Charles University

Faculty of Social Sciences
Institute of Economic Studies

MASTER'S THESIS

Terminal Asset Value of the Prague Stock Exchange

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Study program: **Economics and Finance**

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Academic Year: **2023**

Declaration of Authorship

The author hereby declares that he compiled this thesis independently; using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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Prague, April 28, 2023 Pavel Neumann

Acknowledgments

This author is grateful to his supervisor prof. Ing. Karel Janda, Dr., Ph.D., M.A. for his enormous support, advice and time dedicated for this thesis. Additionally, I would like to thank my family and friends for their support.

This thesis is part of a project GEOCEP that has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 870245.

Abstract

This thesis draws parallel between depositors facing a bank run and investors facing a stock price crash in order to determine a formula for debt ratio that would trigger mass sale of stocks for particular company. To reach terminal debt ratio formula, this thesis firstly discusses a topic of financial crises from stock market and banking perspective. Next, it compares regulation for both institutions on Czech national and EU level. Then, this thesis derives a formula for calculation of terminal debt ratio based on game theory and pricing of the options approach. Lastly, it tests limits of terminal debt ratio framework on companies listed on Prague Stock Exchange and concludes that terminal debt ratio framework is best applicable on non−financial companies that experienced moderate growth in stock price over the examined period.

JEL Classification	C79, G13, D49
Keywords	Game theory, Prague Stock Exchange, Debt Ratio, Stock Market Crash
Title	Terminal Asset Value of the Prague Stock Exchange

Abstrakt

Tato práce ukazuje souvislosti mezi vkladateli, kterým hrozí run na banku, a investory, kterým hrozí pád burzy, aby získala vzorec na zadluženost jmění, které by způsobilo masový prodej akcií dané společnosti. Aby dosáhla tohoto vzorce, tato práce nejdříve rozebírá téma finančních krizí z pohledu akciového trhu a bank. Dále porovnává regulace v obou odvětvích na České a Evropské úrovni. Poté tato práce odvozuje vzorec pro výpočet konečné zadluženosti jmění za pomoci teorie her a hodnocení opcí. Nakonec, tato práce zkoumá limity konečné zadluženosti jmění na společnostech uvedených na Pražské burze a shrnuje, že konečná zadluženost jmění nejlépe funguje na nefinančních společnostech, jejichž akcie prožily mírný růst během zkoumaného období.

Klasifikace	C79, G13, D49
Klíčová slova	Teorie her, Pražská Burza, Zadluženost jmění, Burzovní krize
Název práce	Konečná hodnota aktiv Pražské Burzy

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Acronyms

ESMA European Securities and Market Authority

HQLA High Quality Liquid Assets

LCR Liquidity Coverage Ratio

NSFR Net Stable Funding Ratio

TMR Tatra Mountain Resorts a.s.

Master's Thesis Proposal

Author:	Bc. Pavel Neumann
Supervisor:	prof. Ing. Karel Janda, Dr., Ph.D., M.A.
Defense Planned:	June 2023

Proposed Topic:
Terminal Asset Value of the Prague Stock Exchange

Motivtion:
During its turbulent history, stock markets have been one of the largest recipients of volatility in economy. Ever since people started trading in the stock market, they have been afraid of its crash. Their fears have been rightful. The most notable stock market crashes have sent ripples throughout the economies around the globe.

It is the scope of stock market crash´s impact on financial situation of firms and banks, economics expectations of people, level of unemployment, inflation and many more that shows the importance of studying of it. Recently, due to the war in Ukraine, Moscow Stock exchange suffered a terminal shock, which caused the end of all trading within this exchange and required government intervention. It was clearly shown that the shock was beyond the limits of market to handle. A shock of such disastrous magnitude could happen to any stock exchange in these turbulent times.

One of the lynchpins of stock market topic is David Hirshleifer (2015), who provides summary of the current theories concerning stock markets and its limitations. This general information is discussed in more detail by David M. Frankel (2008), which is focusing on the crashes themselves and provides theory for their occurrence. Moreover, the crashes have been subject to many econometric approaches, one of which is K. M. Zahidul Islam & Sayed Farrukh Ahmed (2015).

Contrary to the previous studies, this thesis will apply methodology of game theory. It will compare the position of the stockholder in stock market, when facing the crash of the entire stock exchange can be compared to the position of person, who has deposited money in bank, which is facing a bank run. Thus, this thesis will focus on adjusting the framework about prediction of bank run proposed by Zeigler (2004) on stock market framework.

By applying this analysis, this thesis aims to derive the framework for calculation of the magnitude of the shock, which would cause absolute termination of trading in the stock market exchange. It will derive the theoretical limits of the stock exchange in regard to market fluctuation. In addition, this thesis is drawing connections between behavior of depositors in bank run and investors in case of stock crash. Due to the connection between these two economic institutions, this thesis will investigate regulations of both institutions and how it impacts these specific terminal scenarios.

This newly adapted model will be used to calculate the terminal value of chosen markets of Prague Stock Exchange, which has been chosen as a source for the underlying data, due to its proximity. Moreover, its stability and shock absorption capabilities make it an intriguing market to study. The size of Prague Stock Exchange makes this analysis possible. If it contained more companies, like NYSE, this study would be exorbitantly long and would require larger scope than diploma thesis.

Additionally, this thesis will apply its derived model to a set of particular companies in Prague Stock Exchange to further test the model in terms of real-world adaptation. It should provide deeper and more specific results for the model´s adaptation and its consistency against the constraints of reality.

Hypotheses:

1. Hypothesis #1: It is possible to apply bank run framework on stock exchange crash
2. Hypothesis #2: There will be a set of assumptions differentiating bank run and stock exchange crash
3. Hypothesis #3: This thesis will derive the terminal magnitude of shock to Prague Stock Exchange

Methodology:

I will use framework for calculating bank run triggering equity value proposed by Zeigler (2004). This approach uses bank´s asset value, face value of deposits, risk free interest rate, interest rate on deposits, standard deviation of bank´s asset value, capital provided by asset holder at time t and liquidation costs to determine the equity value, which would trigger a bank run.

This method has been incredibly useful in determining situations of bank runs for specific bank. However, due to the differences between its assumptions and applications, it will need to be adjusted to suit the needs of the stock market crash instead of bank run. This will result in calculating debt ratio, instead of the absolute value. Additionally, in case of stock market, all companies forming this market will be considered as a single "market" company and their end of year financial statements will provide information for calculations. I plan to examine a set of Prague Stock Exchange markets separately. Later, I plan to unite these markets into Prague Stock Exchange market and calculating terminal value for it. Furthermore, companies will be chosen, and the model will be used to calculate their terminal debt ratio, in order to provided different, and possibly more in depth, view for the analysis

Expected Contribution:

This thesis will connect two important situations for a person in economy – a client of the bank expecting bank run and stockholder risking crash of stock market. This will draw strong connection between two important fields of study and provide differences in assumptions, when dealing with them.
Additionally, this thesis will compute the value of shock to stock prices for Prague Stock Exchange, which would be terminal for it and companies traded there. This will improve our understanding about the limits of the market and its ability to absorb volatility. Framework and data developed in this thesis maybe used for further investigation of stock markets and its vulnerabilities.

Outline:

1. Introduction to the problem
2. Theory: Discussion of existing work in Bank Run theory and stock market crashes and its regulation
3. Framework adaptation: I will discuss how does the model fit the stock market crash and necessary adjustments
4. Data: I will discuss the data available
5. Computations: I will calculate the terminal shock value for Prague Stock Exchange
6. Conclusion: I will summarize what has been gained investigating this topic.

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1 Introduction

Throughout its history, stock markets have been regarded as a significant source and recipient of volatility in the economy. Thus, the possibility of crash of the stock in holding or the market itself has been a lingering issue for all investors. Due to interconnectedness of modern economy, such an event tends to spill out of the stock market and affect all parts of economy. Recently, a major shock forced Moscow Stock Exchange to halt its trading due to an overall crash of stocks. While the cause was driven by political reasons, many other stock markets have experienced high levels of volatility in recent period. One of the lynchpins of stock market topic is Hirshleifer (2014), explaining basic approach to stock markets and alternatives that capture more real–world behaviour. Focusing more on theory behind stock market crashes is Frankel (2008) and who provides possible explanation. Stock market is usually examined through econometric approach, examining past data. An example for such examination, that focuses on long term impacts of stock market crash is Islam and Ahmed (2015). Stock markets were not the only institutions experiencing difficulties. In 2023 alone, banking sectors in US and Switzerland have encountered troubles. These issues have not yet turned into major systemic implications but show further fragility of financial system. On the other hand, crisis in the banking sector is common occurrence. According to Valencia (2018), in a period between 1970 and 2017, there were 151 crises in banking sector worldwide.

The objective of this thesis is to apply game theory and pricing of the options approach to estimate the level of debt, which would trigger mass sale of stock of the chosen company. To achieve its goal, this thesis will compare a position of shareholder facing a crash of company to a depositor facing a bank run. This thesis compares regulations in banking sector and stock markets to determine differences in adverse scenarios, which it examines. To create model applicable to on stocks, it will start from model proposed by Ziegler (2004), which models level of equity that would trigger a bank run. This thesis will then adapt Ziegler´s model and its expectations to fit the stock market situation. By applying terminal debt ratio approach, it aims to calculate the level of debt that would trigger a mass sale of stocks for a company listed on stock exchange. After establishing terminal debt ratio formula, it aims to test its limits on companies listed on Prague Stock Exchange. It examines companies with different level of change in stock price over year. Furthermore, it tests terminal debt ratio framework on the entire Prime market of Prague Stock Exchange, to determine if terminal debt ratio

approach can be used on entire markets in order to estimate level of shock that would cause a crash of entire market.

This thesis is structured in following manner. Chapter 2 discusses financial crises from perspective of stock markets and banking sector. Chapter 3 examines the regulations both institutions are subject to and draws comparison between them. Chapter 4 introduces model to predict bank runs caused by the change of equity in banks and adapts bank run model into terminal debt ratio model, which predicts mass sale of stocks of chosen company. Chapter 5 applies previously derived model on companies listed on Prague Stock Exchange to derive limitations of terminal debt ratio approach. It firstly applies the model on three companies chosen according to their change in stock price and a banking group to test terminal debt ratio framework on company´s robustness towards panic sale of their stocks. Then, Chapter 6 examines its application on the Prime Market of Prague Stock Exchange in order to determine its application to estimate possible collapse of an entire institution. Chapter 7 concludes the entire thesis and suggests possible continuation of research in this field.

2 Financial crises

Term financial crises can be caused by many different acters in the economy. To our examination, we will consider only crises stemming from banking sector and from stock market. While the stock market is regarded as a major source of volatility in financial system, it rarely spirals out of control to cause systemic crises. On the contrary, adverse situations for banks tend to spiral out into wider economy more often. In a period from 1970 to 2017, IMF identified 151 banking crises across the globe (Valencia 2018). This implies more than three banking crises every year.

Focusing on stock market, the most notable crisis caused by the crash of stock market has been the Great Depression in the last century. It has plunged the world economies into few years recession as it spread around the globe. There are generally two views on the stock market crashes. If we agree with the assumption of efficient markets and their information transparency, it is likely that the stock market crash will be considered as a first sign of distress for whole economy, heralding a new era of lower profitability. On the other hand, many academics view stock market crashes as simple burst of bubble, which was cause by informational asymmetry or irrationality on the market (Bond and Devereux 1988). On the contrary, there are alternatives to our standard view of the stock market. Behavioural economics is introducing models that try to deal with the human psyche and irrational behaviour (Hirshleifer 2014). While these models are dealing with inherent weaknesses of general economic theory, they are mostly complex and harder to apply.

Small shocks on the stock market are events that are happening regularly. The evidence suggests that significant shocks tend to be more negative than positive. Only one in ten shocks is considered a frenzy, driving stock price up (Frankel 2008). These shocks can be explained by model with asymmetric traders, where some traders are only having market data, while others know behaviour of other traders and may influence others (Frankel 2008).

Market regulators and central banks have taken man steps to regulate the stock market and reduce its possibility to cause economy wide crises. This is further exacerbated by the stock market´s role in the economy. It is supposed to channel excess funds into companies that need investment and by its activity, it should increase the economic growth of a country. The liquid status does not only bring benefits, but also drawbacks. There is an implication that liquid stocks react quickly to adverse news, so the

managers tend to withhold at least part of bad information. The lack of information may cause the adverse information to accumulate and be released at once, cause crash in the stock price (Chang, Chen, and Zolotoy 2017). So, while liquidity is regarded generally as beneficial feature of stocks, it is important to watch out for its negative drawbacks in potential loss of value.

It brings us closer to the topic of this thesis. Its main goal is to estimate which level od debt would cause the mass sale of stock by investors. Terminal debt ratio is a model that builds on standard debt ratio used for quick and rough estimation. While quick ratios have been disregarded as a simple tool by modern economists, there is sufficient evidence that shows they can be useful in predicting the bankruptcy of a company (Beaver 1966). The estimation of profitability of its stock is a vastly different matter. Multiple discriminant model is built upon the quick ratio framework. It uses quick ratios to efficiently determine the best combination, which separates bankrupt and non–bankrupt companies (Altman 1968). His model does not account for dynamic changes in the market and terminal debt ratio model, which is being introduced in this thesis aims to improve upon that.

While stock market crashes cause immediate negative impacts for the whole economy, there is evidence that they might cause long term effects. Data from stock exchange in Dhaka, Bangladesh, show a negative future implication for investors, as they are viewed more negatively (Islam and Ahmed 2015). Terminal debt ratio developed by this thesis aims to prevent crashes from happening as it seeks to draw a limit for financial leverage for investors, based on market´s preferences.

On the other hand, banking sector is playing more embedded role in the economy. It helps with maturity transformation in order to increase the investment. Banks do face different dangers and operate in vastly different system. While stock markets are generally regulated through informational transparency and low barrier to entry, bank´s main regulatory focus in keeping sufficient levels of capital to its risks. Thus, banking crises have been at the front of sources of financial crises. It is not clear when to consider an event or situation in banking sector a crisis. Generally, it must meet two conditions to be regarded as crises. Firstly, there are signs of financial troubles in banking system – significant losses, liquidations of assets etc. Secondly, there must be policy interventions to counteract these adverse conditions (Valencia 2018).

As mentioned previously, banks fulfil an important role in economy. When a crisis hits, there are some approaches how to support struggling financial sector. First approach is to channel liquidity into the financial sector. Other, widely used method is a use of guarantees (Valencia 2018). It sets the role of government like an insurance

company that insures deposits. These were just a few examples of reactions, to a crisis in financial sector. Compared to support of banking sector, stock market crashes do not receive any when they occur.

The most recent example of bank collapse was a fall of Silicon Valley Bank in 2023. Firstly, its crisis was heralded by the increase in interest rates by Federal reserves. The increase caused investors to be more risk averse and it damaged technology startups – the main clients of Silicon Valley Bank. So, these startups were forced to withdraw increasing amounts of money from Silicon Valley Bank and forced Silicon Valley Bank to sell part of its portfolio with discount, which caused $1.8 billion loss. The bank tried to sell its stock to patch its hole in funding, but on first day, its shares were traded with 60% discount as investors were afraid of its crash. It culminated in a bank run as depositors gained information about market´s worries about the bank´s liquidity issues. Thus, the Silicon Valley Bank collapsed (Reuters 2023). The topic of bank run in option pricing theory is investigated by Ziegler (2004), where it is modelled to be triggered by an equity price. The situation went in accordance with bank run model as the equity price plummeted. It leaves out an important question, whether the bad news caused panic among investors and depositors, or whether investors were first to react and their decrease in stock price cause bank run.

Topic of this thesis is interesting due to the connections between banking sector and stock markets. Both institutions help to channel investment into companies, each receives different level of treatment in times of crises. Furthermore, banks are obliged to keep sufficient level of regulatory capital, which in their case is usually common stock. Common stock as capital is freely traded on stock markets and thus can change value quickly. The further comparison will be discussed especially in next chapter covering regulation of both markets and comparing them.

Financial crises are very impactful and surprisingly regular events, on which financial and non–financial sector reacts. It usually forces a policy reaction from government or regulator in order to limit its damage to economy. While a crisis can start from stock market, or from banking crisis, the behaviour of individuals tends to be same. Investors and depositors attempt to get out as much of their money as possible, before it becomes impossible.

3 Regulations

The goal of this chapter is to provide an overview of regulation for banking, specifically liquidity regulation, and stock market on Czech national level and on EU level. It will help us understand differences in both sectors, especially in chosen stress scenarios and provide insight to understand individual´s behaviour. There is an interesting connection between bank´s liquidity problem and stock market recession, as bank is reliant on market to provide liquidity in case of bank´s financial issues. On the other hand, banks are one of the largest players on the stock markets and can influence price change. This chapter will firstly discuss market regulations applied firstly on Czech national level and then on EU level. In the second subsection, bank´s liquidity regulation will be discussed with reliance on Basel III recommendations and EU wide regulatory application. Lastly, both regulations will be compared in order to highlight differences between both regulations.

3.1 Stock market regulation

Financial markets are well known for its low level of regulation in its trading. On the other hand, there are generally requirements for transparency, which provides large quantities of data regarding the performance of myriad of companies to any interested party or individual. The aim of the following sections is to discuss all requirements for organizers of markets and parties trading there and the specifics of the reporting duties of market organizers and individual companies listed there.

3.1.1 Czech stock market regulation

Czech financial regulation stems from legal background of Czech National Bank and legislative act from 2004, specifying conditions for stock markets. The core one is from act 6/1993 – Czech National Bank act, which sets up whole jurisdiction and rights of central bank. As we might expect, it is not very descriptive of capital markets because it sets up central bank as a regulatory body with its typical rights and obligations. Thus, the main source for legislation connected to it is the law from 2004 – Act on Capital Markets (Zákon o podnikání na kapitálovém trhu). This act sets boundaries for those who seek out investment, want to invest, run the exchange, and oversee the regulation of capital market. It will provide the bulk of regulation of the stock market coming from Czech legal code.

Firstly, the Act on Capital Markets is setting up necessary terminology, involved parties and objects of trade. More specifically, this act divides the customers into two types – professional and not professional. Professional customers are the large players on the stock market such as banks, investments funds and individuals, whose main source of income is from trading on stock market(*Act on Capital Markets*, §2a–d, 2004). In addition to the professional customers, any individual with sufficient knowledge and finances can trade. After setting up who can trade, the law sets up the objects of trade – bonds, stocks commodities, derivatives etc (*Act on Capital Markets*, §3, 2004).

Next, the act deals with companies, that mediate trading. These are companies, that invite us to open a trading account on their site and assist us with trading. The law demands that mediators have suitable corporate form, have their headquarters located in Czech Republic, sufficient starting capital, comply with oversight of Czech National bank, form a sound business plan and scope of operations within the Czech market. Moreover, they must set up its trading rules in accordance with law and have to immediately report any change, that would cause removal of its license (*Act on Capital Markets*, §6a–e, 2004).

It is further specified if they are systemically relevant company. It is the case for companies that offer loans in addition to its market activities and is subject to further restriction. Specifically, it must not have lower capital than average stress value at risk for last 60 trading days. Failure to comply with this regulation will cause a removal of license. Additionally, Czech National bank may take away its right to trade if central bank deems it necessary to solve financial crisis (*Act on Capital Markets*, §6b, 2004).

The company is obliged to put in place strategies to measure and deal with risks associated with the type of business, especially those that are relevant for the financial market. It is required to have a department focused on its measurement and resolution. Moreover, it is obliged to keep inventory of all traded financial instruments. Furthermore, they must do their best to prevent loss of the property of the customer. Czech National bank also keeps oversight of all bonuses and rewards paid by the company to its employees and leadership. Thus, if company is receiving public money as a support in times of crisis, it cannot pay any bonuses to its leadership and limits the variable component of wages. The company must establish mechanism to report any unlawful activities happening on the market. Lastly, trade mediating company is obliged to gather necessary information about the customers and recommend appropriate approach for him. The trader must comply with the customer´s orders and act in his best interest (*Act on Capital Markets*, §6a–e, 2004).

There is a separate set of rules for the organizer of the regulated market. The organizer must set up the rules for trading in accordance with law, monitor possible negative impacts of trades on its market, manage its risks and oversee, whether all parties comply with the rules. Whenever a significant breach of rules or any event deemed important happens in the market, he must immediately report it to Czech national bank. These events include failure to comply with the information transparency rules by any party or some technical issue in the trading system.

Additionally, he must inform Czech National bank about is profitability and the content of its contracts, and all its trading parties, conditions and trading results necessary for oversight. This required information are specified later in the EU market regulation section. Lastly, he must be ready to stop the trading in case of severe adverse conditions (*Act on Capital Markets*, §55–73, 2004).

Next, there are rules that specify trading on the Czech financial markets. Each traded instrument must have its international identification number and it needs to be freely tradeable. Moreover, it does not require the consent of issuer to be traded there, if that case happens, issuer needs to be informed and he does not have to fulfill its information obligations towards the traders. Organizer of the trading platform cannot cancel any specific trades, as it would compromise trust in his operations. Moreover, a mistake in closing the deal does not make the deal irrelevant. Unless it would threaten the interests of investors or the stability of the market, organizer has the right to remove the traded stocks, if they do not fulfill some of its obligations. This action must be reported to Czech National bank. Organizer is obliged to set up clear and transparent rules for trading. additionally, the entry to the market for investors is set up as any person with sufficient knowledge and finance can enter the market. It implies low bar of entry for anyone willing to start trading (*Act on Capital Markets*, §73d–m, 2004).

Last relevant part of this act are rules specific for stock market. Organizer has freedom to set up rules in accordance with the Act on Capital Markets. If he wants to offer a stock for trading, its price multiplied by volume must reach at least million of Euro. Issuer of the stock must publish its annual reports for at least last 3 consecutive years. There cannot be any limit to its tradability. At least 25% of stocks of traded company are obliged be in possession of the public of European union, or there must be no doubt about its tradability. There also must be no information known by organizer of the market, about a possibility of harm caused by trading this stock to an investor. After any party requests its stock to be traded on the stock market, organizer as to respond in 6 months of his request (*Act on Capital Markets*, §73d–m, 2004).

3.1.2 European Stock market regulation

European market regulations fall mainly under ESMA – European Securities and Market Authority. The task of ESMA is to monitor all financial instruments traded in EU and in case of necessity, ESMA can prohibit a trading of instrument, or to prohibit the type of activity altogether. There are twelve regulatory acts regarding the European stock markets. Following is a brief overview of their content and usefulness for this thesis.

CRAR, which focuses on guidelines of credit rating agencies (*CRAR*, Article 1–2, 2009). The regulation is set upon the European Union´s legal act Regulation No 1060/2009. This norm allows ESMA to certificate and oversee rating agencies (*CRAR*, Article 5, 2009). Thus, no rating agency can operate without a consent from ESMA. The rules that the rating agencies are subject to are not strict. The most notable is need for consistency and system in their rating approaches and methodology (*CRAR*, Article 8, 2009). Last significant regulation for credit rating agencies forces them to make their methodology and results available in ESMA´s central repository (*CRAR*, Article 11, 2009).

UCITS sets up rules for collective investment (*UCITS*, Article 1–2, 2009). The scope of UCITS regulation is not relevant for this thesis, thus it will not be discussed further.

Prospectus regulation act sets up rules for forming prospects that are available, when stock of a company is offered to the public (*Prospectus Regulation*, Article 1, 2017). The right is coming from legal act Regulation 2017/1129. The core of Prospectus Regulation lies in key information – what information must be published when company is going public. The information is provided in great legal detail, but for our purposes, it can be best described as any information relevant to potential investor must be included (*Prospectus Regulation*, Article 7, 2017).

Transparency directive forms rules of providing periodic information to the investors, stemming from Directive 2004/109/EC (*Transparency directive*, Article 1, 2004). Transparency directive regulation is a principal regulation for stock markets in European Union. First and most important is a rule that every company listed on stock exchange market must publish its annual reports. The company has 6 months to do so after the end of that year. The report must include key financial indicators and management report (*Transparency directive*, Article 4, 2004). The information duties are going both ways. Investor must notify the company, which shares he acquired, if his voting power reaches any of the thresholds: 5 %, 10 %, 15 %, 20 %, 25 %, 30 %, 50 % and 75 % of the total votes available (*Transparency directive*, Article 9, 2004).

CSDR is based on Regulation (EU) No. 909/2014 and provides information about settlement of financial instruments within the union (*CSDR*, Article 1, 2014). Firstly, CSDR regulation gives ESMA a duty to establish an oversight system for each securities settlement system (*CSDR*, Article 7, 2014). Moreover, the relevant authorities for CSDR regulation are kept by ESMA. For the Czech Republic, the relevant authority is Czech National bank (*CSDR*, Article 12, 2014). CSDR regulation continues to deal with legal necessities about settlement of transactions (*CSDR*, Article 17–37, 2014), which are not relevant for this study. On the contrary, it is obligatory for trading platforms to keep capital requirements to sustain operational, legal, and business risks at central banks (*CSDR*, Article 45–47, 2014). It forces market operators to be responsible for non–systemic risks associated with their business.

Benchmark regulation provides framework how to ensure standards and accuracy of benchmark in accordance with Regulation (EU) 2016/1011 (*Benchmark Regulation*, Article 1, 2016). To briefly summarize this regulation, any party intending to provide benchmarking services must use valid data for the examination and be transparent about their methodology (*Benchmark Regulation*, Article 11 & 13, 2016). Moreover, there is mandatory record–keeping and management of conflict of interest, among other, less relevant requirements (*Benchmark Regulation*, Article 15, 2016).

SECR provides general framework for securitization. SECR draws its legal power from Regulation (EU) 2017/2402 (*SECR*, Article 1, 2017). Securitization and risk mitigation techniques are not a focus of this thesis, so they will not be discussed here.

SSR adjust rules for financial instruments, derivatives and debt instruments and their trading (*SSR*, Article 1, 2012). These rules are coming from Regulation (EU) No. 236/2012. There is mostly legal framework for trading, there is a single important clause. If a liquid share´s value is dropped by more than 10% in a single day, its short position selling might be forbidden (*SSR*, Article 23, 2012). For the purpose of SSR, a liquid share is considered a share that has free float of more than 500 EUR million and more than 500 trades a day or daily turnover higher than 2 EUR million (*Commission Regulation (EC) No 1287/2006*, Article 22).

EMIR sets up rules for bilateral derivative contracts and their reporting duties, compatible with Regulation (EU) No 648/2012 (*EMIR*, Article 1, 2012). Initially, the regulation focuses on general legal clearing requirements: parties involved, contracts between them in order to ensure the fulfilment of contracts between all parties (*EMIR*, Article 4–6, 2012). Moreover, the legislation forces trading venues to have transparent and non–discriminatory access to them. It also allows them to apply fees for their services (*EMIR*, Article 8, 2012). Due to the default risk, trading platforms are obliged

to keep robust risk mitigation techniques (*EMIR*, Article 11, 2012). Moreover, they are obliged to keep available capital of at least 7.5 EUR million (*EMIR*, Article 16, 2012). Trading platforms are required to keep margins, that will cover 99% of the transactions over reasonable period (*EMIR*, Article 41, 2012). It leaves them a large room for interpretation and what they deem necessary according to their own models and estimates. Mediators of trade are obliged to establish and maintain default fund, that allows them to survive in catastrophic, but plausible market conditions (*EMIR*, Article 42, 2012). Moreover, this trade mediating platform has to keep up its liquidity to be able to service its customers at all times. Furthermore, there can be no source of liquidity that would provide more than 25% of it (*EMIR*, Article 42, 2012).

SFTR updates rules for transparency in accordance to Regulation (EU) 2015/2365 (*SFTR*, Article 1, 2015). It focuses on securities financing transactions. The core of SFTR focus is transparency and trade repositories that must keep records and inform supervisors (*SFTR*, Article 4–12, 2015).

Lastly, there are two more complex directives, that will be further discussed. MIFIR and MIFID II. The legal background for these regulations is Regulation (EU) 600/2014 and Directive 2014/65/EU respectively. Both directives are more complex and discuss multiple issues. The older one, MIFIR, is covering the data transparency, reporting transactions to the authorities, trading of derivatives on organized market, non–discriminatory access to clearing and trading, product intervention powers of authorities, authorization, and data reporting of service providers (*MIFIR*, Article 1, 2014). First regulation of MIFIR is concerning formation of waivers, which is a situation when financial instrument could be except from certain rules (*MIFIR*, Article 3–7, 2014). Next regulation is about records of transactions for investment firms. They are obliged to report names, number and quantity of financial instruments that are either bought or sold, clients, price and time of sale (*MIFIR*, Article 26, 2014). Moreover, they are obliged to supply ESMA with reference data about the traded financial instruments (*MIFIR*, Article 27, 2014).

The last one, MIFID II, focuses more on investment firms and cooperation and authorization for supervisors across European stock markets. Therefore, as we can see, the main source of regulation for stock markets is the transparency and access for interested parties without any obstacles (*MIFID II*, Article 1, 2014). The initial aim of MIFID II is to set up coherent process of providing licenses for investment firms. The investment firm must provide program of operations, planned type of business, organizational structure and all information that might be relevant for authorities to consider their application. The authorities are obliged to deny or approve the request

within a six–month period (*MIFID II*, Article 7, 2014). Moreover, if any party seeks to acquire a share in investment firm, that would surpass 20%, 30% or 50%, the party has to notify authorities of its intent. Authorities have to authorize this acquisition and they have 60 days to do so (*MIFID II*, Article 11–12, 2014). Furthermore, it gives investment firms a duty to always act in the best interest of their clients (*MIFID II*, Article 27, 2014). If investment firm suspects take over bid, nondisclosure of inside information or market abuse it can stop trading of the instrument. In this case, it must inform authorities of its decision and provide reasoning for its decision (*MIFID II*, Article 32 & 52, 2014). Lastly, it sets limits to net sizes of open positions for individual parties in agricultural and other crucial commodities, in order to prevent market abuse *(MIFID II*, Article 57, 2014).

3.2 Banking regulation

Banking regulation is a field of economics that has been developing for more than 150 years. Thus, it is very broad and complex topic, which is beyond a scope of this thesis to comprehend and describe. As this thesis is focusing on applying game theory and comparing bank runs with stock market crashes, it is only logical that it will solely focus on single regulatory field in banking –Liquidity risk.

Banking history is considered to have begun by US national banking acts of 1863 and 1864 (Rockoff 1974). With its more than 150 years of history, it has grown into a massive bulk of laws and regulations. In recent times, the most notable driver of regulation has been Bank for International Settlements located in Basel, Switzerland. Thus proposed regulatory standards coming from BIS are called Basel I – III with the oldest Basel I being from 1988 and latest Basel III from 2014, formed as a reaction to 2007–2008 financial crisis (History of the Basel Committee 2014).

3.2.1 Liquidity risk

Need for liquidity regulation has arisen from 2007–2008 financial crisis, when banks had enough regulatory capital, but experienced difficult times due to lack of liquid capital in these adverse times. Thus, one of Basel III goals is to improve liquidity resilience in banking sector. It is done by two main tools of liquidity regulation with goal of ensuring bank´s survival under adverse conditions. These two tools are Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR). LCR guarantees short term resilience over period of 30 days and NSFR is focused on longer time period of more than a year (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.7).

3.2.2 Liquidity Coverage Ratio

As written previously, the main aim of LCR is to ensure bank´s resilience to short time shocks. It is done by forcing banks to keep sufficient High Quality Liquid Assets (HQLA), that they survive stress scenarios for 30 days (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.10).

There is a small issue for supervisors in implementing LCR in their jurisdictions. They need to consider broader context of economy when banks might use HQLAs to obtain more liquidity. For when banks begin to sell these assets, it might cause further damage and increase speed of deterioration of economic health. Thus, there are following recommendations in place.

- Supervisors should observe the situation as early as possible and act if needed
- There should be more ways, how to respond to bank´s LCR getting below 100%
- They need to investigate the drop in LCR with regards to macroeconomic situation and bank´s overall health
- Supervisors should have prepared tools to address the drop in LCR
- Their response to LCR needs to be synchronised with further macroprudential policy

When authorities test LCR, they usually expect reduction in bank´s deposits, loss of unsecured and partial loss of secured funding capacity, outflows caused by bank´s loss of credit rating by three notches, increase in market volatility, unscheduled draws on promised credit and liquidity and need to buy back debt in order to improve reputation in their test's scenarios. It is done in order to simulate conditions of 2007–2008 financial crisis, when otherwise healthy banks experienced liquidity issues, and thus promote resilience.

To compute bank´s LCR, there are only two inputs required. Stock of HQLA and expected Total Net Cash Outflows. These regulations demand banks to fulfil that the HQLA divided by Total Net Cash Outflows must be larger than 100% at all times.

To put it more simply, bank must have more HQLA than expected Total Net Cash Outflows, that might arise under stress scenario. It makes bank always prepared on adverse economic situation in terms of liquidity and magnitude of stress scenario.

Now, it is important to discuss each component of LCR equation in order to determine what assets can be used as HQLA and how large might be expected outflows (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.12).

3.2.3 HQLA

First and foremost, quality of assets that might be used to cover the need of LCR regulation is that they are unencumbered. It implies no restrictions on its trading. Moreover, the key principle behind these assets is that they can be liquidated for cash very easily at very little loss, in short time. Fundamentally, these assets should exhibit low risk. It will provide their good tradability in time of financial distress and lower loss in their sale. In order to easily sell them, these assets should be easily valued. Easily valued assets provide easier access to buyers on wider markets. Additionally, it is advised to avoid assets with high correlation to risky assets and that the assets used as HQLA stock are listed on well developed stock markets with wide array of participants (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.13).

Furthermore, assets for HQLA should have low volatility and low spread historically. It should be considered as high–quality asset by the market as historical data show market´s movement towards high quality assets in times of financial distress. Liquidity of an asset can be tested by sale or repo operations, but if the asset is eligible for central bank´s intraday operations, it cements it liquid status (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.14).

It is also recommended to keep these assets in separate pool as they cannot be used for any other regulatory means (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.15). It is due to the fact that bank has to exclude assets that in HQLA, which if sold might cause bank to not be compliant in other regulation. HQLA can be used for hedging, but bank must account for all possible outflows. Additionally, physical locations and legal entities holding them are obliged to be monitored by bank. Assets do not have to have access to the market but the entity holding them must prove ability to liquidate them (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.16).

Lastly, LCR requirements are fulfilled in single currency, but banks should be able to satisfy HQLA in any currency they trade in. If any assets become not eligible to be classified as HQLA, banks have 30–day period to hold them as a part of HQLA portfolio but must be replaced after that. It is strongly recommended to keep HQLA

portfolio diversified as a single asset is prone to become illiquid in times of crisis (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.17).

HQLA portfolio assets should be divided into three levels according to their quality. Level 1 assets are considered the best assets for liquidity and should comprise at least 60% of HQLA bucket. Level 2 assets are more volatile and thus can only fill up to 40% of HQLA portfolio. Lasty, level 2B assets are very volatile and can only be 15% of whole portfolio and sum of level 2 and level 2B assets cannot be more than 40% (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.17).

Level 1 HQLA assets are the best for liquidity needs of bank. Thus, they can be cash held in HQLA portfolio. It is costly for bank, as the cash is not generating any profit and is just held for regulatory purpose. Another instrument that fits into level 1 category are central bank reserves. Their value is limited to what central bank allows to draw in time of financial distress. Last part used in level 1 HQLA category are securities. Specifically, securities of sovereigns or international monetary institutions that are traded in large and have proven to be liquid. Furthermore, these securities must be only assigned 0% credit risk. Any deterioration of credit worthiness of securities would cause its drop to level 2 HQLA assets (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.18).

Level 2 HQLA assets are generally more volatile. Thus, to prevent unexpected reduction in their value in time of need for bank, 15% haircut is applied. Level 2 assets are either sovereign securities with up to 20% credit risk weight or corporate bonds with higher rating than AA-. Furthermore, the corporate bonds must not be affiliated with bank. It removes an option when bank would use bonds of one of other companies held by the same banking group as a source of HQLA. There is the standard requirement on both of these instruments to be traded in well established markets and thus have large possibility of buyers, when needed (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.19).

Last category of assets, Level 2B consists of either residential mortgage–backed securities, corporate debt securities or common equity shares. These instruments are considered to be more volatile, so they are generally subject to higher haircut. Residential mortgage–backed securities must take 25% haircut. Furthermore, they are not connected to the bank, they have rating of AA or higher and are traded in large markets. There is generally a low level of concentration of these assets on the market, with no more than 20% of price shift over a 30–day period. Moreover, they must have at least 80% loan to value ratio and must be subject to risk retention. Lastly, it is important that their historical data show high level of liquidity in the past (Basel III:

The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.20). Corporate debt securities are subject to 50% haircut and must be traded in well established markets. Moreover, there can be more than 20% change in their price over 30–day period, in order to ensure stability and their rating must be between A+ and BBB-. Last option for level 2B is common equity shares. They must be traded on exchange market with centralised clearing and must not be affiliated to bank. It means that bank cannot use stocks of another company in its holding as common equity for HQLA. Moreover, these stocks must be part of major stock index and must be denominated in bank´s home currency. The must have reputation of reliability in times of financial distress and cannot fluctuate by more than 40% over 30–day period (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.21).

There are alternative solutions for a bank to its lack of HQLA. Central bank might offer to supply liquidity to a bank, foreign currency HQLA might be used as substitute for lack of domestic HQLA or supervisor might allow larger portions of Level 2 assets in the portfolio (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p. 22–24).

3.2.4 Total net cash outflows

Total net cash outflows are considered expected cash outflows subtracted by expected cash inflows over 30–day period. Moreover, total cash inflows are capped at 75% of cash outflows, forcing bank to always keep some assets for liquidity purposes. Cash outflows are composed of expected decline in retail deposits, unsecured funding run off. Cash inflow consist only of contractual inflows, where is no expectation of default within 30–day period (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p. 26).

To calculate cash outflows, we must delve deeper into each category. Firstly, retail deposits are divided into stable and volatile. For stable deposits, which are fully insured deposits, there is generally used 5% run–off rate. If the insurance company, which is insuring deposits, has tools available to obtain more cash in case of financial distress, 3% rate might be applied to these deposits. Speaking about volatile deposits, which are all other deposits, they must receive minimum run–off rate of 10% (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.27).

Moving on to the funding run–off, it is divided into unsecured and secured. Funding is considered as obligations towards legal entities, and they can be secured by collateral. Furthermore, only funding callable within 30–day period or funding that reaches maturity in next 30–day period is considered here. First category of unsecured

funding is provided by small business. It is considered stable with 5% rate if it is insured and unstable with 10+% rate if uninsured (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.29). Next are operational deposits, that obtain 25% rate (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.31). Moving onto deposits at other banks, they receive treatment of 25% if placed in central bank, or 100% if placed in other banks. Funding from non–financial corporates, sovereigns and international monetary institutions obtains 20% rate if secured by insurance, or 40% if unsecured (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p. 32–33). Funding from all other legal entities are treated by 100% rate (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p. 32).

Secured funding runoff is dependent on the collateral. If is backed by level 1 assets or with central banks, it obtains 0% rate. When backed by level 2 assets, it obtains 15% rate. Residential mortgage–backed securities and securities with claims against domestic sovereign or international monetary institution with credit risk up to 20% are treated with 25%. Backing by level 2B assets requires 50% and all other assets obtain 100% rate (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.34).

3.2.5 Cash Inflows

Cash inflows are capped at 75% of cash outflows in order to force bank to keep liquid assets at their disposal at all times (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p. 40). First and largest source of inflows are loans. Uncollateralized loans automatically receive 0% rate, so only collateralized will be discussed. Their rate depends on collateral. Level 1 collateral assumes 0% inflow rate and level 2 assumes 15% inflow. Residential mortgage–backed securities provide 25% inflow. All other level 2B assets and margin lending backed by other collateral provide 50% inflow. Other collateral provides 100% inflow. The low rate for high quality collateral is due to assumption of roll over in time of maturity (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.41). Moreover, all committed facilities receive 0% inflow rate. Retail and business inflows are estimated at 50 % due to rollover. On the contrary, 0% inflows are assumed from other financial institutions (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p. 42).

3.2.6 Monitoring tools of LCR

There are 5 tool categories used for monitoring LCR. Those are Contractual maturity mismatch, Concentration of funding, Available unencumbered assets, LCR by

significant currency and Market related monitoring tools (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p. 46).

Contractual maturity mismatch is considered as a difference between cash inflows and outflows in respective time periods. Goal of the difference between inflows and outflows is to map difference in maturities for every time period and show possible discrepancies that might appear to disadvantage of a bank. There are no rollovers assumed and banks should provide raw data to the supervisors. The supervisors choose time bands, in which the data should be reported (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.46–47).

Concentration of funding report´s main goal to show how well diversified the funding and liabilities are. First report is showing percentage of all funding from each significant counterparty. Significant counterparty is a counterparty that provides at least 1% of all funding to a bank. Secondly, percentage of all liabilities to each type of instrument. Any insignificant instruments, which have less than 1% of all liabilities, do not have to be reported. Lastly, all assets and liabilities in each currency, which comprises more than 5% of all liabilities must be reported (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.48–49). It helps supervisors to monitor risk to a single counterparty, instrument or currency.

There is an obligation for banks to report a location, type and amount of unencumbered assets that can be marketed as collateral or are eligible for central bank´s standing facilities (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.50). Furthermore, for foreign currency, in which more than 5% liabilities are denominated, LCR has to be reported and as calculated as simple HQLA in foreign currency over total net cash outflow in each significant currency over 30–day period (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p.51). Lastly, supervisors should monitor market wide information, with a focus on financial sector. Furthermore, they should monitor specific position of a bank in order to obtain complete picture and determine overall health of bank (Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools 2013, p. 52).

3.2.7 Net Stable Funding Ratio

Goal of NSFR is to ensure stable funding ratio compared to bank´s assets. Its stable funding structure should improve bank´s resilience towards disruptions and ensure its survival in times of financial distress. The NSFR limits overreliance on short–term wholesale funding, encourages better assessment of funding risk across all on– and off–balance sheet items, any by doing so, improves stability of banking sector. It is

calculated as (Available amount of stable funding) / (Required amount of stable funding) ≥100%, forcing bank to keep their funding healthy in order to prevent liquidity and maturity issues.

Maturity transformation is one of the crucial functions of banks, that improves efficient allocation of resources. NSFR´s goal is to provide incentives to reduce reliance on unstable funding assets. Furthermore, it should reduce its reliance on cheap unreliable wholesale funding in times of bank´s expansion. This expansion can weaken bank´s ability to respond to liquidity shocks and it might cause systemic weakening of highly interconnected banking sector (Basel III: The Net Stable Funding Ratio 2014, p. 5–6).

The amounts of available and required stable funding specified in the standard are calibrated to reflect the presumed degree of stability of liabilities and liquidity of assets. Calibration of liabilities happens across two dimensions – "Funding tenor" – it describes that longer liabilities are usually less risky than short term ones and "Funding type and counterparty" – which implies that short term retail deposits from individuals and small businesses are more stable than alternative short term funding options. Furthermore, there are 4 criteria, by which the fundings are measured (Basel III: The Net Stable Funding Ratio 2014, p. 7).

- **Resilient credit creation** – The NSFR requires stable funding for some proportion of lending to the real economy to ensure the continuity of this type of intermediation

- **Bank behaviour** – The NSFR is calibrated under the assumption that banks may seek to roll over a significant proportion of maturing loans to preserve customer relationships

- **Asset tenor** – The NSFR assumes that some short–dated assets (maturing in less than one year) require a smaller proportion of stable funding because banks would be able to allow some proportion of those assets to mature instead of rolling them over

- **Asset quality and liquidity value** – The NSFR assumes that unencumbered, high–quality assets that can be securitised or traded, and thus can be readily used as collateral to secure additional funding or sold in the market, do not need to be wholly financed with stable funding

Stable funding is divided into five categories and each category obtains weight. To obtain available stable funding, we multiply all assets by their respective weight and then sum them (Basel III: The Net Stable Funding Ratio 2014, p. 7). First category are

liabilities with 100% weight and capital. It is mostly regulatory capital and all capital instruments with maturity larger than 1 year. Instruments with options must be excluded, as the option might be used to remove funding before its maturity. Furthermore, secured and unsecured borrowing also fits into the first category if it has maturity larger than 1 year (Basel III: The Net Stable Funding Ratio 2014, p. 8). Next level are liabilities with 95% weight rate. Those are mostly deposits from individuals and small businesses with maturity under 1 year. These deposits tend to be very stable and are unlikely to be affected by shocks. Slightly less stable are non–maturity deposits and term deposits with residual maturities of less than 1 year provided by retail and small business owners. They receive 90% weight factor. Moving onto a category of unreliable funding, there are firstly liabilities to non–financial corporates with maturity smaller than 1–year, operational deposits and funding from sovereigns, public sector entities and all other funding with maturity between 6 months and a year. All these liabilities are so volatile that they receive factor of 50%. Final category are completely unreliable liabilities with 0% weight. That implies that these liabilities are completely unreliable regarding stable funding. Into the final category all other equities and financial instruments fit (Basel III: The Net Stable Funding Ratio 2014, p. 9–10).

Now it is important to discuss the other variable in the NSFR equation – required stable funding. It measures the asset´s side requirement for funding. Each banking asset and off– balance sheet exposure obtains required stable funding (RSF) factor, which should provide aggregate need of funding for the asset. It is crucial not to forget off–balance sheet items as they might cause shocks in short term, especially regarding liquidity. The best example for RSF factor might be difference between cash and bank loans. Cash is bank´s asset that does not need any funding as it contains no risk. On the other hand, loans that bank provide might need some adjustment and require funding to operate. Thus, to calculate required stable funding of bank´s entire asset side, it needs to multiply each asset by its RSF factor and sum the results. If available stable funding is larger than required, bank fulfils the regulation. On the other hand, drop in NSFR signals potential problems (Basel III: The Net Stable Funding Ratio 2014, p. 10–11).

We will now discuss the different categories and their respective RSF factors. Riskless types are only three: Cash, central bank reserves and claims on central bank with maturity smaller than 6 months. These assets are readily available and do not require any funding (Basel III: The Net Stable Funding Ratio 2014, p. 12). Another asset class are those with assigned 5% factor. These assets are central bank reserves. Assets with 10% risk factor are unencumbered loans to financial institutions with residual maturities of less than six months, where the loan is secured against sovereign bonds or other LCR level 1 assets. Next class of assets obtains 15% RSF factor weight. These

are either marketable securities with claims against sovereigns or international financial institutions with up to 20% credit risk weight, corporate debt securities with rating better than AA- or other unencumbered loans to financial institutions with maturity under 6 months.

Moving onto riskier asset classes, there are assets with 50% assigned RSF factor. These are residential mortgage–backed securities with credit rating of AA or better, corporate debt securities with rating between A+ and BBB- and common equity, not affiliated with bank or banking group. Moreover, all HQLA that are encumbered for 6–12 months, loans to financial institutions with maturity 6–12 months and all other assets with maturity lower than 1 year (p.13, Basel III: the Net Stable Funding Ratio, 2014). 65% risk factor is assigned to all unencumbered residential mortgages ad other unencumbered loans with maturity of 1+ years with credit risk 35% or lower. Another asset class assigns 85% RSF factor are cash, securities or assets used as initial margin for derivatives or that contribute to default fund. Furthermore, there are unencumbered performing loans that were not already mentioned previously, unencumbered securities with maturity of 1+ years, that are not HQLA assets and physically traded commodities like gold. Lastly, there are assets with 100% RSF factor, which are all the other assets, most notably assets encumbered for more than a year (Basel III: The Net Stable Funding Ratio 2014, p. 14–15).

Off balance sheet exposures, that are irrevocable and conditionally revocable and promise to provide liquidity or credit to a client receive 5% RSF rating (Basel III: The Net Stable Funding Ratio 2014, p. 16).

3.2.8 Reporting

Commission Implementing Regulation (EU) 2016/322 Commision Implementing Regulation (EU) 2016/322 sets up format of the liquidity report and its frequency. Banks are obliged to report liquidity periodically on monthly basis on the 30th day of the month (Commission Implementing Regulation (EU) 2016/322 of 10 February 2016, Article 1). They are reporting the following data: Liquid assets and their structure on all levels, cash outflows and cash inflows, collateral swaps and derivatives, and lastly, calculate desired ratios that describe liquidity status of bank on many levels (Commission Implementing Regulation (EU) 2016/322 of 10 February 2016, Annex 1). It is further updated by Commission Implementing Regulation (EU) 2021/451, which further updates specific data to report.

3.2.9 Comparison of regulation

From stock market regulation section, we can see that the level of regulation heavily depends on the type of participant we are. If we are an investment firm, we must fulfil a plethora of rules and laws to ensure healthy competition and as small barriers to enter as possible. As an investor, most of the laws work in our favour as we are the one experiencing risk that we do not manage. For companies seeking investment, they are obliged to inform market as transparently as possible to prevent misinformation and bubble creation. While banking sector is directly monitored by central banks, stock market is firstly monitored by market organizer, who then reports sufficiently large irregularities to supervisor of the entire economy.

On the other hand, banking sector is one of the most regulated industries in developed economies. Its regulation has made some great advances in prevention of liquidity issues for banks and to solve systemic threat posed by lack of liquidity. Through simple and consistent instruments, banks are obliged to inform central banks of their health and ability to respond to arising problems. Banks must obtain sufficient profitability in order to fund all the regulatory standards, which are costly. Thus, banks have been forced to reduce risk and profitability due to need for economic stability of the entire economy.

If we investigate comparison of bank runs and stock market crashes, stocks markets have in place approach that immediately react to the adverse situation – they simply stop trading with instrument or their multitude if they experience too big drop in price. Compared to them, banks are more susceptible to bank runs. They are obliged to be ready for possible run and must prepare portfolio that they will liquidate if the need arises. By burning through its portfolio, they buy time for supervisor to decide about the health of bank and whether it must be saved or must default. On the contrary, they also inform depositors that they are experiencing liquidity issues, further exacerbating the panic. The supervisory response is much slower as the quickest way to halt a bank run is through quantitative easing, which is very controversial step to take. So, this combination of factors makes bank run much more dangerous scenario for economy than fall of stock on market.

4 Model & Adaptation

For the determination of the value of shock, that would trigger the collapse of the Prague Stock Exchange, this thesis will adapt model introduced by Ziegler (2004). Ziegler´s model describes calculation procedure to estimate the equity value, which would trigger a bank run. It applies game theory and pricing of options to reach its result. This chapter will discuss this theoretical model and its adjustment for stock market. Moreover, it will compare the assumptions and derive theoretical limitations of the new model.

4.1 Bank run model

Ziegler´s model relies on the following data for its calculations:

1. bank´s asset value **S**;
2. standard deviation of the asset value **σ**;
3. initial capital provided at the start **x**;
4. face value of deposits **X(t)**;
5. risk free interest rate **r**;
6. interest paid on deposits **r***;
7. proportional liquidation cost in case of run **α**;
8. proportional liquidation costs if no run occurs **β**.

Firstly, we begin with two depositors, A & B. Each one deposits X_0 at the time of bank formation t=0. Then for each unit of currency, equity holders add x≥0 units of capital. Bank invests this money into assets with initial price $S_0=X_0$. The value of these assets follows the Brownian motion.

$$dS_t = \mu S_t dt + \sigma S_t dB_t \tag{1.1}$$

It means that at the time t, the value of bank´s assets is 2(1+x) S_t. Moreover, the evolution of the individual´s deposit is $X(t) = X_0 e^{r^*t}$, where r* is the interest paid by the bank to the depositor and X_0 is the initial deposit.

The core of the model arises from the decision when to withdraw, which is done by the depositors. When the bank´s assets are diminishing, there is not enough money for both depositors to withdraw their full deposits. Thus, first one to withdraw will get

$$\min[2(1-\alpha)(1+x)S_t, X(t)]. \tag{1.2}$$

The implication of this equation is that the depositor either obtains the value of bank´s assets, which are discounted by liquidation (1-α), or the value of deposit, if the bank´s assets are sufficient. Thus, the second to withdraw is obtaining

$$\max[0,2(1-\alpha)(1+x)S_t - X(t)]. \tag{1.3}$$

This has the similar logic as the second depositor either obtains remainder of bank´s assets, or nothing, because there is nothing left.

So, it can be easily seen, that in this model, depositors are incentivized to be the first one to withdraw, when there are signs of failure of the bank. This creates the possibility of bank runs in this model.

Moreover, these situational decisions arise, when

$$S_t < \frac{X(t)}{(1-\alpha)(1+x)}. \tag{1.4}$$

This equation implies that the risk of bank run arises, when the value of liquidated bank assets is lower than its discounted deposits, bolstered by equity.

Thus initially, the levels of α and x have to be large enough, that the

$$S_t \geq \frac{X(t)}{(1-\alpha)(1+x)} = \bar{S_t}. \tag{1.5}$$

If the condition was not met, the depositors would be irrational in their decision to give their money to banks. By rewriting the initial conditions, we arrive at

$$x > \frac{\alpha}{1-\alpha}. \tag{1.6}$$

Now, we move onto deriving the formula for the asset value triggering the bank run. It is important to discuss three major assumptions for this derivation.

Assumption 1.1 When the bank run happens, it happens immediately, and equity holders are unable to recapitalize bank.

Assumption 1.2 As son as (1.4) condition is met, the bank run occurs, and bank must be liquidated.

Assumption 1.3 Banks can liquidate the project at the cost of β, when bank run is not happening. β is smaller than α.

The bank has down–and–out call option on liquidating assets with varying price of deposits and knockout price. For the final calculation, it is necessary to define the following.

Knockout price is determined by

$$K(t) = \frac{1-\beta}{1-\alpha} X(t).$$

The perpetual value of call option

$$C_\infty((1+x)(1-\beta)S_t, K(t))$$

represents value of bank´s equity, when depositors choose to withdraw.

Thus the bank´s equity value when the depositors choose to run on the bank is

$$C_\infty = (1-\beta)(1+x)(S_t - \bar{S_t}(\frac{S_t}{\bar{S_t}})^{-\gamma*})$$

which gives the value of bank´s equity, which would make depositors consider bank run. It is asset value of net liquidation costs, minus the expected losses resulting from the run, which are equal to the discount resulting from the knock–out feature of the option.

4.2 Terminal debt ratio model

This part of the thesis will adapt Ziegler´s model to fit the needs of the stock market while using the same approach. It will start by the same step of defining the values used for calculations and their meaning:

1. company´s asset value **S**;
2. standard deviation of the stock value **σ**;
3. bank loans for each unit of capital invested **x**;
4. face value of investment **X(t)**;
5. risk free interest rate **r***;
6. interest paid on investment **r**;
7. proportional liquidation cost in case of panic sale **α**;
8. proportional liquidation costs if no panic sale occurs **β**;
9. Discount caused by first sale **δ**.

There are additional assumptions that must be made. Firstly, we must consider interest rate differential as r-r*, as investors obtain larger than r* returns usually. So, compared to the initial bank run model proposed by Ziegler (2004), there is a change in notation. Moreover, it needs to be assumed that the company´s asset value follows the shocks to the company´s stock value. Furthermore, there is an added discount, which will symbolize market´s reaction to sale and will cause lower price by δ percent.

We begin with establishment of the company. We denote this establishing period as t_0. Initially, there are two investors, A and B. Each investor invests in the beginning into

a single company. Their investment together forms X_0 capital in the beginning. Then, the company takes on additional unites of debt for each unit of capital denominated as x. Now, we assume that the value of assets of the company follows Brownian motion and the market value of the investment at time t is $X(t) = X_0 e^{r*t}$. That means we assume stable long–term growth for the value of the company and no dividends paid in that time. So, at the time t, the company´s balance sheet looks like this:

Table 4.1: Model Company´s balance sheet

Assets	Liabilities
$(1+x)\ S_t$	X(t) x

Moving on to the decisions available to investors, like the depositors in Ziegler´s model. When there are signs of the crisis and there is a large possibility that the company will be forced to end its operations, first investor can still sell for market value of his investment or wait for liquidation of the company. So, his decision problem can be express as

$$\max[X(t), (1-\alpha)(1+x)S_t - xS_t]. \tag{2.2}$$

Whatever he chooses, it is then multiplied by the percentage of shares he owns, to obtain his payoff. It implies that he can sell stock at full price as the first seller, or wait for liquidation, if he will obtain more by it. As he is a stockholder, he will be receiving only residual claims. On the other hand, investor that sells second can only obtain

$$\max[(1-\delta)X(t), (1-\alpha)(1+x)S_t - xS_t]. \tag{2.2}$$

It is again multiplied by percentage of shares owned by second investor in determining the final payoff. Delta denotes a discount that markets apply, because the first investor already sold, so the demand has been reduced. Thus, as we can see, the indifference point, when investors should not care whether to sell or do not sell is when

$$X(t) = (1-\alpha)(1+x)S_t - xS_t. \tag{2.3}$$

It can be described as stock price being equal to the money obtained from liquidation of the company. Now we express S_t from this equation.

$$\overline{S_t} = S_t = \frac{X(t)}{(1-\alpha-\alpha x)} \tag{2.4}$$

This is the asset value of the company, for which the investor is indifferent to selling first or waiting for liquidation. We will denote this point as $\overline{S_t}$.

Thus if

$$S_t < \frac{X(t)}{(1-\alpha-\alpha x)} \tag{2.5}$$

the investors are incentivized to sell first, and the liquidation is not as beneficial. This situation will thus result in the mass sale of stocks.

Now, it is imperative to form assumptions like Ziegler (2004).

Assumption 2.2 When the condition for panic sale is met, the mass sale of stocks happens immediately and unstoppably, forcing company to be liquidated.

Assumption 2.2 The similar assumption to 1.3 does not have to hold at all times due to the nature of the stock market. As the price of stock is composed of not only the book value but also the expectation of future growth. Expectation of growth is not captured by this model, so there is no set difference between discounts.

Assumption 2.3 Company´s potential of growth and other forward looking, market specific variables remain unchanged.

Under these assumptions, there are two perpetual down–and–out call options, with exercise price of X(t) and asset value of $(1-\alpha)(1+x)S_t - xS_t$ (asset value of option). Now we calculate a knockout price K(t). With these inputs, we can calculate the price of down–and–out call option of the investment. Starting with knockout price, we start from the previously derived condition of being incentivized to sell first when

$$S_t < \frac{X(t)}{(1-\alpha-\alpha x)}. \tag{2.6}$$

Thus, we express this condition in units of $(1-\beta)(1+x)S_t - xS_t$.

$$K(t) = (1-\beta)(1+x)\overline{S_t} - x\overline{S_t} = (1-\beta-\beta x)\frac{X(t)}{(1-\alpha-\alpha x)} = \frac{(1-\beta-\beta x)}{(1-\alpha-\alpha x)}X(t)$$

which is the value of knockout price in this model.

Let $C_\infty((1-\beta)(1+x)S_t - xS_t, K(t))$ denote the value of perpetual down–and–out call option. Detailed approach of this calculation with all additional information can be found in Ingersoll (1987 , p. 371)

Now we assume

$$V = \frac{(1-\beta)(1+x)S_t - xS_t}{X(t)}.$$

And we define

$$F(V) = \frac{C_\infty}{X(t)}.$$

which has to satisfy the ordinary differential equation

$$\frac{1}{2}\sigma^2 V^2 F'' + (r-r^*)VF' - (r-r^*)F = 0. \tag{2.7}$$

Subject to

$$F\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)=0 \tag{2.8}$$

(2.8) is homogenous, linear, second order differential equation, thus all solutions are combinations of V and $V^{-\gamma}$. This implies the solution of

$$F(V)=V-(\frac{1-\beta-\beta x}{1-\alpha-\alpha x})^{1+\gamma^*}V^{-\gamma^*}$$

and

$$\gamma^*=2\frac{r-r^*}{\sigma^2}.$$

This will be substituted back into the equation of

$$C_\infty=F(V)X(t)=VX(t)-\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}X(t)V^{-\gamma^*}.$$

$$C_\infty=\frac{(1-\beta)(1+x)S_t-xS_t}{X(t)}X(t)-\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}X(t)(\frac{(1-\beta)(1+x)S_t-xS_t}{X(t)})^{-\gamma^*}$$

$$C_\infty=(1-\beta)(1+x)S_t-xS_t-\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}((1-\beta)(1+x)S_t-xS_t)^{-\gamma^*}X(t)^{1-\gamma^*}$$

This equation gives the size of company´s debt when the investors might choose to opt for mass sale of stocks. By dividing C_∞ by S_t we obtain the debt to asset ratio, which would trigger the mass sale of the stocks.

Thus, desired ratio is

$$R = \frac{C_\infty}{S_t} = \frac{(1-\beta)(1+x)S_t - xS_t - \left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}((1-\beta)(1+x)S_t - xS_t)^{-\gamma^*}X(t)^{1-\gamma^*}}{S_t}.$$

$$R = (1-\beta)(1+x) - x - \frac{\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}((1-\beta)(1+x)S_t - xS_t)^{-\gamma^*}X(t)^{1-\gamma^*}}{S_t} \quad (4.3)$$

The model provides the debt ratio, for which the companies are in danger of losing value on their stock. Thus, when company reaches terminal level of debt, their stock has increased volatility. If terminal level is met across the markets, it might pose danger to the economy. So, this framework can be used as a warning tool, showing how close a company is to possible mass sale of its stock and subsequent decrease in value.

Terminal debt ratio is a theoretical calculation, which might be limited by the real–world conditions. It focuses mainly on past volatility and book value of the company, so it does not capture the potential of growth of the company. Furthermore, it might happen that β might be larger than 1, due to the nature of stock market. Originally, Beta is assumed to be around 0, so by applying absolute value, we obtain result that will be very compatible with general framework. This problem is solved most easily by applying absolute value on the result. Negative value is not possible and is just skewed by different nature of both markets. Its logic stems from assumption 2.2, which implies a possibility of negative discounts.

Thus in summary, for as long as the value of assets of the company follows Brownian motion, value of investment is assumed to steadily grow over long–term period, the sale of stock causes reduction of demand and price for that stock, and there is nochange in company´s potential of growth or other forward looking, market specific variables, the debt ratio calculated through valuation of options is providing the terminal value for the company´s share of debt. To test terminal debt ratio model further, it will be tested on the data from Prague Stock Exchange in the next chapter, to determine possible limitations of the real stock market to its framework.

5 Prague Stock Exchange Single Company Calculation

In this chapter, we will test terminal debt ratio framework on the companies listed on Prague Stock Exchange separately. Only in the following chapter, we will combine these companies into markets that will be examined by terminal debt ratio.

5.1 Model inputs and their derivation

To apply terminal debt ratio on any company, we will need to obtain the necessary input values into the model. Thus, the following values will be needed:

1. company´s asset value **S**;
2. standard deviation of the stock value **σ**;
3. bank loans for each unit of capital invested **x**;
4. face value of investment **X(t)**;
5. risk free interest rate **r**;
6. interest paid on investment **r***;
7. proportional liquidation cost in case of panic sale **α**;
8. proportional liquidation costs if no panic sale occurs **β**.

Comparing the inputs to the model, it can be observed that the δ is missing. In this case, it is not necessary to obtain precise value. We only need to make a realistic assumption of $\delta>0$, which is one of the key components of the model. While δ satisfies this condition, it forms motivation for investors to be first to sell, as they face potential discounts, if they are latter ones to sell.

Company´s asset value and size of bank loans for each capital invested can be obtained from end of year financial statement of the company. In case we examine markets, the market´s data will be composed of information by individual companies, so we will only need to transform them into market data. Moreover, risk free interest rate, returns on stocks, face value of investment and deviation of stock value will be obtained from Finance Yahoo or any similar source of stock data.

Unluckily, there is no way of general information about the values of α and β. They must be calculated from the model.

To compute α, we will have to go back to the necessary condition of (2.4)

And we obtain

$$\alpha = 1 - \frac{X(t)}{S_t}.$$

Thus, we can see that the value of α is dependent on value of stocks, asset value and share of bank loans.

Additionally, value of α must also fulfil the condition of initial investment

$$S_t < \frac{X(t)}{(1 - \alpha - \alpha x)}.$$

This can be rewritten as $-\alpha(1 + x) < \frac{X(t)}{S_t} - 1$, because S_t and (1-α-αx) are larger than 0. So, we simply multiply it by -1 and apply formula for α . $1 - \frac{X(t)}{S_t}(1 + x) > 1 - \frac{X(t)}{S_t}$ which works as long as share of debt is not negative.

Now we will also need to obtain β. For its derivation, we will rely on Janda and Marek (2022), where they were deriving the value of β for Ziegler (2004) model. They have reached the equation of $\beta = \frac{\gamma^*}{\gamma^* + ((1+x)(1+\alpha))^{\gamma^*+1}}$. This will be a source for deriving value of beta in this model. They have reached that the value of β is dependent on the γ^*, which is measuring growth of profit and is similar in both models. Additional input is the (1+x)(1+α), which is used to modify asset value in Ziegler´s model. In this model, there is a similar multiplicator of (1+x)(1-α)-x, which can be transcribed as (1-α-αx).

Thus to obtain β, we will use this equation.

$$\beta = \frac{\gamma^*}{\gamma^* + \left((1 - \alpha - \alpha x)\right)^{\gamma^*+1}}$$

Finally, we are able to obtain all required values for calculating terminal debt ratio model.

5.2 Single company examination

This section will use the model developed in previous chapter to determine the debt ratio, which would cause mass sale of stocks for equity holders of these companies. It will apply data from 2021, obtained from various sources. For the model´s examination, Colt CZ, Tatra Mountain Resorts, Energoaqua and Erste Group bank will be chosen. These companies have been chosen, because Tatra Mountain resorts experienced negative return on its stocks, showing decline of company´s value, Colt CZ´s stock value skyrocketed after more than 70% increase in their value. Energoaqua was steadily growing in more theoretically typical fashion around 10% and lastly, Erste group is a banking group. Banks have different balance sheets, especially higher debt ratio, due to deposits. It should provide sufficiently different subjects for examination of limits of terminal debt ratio model. Thus, the choice of companies roughly covers the spectrum from negative to massive growth of stock returns.

Colt CZ

Colt CZ has been chosen as a company that experienced a massive growth over 2021. Colt is major small arms manufacturer located in Czech Republic. It has good market position, it is reliant on the exports, as the vast majority of its production is sold either in other European countries, or in USA. There is reliable demand for its goods. This demand fluctuates depending on various gun restricting laws being brought into effect across the world. We need to amass the inputs needed for computation of the model.

Firstly, we need to amass data necessary for computation. We will start to rely on the end of year financial statement of the company (Colt CZ group 2021). It will provide value of company´s assets and its share of debts. For Colt CZ, its value of assets was 17 013 mil CZK in 2021 and share of its debt was 69.19%. Now, we turn to market data. According to Finance Yahoo its standard deviation was 66.65 CZK, and its mean price of stocks was 432 CZK thus its standard deviation was 15.43% of its mean value for the period of 2021 (‘Colt CZ Group SE (CZG.PR) Stock Price, News, Quote & History – Yahoo Finance’ n.d.). Moreover, risk free rate was 2% for 2021 (‘Average Risk Free Rate Czechia 2022’ n.d.). Finally, the remaining data we need to obtain can be obtained from Prague Stock Exchange website. Face value of investment was 17 138.2 mil CZK and its return was 70.47% (COLTCZ Prague Stock Exchange). This should provide all required data with the exception of α and β. But we will use previously determined formulas to compute them.

To compute α, we simply plug in values into a formula.

$$\alpha = 1 - \frac{X(t)}{S_t}$$

So, we obtain

$$\alpha = -0.74\%.$$

As α is discount if mass sale occurs, this implies that by selling now, stockholders obtain premium of 0.74%. This is likely caused by the shocking growth of the company.

Now we move on to compute β, from its derived formula. We need to obtain γ^* first. γ^* is computed as double the interest rate differential divided by variance of stock price. After putting in the values for Colt CZ we obtain

$$\gamma^* = 2\frac{r - r^*}{\sigma^2} \cong 57;$$

$$\beta = \frac{\gamma^*}{\gamma^* + ((1 - \alpha - \alpha x))^{\gamma^*+1}};$$

$$\beta = 0.9652.$$

Finally, we have obtained all the values for the formula so we can compute the desired ratio.

$$R = (1-\beta)(1+x) - x - \frac{\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}\left((1-\beta)(1+x)S_t - xS_t\right)^{-\gamma^*}X(t)^{1-\gamma^*}}{S_t}$$

After plugging in the values and using absolute value, due to the value of α, we obtain the value for terminal debt ratio

$$R = 63.3\%.$$

So, we have calculated terminal debt ratio, which estimates that by keeping all the input values identical, the panic sale of stocks should happen at debt ratio of 63.3%. As we can see, the value of terminal debt ratio is lower than the actual debt ratio of the company. This is at odds with the massive return on stock the company experienced over 2021. The reason for this value arises from the values of α and β. As we can see, the value of α is negative, implying a bonus, if we as an investor sell now, instead of later. Furthermore, massive discount of β implies that the majority of our investment could be lost, if we opt to sell later. Thus, using terminal debt ratio, we were able to determine that Colt CZ is currently overvalued on the market.

Tatra Mountain Resorts

Tatra Mountain Resorts is an example of company, for which year 2021 was not good, in terms of its stock value. It experienced a severe decline, so it will be an example of company that is not growing. It is a real estate and tourism focused company, located mainly in Slovakia. Its main business focus is operating hotels in Tatra mountains. This was likely caused by the COVID–19 pandemic as tourism level dropped significantly. Now, it is important to review input data for the model.

For computing the ratio of loans to assets, that would trigger a mass sale of stock by investors, we will require the input values of the model. Firstly, asset value is 556 761 000 EUR, face value of investment was 214 630 336 EUR and share of loans the company owes is 91.90% as of 2021, according to its end of year financial statement (Tatra Mountain Resorts a.s. 2021). We need these values in CZK, so we will multiply them by mean exchange rate for 2021 – 25.65 CZK per EUR (‘Czech Koruna to Euro Spot Exchange Rates for 2021’ n.d.). This yields 14 280 mil. CZK of asset value and 5 505 mil. CZK of face value. Secondly, we need to obtain market data. We can obtain them from Finance Yahoo – Standard deviation of TMR´s stock price has been 66.46 CZK, which we divide by mean value for selected period – 877 CZK, to obtain standard deviation in percentage of 7.58% for 2021 (‘Tatry Mountain Resorts, a.s. (TMR.PR) Stock Price, News, Quote & History – Yahoo Finance’ n.d.). Moreover, risk free interest rate for 2021 was 2%. Lastly, according to the Prague Stock Exchange website return on stocks was -17.89% for 2022 (‘TMR | Prague Stock Exchange’ n.d.).

Now we only need to compute the values of α and β. According to the previous derivation,

$$\alpha = 1 - \frac{X(t)}{S_t}$$

so we simply put in values for TMR, which we already know.

$$\alpha = 1 - \frac{5\ 505\ mil}{14\ 280\ mil} = 61.45\%$$

And for β, we simply compute γ^*. For TMR, value of γ^* is

$$\gamma^* = 2\frac{r - r^*}{\sigma^2} = 2\frac{-0.1789 - 0.02}{0.0758^2} \cong -69.$$

Now we know all the values to compute β.

$$\beta = \frac{\gamma^*}{\gamma^* + ((1 - \alpha - \alpha x))^{\gamma^*+1}} = \frac{-69}{-69 + ((1 - 0.6145 - (0.6145 * 0.9190)))^{-69+1}}$$

We obtain β = 1.

We can now compute the desired ratio according to

$$R = (1-\beta)(1+x) - x - \frac{\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}\left((1-\beta)(1+x)S_t - xS_t\right)^{-\gamma^*}X(t)^{1-\gamma^*}}{S_t}.$$

Since β=1, it can be simplified into

$$R = -x - \frac{\left(\frac{-x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}(-xS_t)^{-\gamma^*}X(t)^{1-\gamma^*}}{S_t}.$$

And now we put the real numbers in and due to β=1, we also apply absolute value.

And we obtain

$$R = 0.919 = 91.90\%.$$

Thus, the terminal debt ratio implies that panic sale should happen at debt ratio value of 91.90%, which is equal to the current debt ratio. So, the panic sale should be happening now, according to the terminal debt ratio framework. Terminal debt ratio implies selling, if the company is not profitable, as our investment only decreases. The foreseen panic sale did not happen, which implies that this ratio is not efficient in predicting if stocks that are not generating profit will be sold in mass sale by investors. This is caused by inability of terminal debt ratio to deal with the potential of growth. During 2021, Covid–19 pandemic stifled tourism industry and it was reflected in their book values. On the other hand, market still kept the hope of lifting travel restrictions and increases in the values of this industry. Thus, the panic sale did not happen, and company was not forced to default.

Erste Group Bank

Erste Group is a major player in financial markets in central and southeastern Europe. It contains largest banks in the region and has thus developed profitable position in its markets. Its large profit for the last year makes it an interesting subject to examine in the analysis. Furthermore, it represents a bank. Bank´s portfolio is generally vastly different from other companies. It contains larger share of debt, and its stock price tends to be more stable. Thus, we will determine if this model can be used on banks.

We will once again begin by amassing data for the inputs. Starting with their end of year financial statement, Erste group bank is holding 307,428 mil EUR of assets and share of their debt is 92.35% as of 2020. Moreover, face value of investment is 17,772 mil EUR (Erste Group Bank AG 2021). We need these values in CZK, so we will multiply them by mean exchange rate for 2021 – 25.65 CZK per EUR (‘Czech Koruna

to Euro Spot Exchange Rates for 2021' n.d.). This yields 7 885 528,2 mil. CZK of asset value and 455 851.8 mil. CZK in face value of investment. Speaking of market data, standard deviation of its stock was 91.35 CZK and its mean 696 CZK, making standard deviation being 13.125% of its price for 2021 ('Erste Group Bank AG (ERBAG.PR) Stock Price, News, Quote & History – Yahoo Finance' n.d.). Last data will be obtained from Prague Stock Exchange website providing us with yearly return of 55.38% ('ERSTE GROUP BANK | Prague Stock Exchange' n.d.).

We are still lacking α and β, so we need to compute them first.

$$\alpha = 1 - \frac{X(t)}{S_t}$$

And solving it yields

$$\alpha = 0.942.$$

We will now use α to compute the value of β. We also need to obtain value of γ^*.

For Erste group it is

$$\gamma^* = 2\frac{r - r^*}{\sigma^2} = 2\frac{0.1631 - 0.02}{0.1313^2} = 16.$$

Now we simply compute β out of its formula

$$\beta = \frac{\gamma^*}{\gamma^* + (1 - \alpha - \alpha x)^{\gamma^*+1}} = 0.036\% = 100.02\%.$$

Finally, we can compute the final ratio for Erste group. As β is larger than 1, we will also apply absolute value to the result.

$$R = (1-\beta)(1+x) - x - \frac{\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}((1-\beta)(1+x)S_t - xS_t)^{-\gamma^*}X(t)^{1-\gamma^*}}{S_t}$$

$$R = 92.39\%.$$

Thus, according to terminal debt ratio, the share of debt would have to increase by 0.04% in order to trigger a mass sale of Erste stock, while keeping input values constant. This seems unrealistic as such fluctuation could happen on regular basis. Thus, it appears that this framework is being oversensitive on banks. On the other hand, even a slight decrease in value of capital can have massive repercussions on banks, as they are subject to many panic related risks and such drop in value could

herald potential financial difficulties. So, this situation would require further study in wider setting.

Energoaqua

Energoaqua has been chosen as it had experienced a modest growth of 6.56% over 2021 and thus is fairly close to the intended use of framework around 5–10% growth annually. Energoaqua is company, which focuses on production of electricity, heating and distribution of natural gas. Moving onto the data required for computation, we start with their end of year financial statement, Energoaqua is holding 2 718 mil CZK of assets and share of their debt is 13.58% as of 2021. Moreover, face value of investment is 1822.6 mil CZK (Energoaqua a.s. 2021). Speaking of market data, standard deviation of its stock was 207.3 CZK and its mean 2646 CZK, making standard deviation being 7.83% of its price for 2021 ('ENERGOAQUA, a.s. (ENRGA.PR) Stock Price, News, Quote & History – Yahoo Finance' n.d.). Last data will be obtained from Prague Stock Exchange website providing us with yearly return of 6.56%. ('ENERGOAQUA | Prague Stock Exchange' n.d.)

Same as previously, we compute the values of α and β for the computation of terminal debt ratio.

$$\alpha = 1 - \frac{X(t)}{S_t}$$

And solving it provides

$$\alpha = 0.3294 = 32.94\%.$$

Now we need to compute value of γ^*

$$\gamma^* = 2\frac{r - r^*}{\sigma^2}.$$

For Energoaqua it is

$$\gamma^* \cong 15.$$

Now we simply compute β out of its formula

$$\beta = \frac{\gamma^*}{\gamma^* + (1 - \alpha - \alpha x)^{\gamma^*+1}} = 0.999.$$

Finally, we can compute the final ratio for Energoaqua group by plugging all value into formula

$$R = (1-\beta)(1+x) - x - \frac{\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}((1-\beta)(1+x)S_t - xS_t)^{-\gamma^*}X(t)^{1-\gamma^*}}{S_t}$$

$$R = 18.91\%.$$

The terminal debt ratio framework implies that if Energoaqua reached 18.91% of debt ratio, while keeping the input values unchanged, the panic sale of Energoaqua´s stock would take place. This situation could arise by company taking on additional debt, while keeping the value of stock same. This implies company obtaining loan for 144,9 mil CZK, without having any impact on its stock value. It is unlikely that such loan would not impact stock price. If it was loan used for expansion as additional investment, it would likely cause increase in stock price. On the contrary, if this loan would be used to cover the losses, it would certainly trigger a decrease in stock price and increased the speed of selling stocks by investors.

On the other hand, this might be also interpreted as Energoaqua´s stock, losing its value. Thus, the share of debt would increase. The value of its stock would have to drop to 93% of its mean value. In this state, there would be a massive sale of stock, if all assumptions of this model would be fulfilled. This situation is unlikely, as Energoaqua is a part of vital industry for state, so the government would likely step in and provided remedy to this situation, before the value of Energoaqua´s stock could drop so low.

5.3 Single Company Calculation Summary

As we can see in following table,

Table 5.1: Results of Single Companies

Company	Debt ratio in 2021	Terminal debt ratio
Colt	69.19%	63.30%
TMR	91.90%	91.90%
Erste	92.35%	92.39%
Energoaqua	13.58%	18.91%

terminal debt ratio has provided best results for non–financial companies that experience growth over the examined period. As was determined previously, terminal debt ratio estimates that it was better to sell Colt sooner as it experienced its massive

growth. Holding it risks reduction in premium caused by high demand. Next example is the TMR, which experienced a decline in the stock value over 2021. It shows that terminal debt ratio is inapplicable on companies that are experiencing decline in stock price over examined period, as it estimates that the company should have experienced panic sale of its stock. It is the limitation of the model as it is just two period model, it makes no sense for rational investor to keep their shares of the company that experiences straight loss. Furthermore, terminal debt ratio model suggests that the bank´s stock price is very sensitive to the increases in debt ratio. This was provided by an example of Erste Bank Group, which implies that a slight increase of debt by 0.04% would trigger the panic sale of Erste stock.

The best situation to obtain consistent results is when company experiences a mild growth over the examined period, like Energoaqua did. Terminal debt ratio estimated that its debt ratio would have to be 18.91% to trigger panic sale, while keeping other input values unchanged. Thus, to reach this level of debt, Energoaqua would have to lose 7% of its stock value or take on additional debt, while experiencing no changes to its profitability.

During calculation, when return on stocks is massively greater than risk free interest rate, there is a possible simplification of formula. It causes the interest rate differential will be very high, which will result in part of the terminal debt formula to move swiftly towards infinity. Due to this nature, we can simplify the formula of

$$R = (1-\beta)(1+x) - x - \frac{\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}\left((1-\beta)(1+x)S_t - xS_t\right)^{-\gamma^*}X(t)^{1-\gamma^*}}{S_t}$$

into

$$R = (1-\beta)(1+x) - x - \frac{\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*}}{S_t}.$$

For any calculation with $r \gg r^*$.

While this thesis has examined rudimentary examples that this formula might be used on, there are still possible types of companies that it was not applied on. It would have to examine larger stock markets, like New York Stock Exchange and test in on different industries. There might be further outliers like banks with their skewed balance sheet. So, the results imply terminal debt ratio´s application on non–financial companies which experienced growth over the past year or the examined period. There might

appear to be outliers like banking sector, so it would be best applied with caution, until all industries are examined.

6 Application on markets

As mentioned previously, balance sheets and data of banks and other industries are generally very different. Furthermore, if we compare more standard company with bank, while assuming both generating same amount of profit, banks tend to have larger amount of assets and larger share of debt. Thus, by mixing standard companies with other, it might skew the terminal debt ratio and give too large weight on banks. In order to prevent skewing the data, we will divide all stocks listed on Prime market of Prague Stock Exchange into stocks of banks and other, non–financial companies. After obtaining the required values, the approach will be similar to previous calculations.

6.1 Banks

Terminal debt ratio does not seem to be very efficient in determining the debt ratio for a single bank, it might be more efficient if we apply it for multiple banks. Thus, we form a dataset composed of Erste Group, Komerční and Moneta Money banks. We obtain data the similar was as in specific firm scenarios from 2021 annual reports, Prague Stock Exchange and Finance Yahoo data sources. In order to compute asset value and face value of investment of the entire dataset, we will simply sum the asset values and face values respectively. The other inputs are harder to obtain. Easiest was to obtain them is to make weighted average by their share of face value.

Table 6.1: Banks market

Variable	Erste Group bank	Komerční banka	Moneta Money bank
S	7 885 528.2 mil.	1 244 400 mil.	340 222 mil.
X(t)	455 857.7 mil.	177 696 mil.	47 906.3 mil.
r	55.38%	42.10%	34.51%
σ	13.13%	11.54%	8.14%
x	92.35%	89.81%	91.33%
Share in dataset	66.89%	26.08%	7.03%

Thus together, we obtain a “company” with asset value of 9,470,150 mil. CZK, face value of stock price of 681,460 mil. CZK, stock growth rate of 50.45%, standard

deviation of stock price of 12.36% and debt ratio of 91,62%. So for computing a terminal debt ratio, we need to obtain the values of α and β.

α is again computed from the same formula.

$$\alpha = 1 - \frac{X(t)}{S_t}$$

And solving it with real values yields

$$\alpha = 0.9280 = 92.80\%.$$

Now, we need to obtain value of γ^*.

For Banks of the prime market, it is

$$\gamma^* = 2\frac{r - r^*}{\sigma^2} = 2\frac{0.5045 - 0.02}{0.1236^2} \cong 63.$$

Now we simply compute β out of its formula

$$\beta = \frac{\gamma^*}{\gamma^* + (1 - \alpha - \alpha x)^{\gamma^*+1}} \cong 0.$$

Since β is equal to 0, we can simplify the equation to

$$R = 1 - \frac{\left(\frac{1}{1 - \alpha - \alpha x}\right)^{1+\gamma^*} (S_t)^{-\gamma^*} X(t)^{1-\gamma^*}}{S_t}.$$

Finally, we can compute the final ratio for Banks of prime market and after plugging in the values, we obtain

$$R \cong 1.$$

So, debt ratio of banking sector would have to reach value of 1, while keeping the inputs unchanged, to trigger the panic sale of its stock. This implies resilience of banking sector towards shocks of stock price. This result is irrelevant as it is above the value, when the banking supervisor would act and terminate the bank. So, in this case, the market condition is less strict than regulatory one, resulting in regulatory condition being the only relevant one.

6.2 Prime market non–financial companies

In this section, we will apply terminal debt ratio framework on the remaining companies that constitute Prime market of Prague Stock Exchange. Specifically, this means that we will combine information about Colt CZ, Kofola, Vienna Insurance

Group and Tatra Mountain Resorts to form a “single company”. Approach will be similar to previous situation with banks as we will sum up asset value and face value of investment of companies and apply weighted average on the rest of data. The weighted average will be again set up by the share in total face value of investment.

We obtain a company with asset value of 1,376,899 mil. CZK, face value of investment of 104,199 mil. CZK. Furthermore, there is a 21.55% return on investment, 6.34% deviation of stock price and 85.99% debt ratio of this “company”. So, we only need to compute values of α, β and γ^*.

α is again computed from the same formula.

$$\alpha = 1 - \frac{X(t)}{S_t}$$

And solving it with real values yields

$$\alpha = 0.9243 = 92.43\%.$$

We compute the value of γ^*

$$\gamma^* = 2\frac{r - r^*}{\sigma^2} = 2\frac{0.2155 - 0.02}{0.0634^2} \cong 97.$$

Now we simply compute β out of its formula

$$\beta = \frac{\gamma^*}{\gamma^* + ((1 - \alpha - \alpha x))^{\gamma^*+1}} \cong 0.$$

Finally, we can compute the final ratio for standard companies of Prime market of Prague Stock Exchange.

$$R = (1-\beta)(1+x) - x - \frac{\left(\frac{1-\beta-\beta x}{1-\alpha-\alpha x}\right)^{1+\gamma^*} ((1-\beta)(1+x)S_t - xS_t)^{-\gamma^*} X(t)^{1-\gamma^*}}{S_t}$$

$$R = 1$$

As we can see, R practically equal to 1 implies extreme resilience in regard to the size of debt, as panic sale of stock would only occur, if the debt ratio reached 100% with unchanged inputs. That would also imply a possibility of investors, disregarding the value of debt altogether. Moreover, there is an issue with using terminal debt ratio on a market itself as there is very large discrepancy between companies, their share of debt, value of their stock and their return on stocks. Due to the standard financial

leverage, stock with higher debt should experience larger growth in good times. Thus, due to all these differences, it is unlikely that terminal debt ratio would be any useful in determining a point, in which investors would cause a mass sale of stocks on the entire market.

6.3 Calculation summary

Terminal debt ratio has shown that it is well applicable on non–financial companies that exhibit growth of their stock value over the examined period. On the other hand, we have found some of its limitations. Firstly, it cannot be applied to the companies, which lost stock value over the time period. Furthermore, it struggles with banking sector due to its large amount of debt and suggest large sensitivity to stock prices. Lastly, it cannot be applied to the market as a whole as the companies with higher capitalization drive the ratio. This makes the market itself incredibly resilient on paper, but the relationship disregards any correlations and relationships between stocks of different companies. Terminal debt ratio framework does not capture the relationship mentioned before so it is not a good tool to estimate the crash of an entire market.

Moreover, terminal debt ratio would benefit from more frequent data, but is limited to company´s reports which happen on quarterly basis at most. It would be beneficial to evaluate terminal debt ratio framework on weekly or daily basis. Unluckily, it is impossible due to reporting issues. Due to the nature of stock market, estimation on stock sale based on last year performance has only a limited informational value as it is future driven. It does not take into consideration new growth opportunities, company´s business plan and other frequent topics of financial news. Thus, it only provides a partial information and should be used to obtain rudimentary information about the resilience of company´s stock to panic sales. It appears that the best way would be to apply terminal debt ratio framework in to compare the resilience of stock to the company´s annual reports and performance.

On the other hand, terminal debt ratio can be applied on the publicly traded companies that experienced moderate growth over examined period. It then calculates the level of debt ratio that if company reached with its current inputs – company´s asset value, standard deviation of the stock value, bank loans for each unit of capital invested, market capitalization (face value of investment), risk free interest rate and return on stocks, a panic sale of its stocks would occur, and company would likely be liquidated. While the terminal debt level cannot be taken literally, as the inputs to the model are changing on incredibly frequent basis, terminal debt ratio can be applied as a tool to warn the company´s management about the potential new additional debt and terminal

debt ratio can be used to compare how close companies are to panic sale, based on their past performance.

7 Conclusion

This thesis has focused on drawing connection between banking sector´s liquidity problem and stock market´s problem, regarding sudden losses of value of particular stocks. To draw the comparison, it has differences in financial crises, which stem either from banking sector or stock market and demonstrated their impacts. Furthermore, it has discussed differences in regulations, regarding both sectors. While stock market´s regulation relies on transparency and low barrier to entry, banking sector faces very serious regulations regarding its liquidity. Bank must be ready to survive stress scenarios without any outside help. On the other hand, stock market has regulation set in place, which will automatically prohibit trading the stock, which experiences sufficient losses. Thus, the banking sector is the one, which is monitored and does not receive any automatic help, in case of financial distress.

After establishing regulatory and general conditions of both sectors, this thesis briefly describes bank run model created by (Ziegler 2004). Ziegler´s bank run model is measuring the value of equity, which would trigger bank run by depositors, by applying the tools of game theory and pricing of options. It is the basis of the next step of this thesis, as it adapts bank run model to be applicable on stock markets and investor´s decision to sell, based on the level of company´s debt. This thesis adjusts assumptions and modifies bank run framework into terminal debt ratio. Terminal debt ratio computes the level of debt in a company that would cause mass sale of stock based on the following inputs: company´s asset value, standard deviation of the stock value, bank loans for each unit of capital invested, current value of invested capital, risk free interest rate, return on stocks, proportional liquidation cost in case of mass sale of stocks and proportional liquidation costs if no mass sale of stocks occurs. Furthermore, theoretical limits of terminal debt ratio framework are established, such as its inability to account for the potential of growth of the company and overreliance on book values.

Theoretical limitations are not enough to apply terminal debt ratio framework in practical situations. Thus, this thesis chooses four companies from Prague Stock Exchange and calculates their debt ratio, which would trigger mass sale of stocks. It chooses Colt CZ as a company that experienced massive growth over examined period of 70+%. It determines that according to terminal debt ratio framework, stockholders should have sold the company earlier, as they would receive premium for their sale and there is a massive potential that they will lose large amount of their investment in the

long run. So, for Colt CZ, the run has inversed effects. Next chosen company was Energoaqua, which represents company, that experienced more modest growth of <10%. It is a more typical example of company, terminal debt ratio would be used on, as the panic has negative effect. Terminal debt ratio has determined that the company level of debt would have to reach 18.91% from its current 13.58%. Last example of non–financial company was Tatra Mountain Resorts a.s. It has experienced negative return over the examined period. Terminal debt ratio did confirm the expectations of not being suitable for companies with negative return on their stocks as it suggested panic sale of stocks on current level of debt. Contrary to terminal debt ratio framework, Tatra Mountain Resorts a.s. did experience a decrease of its stock value, but not its crash. Finally, this thesis examined Erste Banking Group AG. It was an example of bank, in order to determine, if we can apply terminal debt ratio on banking sector. The results imply massive sensitivity of banks to its debt ratio, which needs further examination.

The last section of this thesis examines a possibility of applying the terminal debt ratio to the entire markets. It is done by transforming the companies listed on the market into a single "company" through weighted average multiplication. The market approach was tested on the stock of banks and on the rest of non–financial companies listed on prime market Prague Stock Exchange. Terminal debt ratio approach appears to not be efficient in market setting, as results for both groups were practically one, implying that the panic sale of stock would occur only if the debt ratio of companies reached 100%. It shows that the terminal debt ratio is not suitable for this case, as stock crashes can occur. Likely cause of this inefficiency is the lack of forward looking approach in terminal debt ratio framework.

To sum it up, this thesis has established a tool, useful for determining the resilience of companies to the panic sale of its stock. It has provided useful results for instances of single companies on the stock market. It should not be used on companies that experienced negative or massively positive growth over examined period. Otherwise, terminal debt ratio approach can calculate debt ratio level, which would cause the panic sale of stocks, if inputs were kept constant. Terminal debt ratio cannot be applied this way, as the inputs will not remain unchanged. Asset value and stock price are the most notably changing input values, which change in matter of seconds every day. Thus, the terminal debt ratio framework should be used as an indicator of how close the company is to panic sale induced by the past performance. On the other hand, it has proven to be unapplicable to the entire markets for predictions. We suggest focus of future research upon further testing of the terminal debt ratio framework and incorporation of additional market forward–looking market features into its framework to improve its

predictive potential. Furthermore, it provides a bridge between banking and stock markets research, which should receive more attention due to connection between both sectors and the reliance on this connection in situations like bank´s liquidity crunch.

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