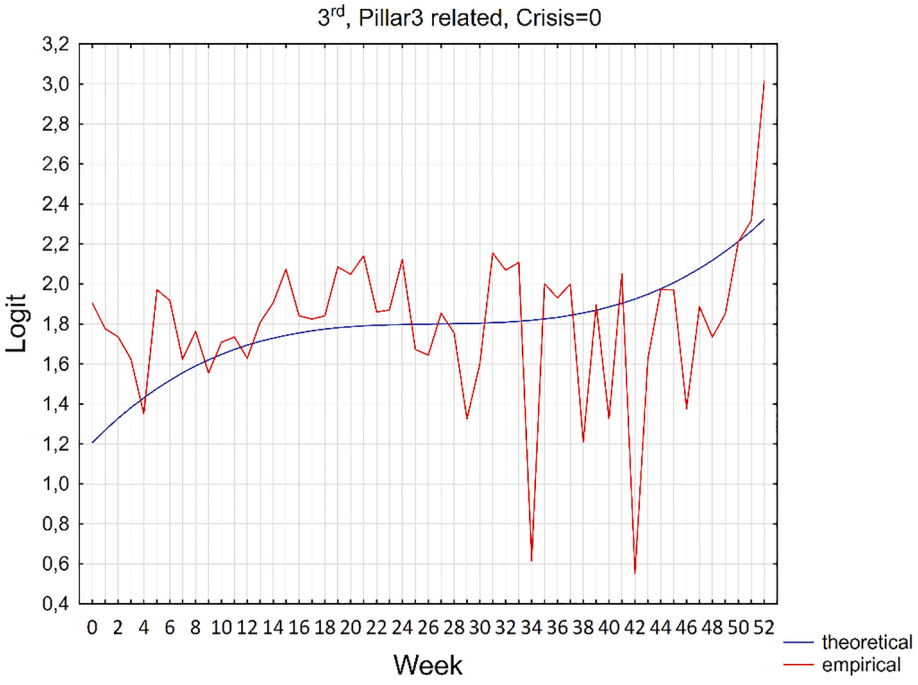

Fig. 3. Logit visualisation of the third-degree polynomial model of the Pillar3 related category.

of the crisis was identified for the web category *Business Conditions,* where the access rate almost doubled. On the other hand, access to the web category *We support* decreased in the years after the crisis. In the case of the web category *Reputation*, *Pillar3 related* and *Pillar3 disclosure requirements,* the probability of access decreased, but the behaviour of the visitors was the same as in the years of the financial crisis. The visitors had higher interest at the beginning of the year and during the year interest decreased but at the end of the year, it began to increase again.

From the detailed weekly analysis (of the years 2009–2012) of users' behaviours on the web portal of published financial and risk information by a commercial bank, it was discovered that the results of the analysis correspond to the results of previous quarterly analysis (Munk et al., 2017). The stakeholders had the highest interest in the mandatory and supplementary Pillar 3 information during the first quarter, where the period around the 10th week could be specified (that week displayed the highest interest in these web categories). On this basis, it can be concluded that the required quarterly publication frequency of the results is not necessary for market discipline. It would be sufficient to publish this information annually, ideally in the early weeks of the year.

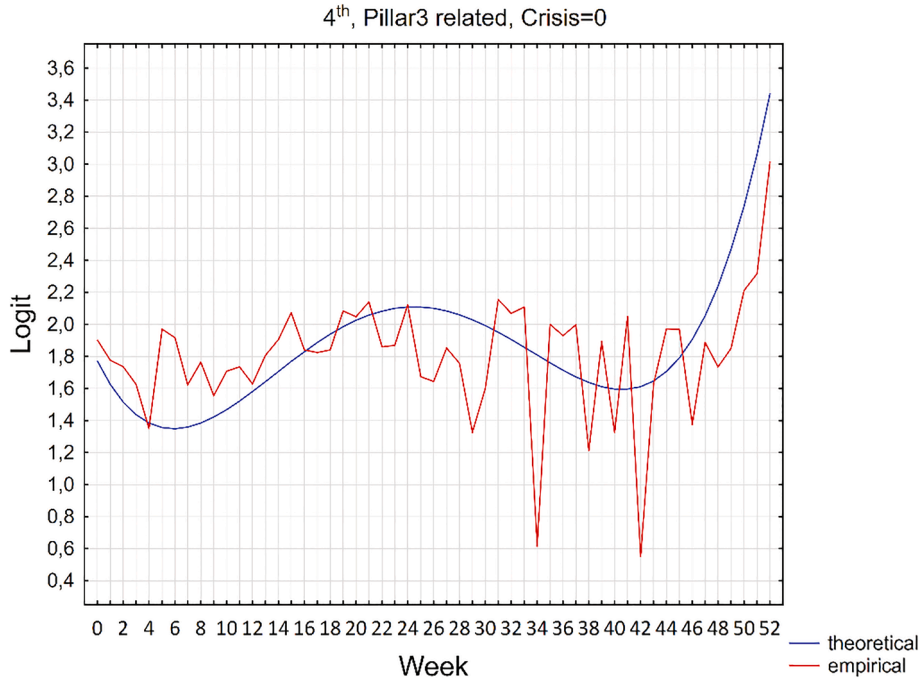

Fig. 4. Logit visualization of the fourth-degree polynomial model of the Pillar3 related category.

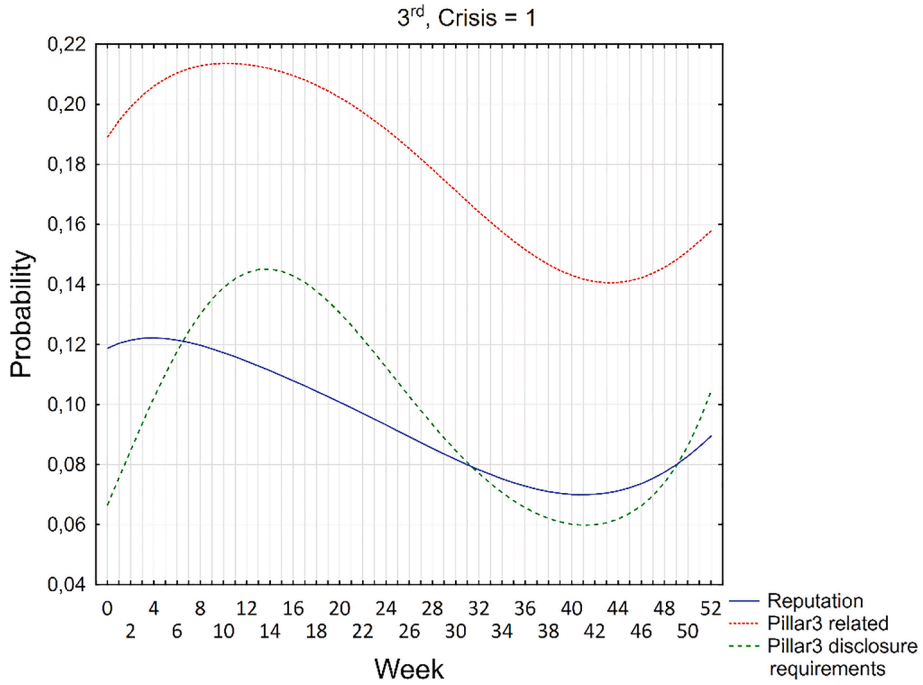

Fig. 5. Probability visualization of market discipline related categories during the years of the financial crisis.

5. Discussion and conclusion

The process of enhancement of market discipline has been implemented by Pillar 3 requirements since the introduction of the Basel II regulations, and it has been identified as its key objective. The Pillar 3 information disclosure document objective is to provide meaningful, comparable, and relevant disclosures. The document has been revised several times to achieve consolidated disclosures. It offers obligatory forms, flexible forms, and new dashboards of key metrics. Moreover, to achieve more consolidation, EBA guidelines on disclosure requirements have been published to enhance the consistency and comparability of institutions' disclosures. The guidelines aim to ensure market discipline, and they are based on the update of the Pillar 3 requirements by the Basel Committee in January 2015.

All of these ongoing changes suggest that the main goal of Pillar 3 information disclosures requires the delivery of relevant information to key market participants and consequent enhancement of market discipline mechanisms. Therefore, any analysis of the current structure and the content of disclosures is inevitable, and the design of the relevant disclosure models is important for delivering sufficient information to

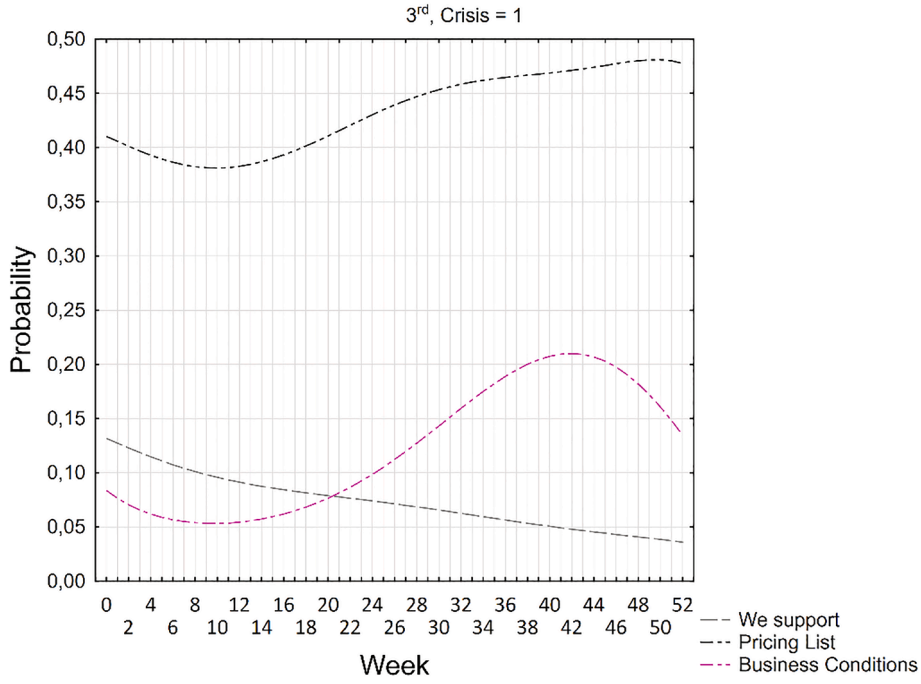

Fig. 6. Probability visualization of other categories during the years of the financial crisis.

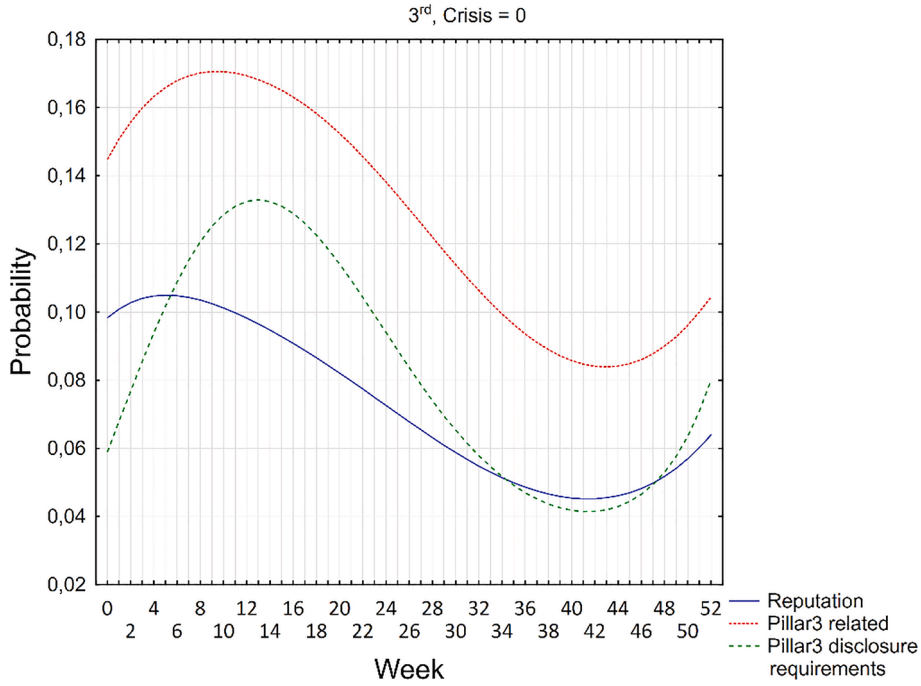

Fig. 7. Probability visualization of market discipline related categories during the years after the financial crisis.

stakeholders, and for their ability to assess bank risk-taking. Consequently, based on the analysis of the depositor's interest in disclosures after turbulent times and on the assessment of the current regulatory disclosure standards, it creates the opportunity to design a data structure model, which would help to achieve this meaningful goal and ensure relevant disclosures to avoid market discipline failure.

In this study, key findings have been identified. Firstly, in turbulent times depositors' interest was highest in the *Pricing List* web category (lowest in the first weeks of the year), which is followed by the *Pillar 3 related* web category, which was the highest in the first two quarters of the year. Peaks for the Pillar 3 categories (*Pillar 3 related, Pillar3 disclosure requirements*) were identified in the first weeks of the year. In the second half of the year, *Business Conditions* has the highest interest (lowest interest in the first half of the year). It is important to note that *Pillar 3 disclosure requirements* recorded a minor increase in the first quarter. After turbulent times, the highest interest is identified in the *Pricing List* web category. It was replaced by *Business Conditions* in only a few weeks in the third quarter. This category has been identified as having twice as high levels of interest in comparison to turbulent times. Lastly, the web categories *Reputation*, *Pillar 3 related,* and *Pillar 3*

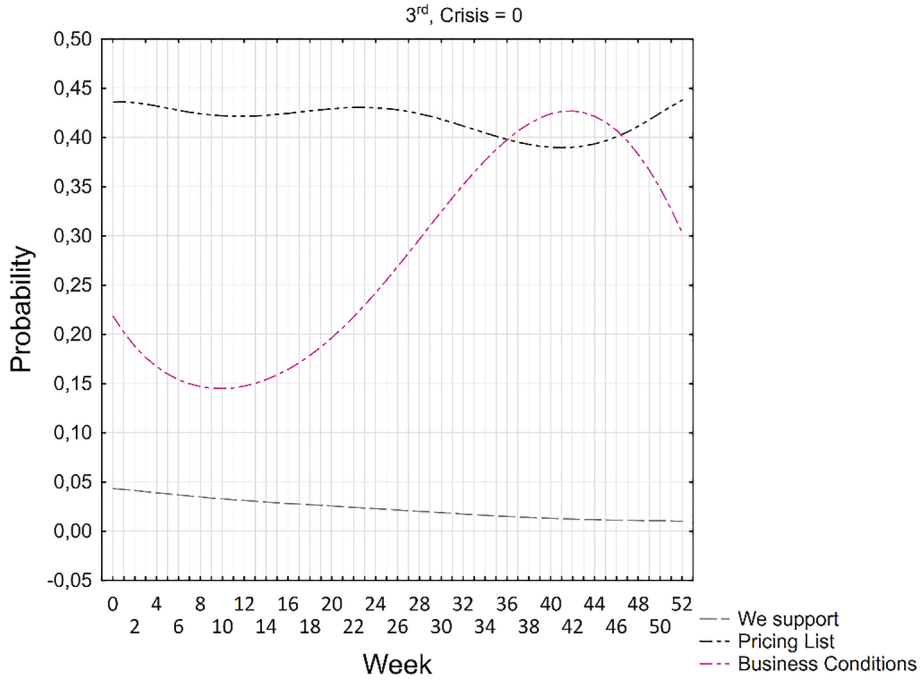

Fig. 8. Probability visualization of other categories during the years after the financial crisis.

disclosure requirements have displayed declining interest, which is in conjunction with Munk et al. (2017) (in turbulent times). Moreover, the behaviour of depositors' in these categories is also high at the beginning and the end of the year, and during the year, a decline in interest is identified. These findings also suggest that depositors do not show interest in *Pillar 3 related* and *Pillar 3 disclosure requirements* but instead in the current status of the commercial bank, especially in the *Business Conditions* and *Pricing List* categories.

Generally, these results are in line with De Araujo and Leyshon (2016) that conclude that stakeholders have a higher interest in other types of information than Pillar 3 disclosures or financial risk disclosures (Giner, Allini, & Zampella, 2020). It should be noted that our results related to the analysis of the interest of stakeholders in Pillar 3 disclosures during turbulent times are only in conjunction with our previous studies because the research volume within this topic is low.

These findings suggest that changes in commercial banking disclosures in favour of achieving Pillar 3 goals are inevitable, even after years of crisis. Consequently, changes in banks' disclosures are insufficient and we agree with Kuranchie-Pong et al. (2016) that disclosures should add value to key market participants to assess the risk profiles of banks to enhance effective market discipline, which is also in line with regulators' expectations. The removal of redundant and addition of useful information is essential to deliver relevant and sufficient disclosures to key market participants. This serves as a background for the identification of a disclosure model which is attractive and relevant for key market participants. The challenges for this topic are the low interest of depositors in officially requiring Pillar 3 disclosures, as the main issue is also the structure and identification of a relevant model based on disclosed information, which would enhance the interest of key market participants. Mainly, the existence of some limitations in this research encourages further study of this topic, which is inevitable.

6. Implications and limitations

The goal of the Pillar 3 regulation framework is the promotion of transparency and enhancement of public disclosures by financial institutions to reinforce market discipline. Therefore, the outcomes of the study, such as the identification of the nature of parts, content and specific categories of Pillar 3 disclosures, which are important to stakeholders, along with those types of information viewed as efficient are crucial to implementing effective market discipline as a supervisory goal. There are a few implications from our results. Firstly, the disclosures are most attractive at the beginning and the end of the year. During turbulent times, strategic issues like business conditions have the highest peak in attractiveness. The other implications are related to depositors' incentives to discipline commercial banks during turbulent times, which are lower for banks with good business conditions and pricing compared to riskier banks, because interest in Pillar 3 related disclosures is low. Moreover, this information is most important at the beginning and end of the year. During the year, there is an implication that their interest is concentrated on managerial actions and strategic issues, which covers current business conditions. These results can be firstly used by regulators in the process of designing new Pillar 3 regulations as they propose practical changes to the design of the disclosure framework. Secondly, commercial banks and financial institutions can use these outcomes when designing their Pillar 3 disclosures on their websites and provide voluntary information disclosures to attract their depositors. Accordingly, enhancement of market discipline through effective disclosures brings a range of benefits to market participants, such as stability on financial markets through potential avoidance of market discipline failure in turbulent times, and to society in general. Finally, we have identified the analysis of the categories of Pillar 3 disclosures in more detail and in other countries as topics for future research.

Our research has few limitations, mainly in the data analysis. There are limited options in obtaining historical data from banking and financial institutions. Storage of such data is difficult as web server records much information about each access to the web portal page. The institutions must have large data storage capabilities to preserve all the historical data, and that is why they often store only a fragment of historical data (e.g. only one year, month, etc.), based on the available data storage. Another limitation is also connected to working with historical data. In this case, it is about the structure of the web portal. As time passes, the web portal evolves with the needs of both visitors and administrators. During data pre-processing phases, various methods require a site map. Because the web portal has changed over time on

several occasions, it is rather difficult to obtain an accurate and complete site map of a web portal. It is possible to obtain an incomplete site map from the log file, but still, it is an issue that can result in generating inaccurate data. The last limitation is connected to the evaluation of the data analysis results as standard evaluation methods could not be used. This was because the examined variable has many categories (web pages). Novel evaluation methods were designed to evaluate the model across various levels (counts of accesses, probabilities, and logits).

CRediT authorship contribution statement

Michal Munk: Conceptualization, Methodology, Formal analysis, Writing - review & editing. **Anna Pilkova:** Conceptualization, Writing - review & editing, Supervision. **Lubomir Benko:** Methodology, Investigation, Writing - original draft. **Petra Blazekova:** Conceptualization, Writing - original draft. **Peter Svec:** Data curation, Resources, Writing - original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eswa.2021.115503.

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