Blockchain – a new accounting paradigm

Implications for credit risk management

Authors: Anastasiia Potekhina
         Ivan Riumkin

Supervisor: Catherine Lions

Student
Umeå School of Business and Economics
Spring semester 2017
Master degree thesis, 1st year, 15hp
Abstract

Blockchain technology and its numerous applications have become a major catalyst of new ideas and solutions for the financial sector. A headline containing the word “blockchain” attracts tons of attention from the media and new start-ups developing something in blockchain receive huge investments. But the theoretical framework for blockchain even for financial industry remains raw and empirical evidence is insufficient.

In this study, we explore the theoretical framework for blockchain applications in accounting, identify the core benefits and downside, and discuss its implications for auditing and accounting in general and for credit risk management in particular.

The research methodology of this study is designed to satisfy objectivist ontological position and positivist epistemological stance as the notion researched is considered to be primarily external to affected social actors, consequently the quantitative methods are used to establish the relationships between the variables, in turn the variables are produced by a deductive approach from general theories and ideas which exist in abundance in the area but lack empirical observations. A case study was consequently chosen as a research strategy to add a real-life touch to our statistical modelling. In the case study where we use financial data of Ericsson corporation to model theoretical effects of blockchain accounting on credit scores measures we add an empirical dimension to the research in a real-life context. Then we discuss the findings and try to draw general conclusions and identify consequences of the results for different affected parties. As it is always important to do when dealing with new technologies we discuss potential ethical advantages and issues resulting from the technology’s implementation.

The study aims to review the current theoretical framework for blockchain accounting in a coherent way as the current literature seems to be disjointed and multiple sources doesn’t focus solely on accounting applications. The empirical study aims to identify a measurable material effect on a very specific problem of credit risk modelling under a broader blockchain accounting paradigm.

There are two primarily findings of the research. Fist is the fact that the potential material effect of blockchain accounting on credit scores measures is confined within boundaries of actual volatility of quarterly credit scores and thus the technology will have larger implications for companies with high volatility of credit measures. The second finding is that the implications will be not solely positive in the form earlier identification of financial distress and quicker reaction to resolve the troubles but also may affect the company negatively by exacerbating the economic short-termism problem, the problem that hasn’t been discussed in connection with blockchain accounting before.

Key Words: Blockchain, Credit risk modelling, Real-time accounting.
Acknowledgements

First and foremost, we would like to express our sincere gratitude to our supervisor professor Catherine Lions for her attentive help, commitment and encouragement that allowed us to push through all the hurdles while working on this so-far biggest research project of our university studies.

Anastasiia Potekhina & Ivan Riumkin

Umeå 2017-05-23
# Table of contents

List of figures .................................................................................................................. vi
List of tables .................................................................................................................... vii
Chapter 1 – Introduction................................................................................................. 1
  1.1 Theoretical background and research gap.............................................................. 1
  1.2 Research question ................................................................................................. 3
  1.3 Target audience and purpose of the research....................................................... 3
  1.4 Subject choice ...................................................................................................... 3
  1.5 Delimitations ....................................................................................................... 4
Chapter 2 – Scientific method ....................................................................................... 5
  2.1 Ontological assumption ....................................................................................... 5
  2.2 Epistemological assumption ............................................................................... 5
  2.3 Approach to research ......................................................................................... 6
  2.4 Research design .................................................................................................. 6
  2.5 Literature search .................................................................................................. 8
  2.6 Ethical considerations of the research .................................................................. 9
Chapter 3 Theoretical framework................................................................................ 10
  3.1 The blockchain .................................................................................................... 10
  3.2 Blockchain in finance and accounting ............................................................... 11
  3.3 How blockchain-based accounting will transform the auditing profession ........ 14
  3.4 Overview of the blockchain solutions under development................................. 15
    3.4.1 Rubix by Deloitte .......................................................................................... 15
    3.4.2 Harmony by Factom ..................................................................................... 15
    3.4.3 Balanc3 ......................................................................................................... 15
    3.4.4 Tierion .......................................................................................................... 15
  3.5 Limitations of the technology and problems on the way to implementation ........ 16
    3.5.1 Issues associated with business models and regulatory framework .......... 16
    3.5.2 Technological challenge ............................................................................. 17
  3.6 The problem of time lag between the financial statements .................................... 17
  3.7 Credit risk and credit risk modelling ................................................................... 18
    3.7.1 The credit risk management process ............................................................ 19
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8</td>
<td>Altman’s Z-score model</td>
<td>21</td>
</tr>
<tr>
<td>3.9</td>
<td>Merton Distance to Default Model</td>
<td>23</td>
</tr>
<tr>
<td>Chapter 4 – The case study set-up</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>4.1</td>
<td>Quantitative data collection</td>
<td>27</td>
</tr>
<tr>
<td>Chapter 5 – A case study</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>5.1</td>
<td>The Z-score intra-quarterly fluctuations modelling</td>
<td>29</td>
</tr>
<tr>
<td>4.3</td>
<td>Merton Distance to Default intra-quarterly fluctuations modelling</td>
<td>32</td>
</tr>
<tr>
<td>Chapter 6 – Results and discussion</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>6.1</td>
<td>The findings and their meaning in the blockchain accounting framework</td>
<td>34</td>
</tr>
<tr>
<td>6.2</td>
<td>Discussion and overview of benefits, dangers and ethical aspects</td>
<td>35</td>
</tr>
<tr>
<td>6.2.1</td>
<td>Ethical aspects of blockchain</td>
<td>38</td>
</tr>
<tr>
<td>Chapter 7 - Conclusion</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Chapter 8 – Quality of the research</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>8.1</td>
<td>Reliability and replication</td>
<td>42</td>
</tr>
<tr>
<td>8.2</td>
<td>Validity and generalizability</td>
<td>42</td>
</tr>
<tr>
<td>References</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>
**List of figures**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>the research onion (Saunders et al, 2014 p106).</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>Disruptive Computing Paradigms</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>A concept of blockchain accounting system</td>
<td>17</td>
</tr>
<tr>
<td>4</td>
<td>Credit risk management process</td>
<td>21</td>
</tr>
<tr>
<td>5</td>
<td>The Z-score model</td>
<td>23</td>
</tr>
<tr>
<td>6</td>
<td>Average Z-scores and S&amp;P bond rating</td>
<td>24</td>
</tr>
<tr>
<td>7</td>
<td>Z-scores with quarterly and daily accounting data</td>
<td>33</td>
</tr>
<tr>
<td>8</td>
<td>Z-scores with quarterly and daily accounting data,</td>
<td>34</td>
</tr>
<tr>
<td>9</td>
<td>Daily and quarterly fluctuations of Merton DDs</td>
<td>35</td>
</tr>
<tr>
<td>10</td>
<td>Daily and quarterly fluctuations of Merton DDs, Apple</td>
<td>35</td>
</tr>
<tr>
<td>11</td>
<td>Security integrity and confidentiality</td>
<td>39</td>
</tr>
</tbody>
</table>
List of tables

Table 1 – Relevant Situations for Different Research Strategies (Yin, 1994 p6) 10
Table 2 – Financial data for Z-score calculation (million SEK) 31
Table 3 – Financial data for DD calculation. 34
Table 3 – Benefits and disadvantages of blockchain-based accounting systems. 38
Chapter 1 – Introduction

In the introductory chapter, we briefly discuss the blockchain technology and identify the gap between general theoretical framework and actual empirical evidence of the technology’s benefits. We set the research questions and purpose of the study together with the main audience that can benefit from the research’s findings.

1.1 Theoretical background and research gap

The blockchain technology embodies the idea of transferring valuable digital assets such as currency without any third-party intermediary. Middleman is important in transaction of digital assets to prevent a problem known as double-spending. For example, double-spending of the same unit of digital currency by sending it to several recipients simultaneously. Banks and other financial intermediaries are needed to supervise the transaction process to prevent the double-spending by careful constant verification of every transaction. Having a middleman results into a long lag between the transaction and hefty fees. Blockchain is an ingenious solution to eliminate the need for a trusted intermediary in many areas of financial relationships and accounting.

Unsurprisingly, the notion of blockchain being used as an accounting platform by conventional corporations most extensively covered by accounting firms in their industrial reports. In this sense, industry is ahead of academia in the attempt to create a comprehensive theoretical framework for implementation of the technology. Most notably, a paper by Deloitte (2016) “Blockchain technology a game-changer in accounting?” emphasizes that the use of blockchain can greatly simplify the procedures of verifying the integrity of accounting data which can result into significant monetary and perhaps more importantly organizational benefits such as reduced time for conducting audit and ultimately automatic audit may become a reality. As a next step of development of blockchain systems, smart-contract applications can be created such as invoices being paid automatically. Ernst and Young (2016) in their report expressed the same view as Deloitte that the blockchain technology has a potential to change the role of accountants, more specifically they highlight the increased level of trustworthiness of the accounting data under the blockchain regime as it may be programmed in a way to check every transaction and identify unusual patterns which in turn can be checked manually. EY outline the problems which currently need to be resolved before such systems can be implemented: organizational routines which are not mature enough to effectively work with blockchains, uncertain legal framework, technological barriers and high requirements for energy consumption needed to maintain the network. Lazanis (2015) argues that blockchain accounting can greatly reduce the role of human accountants or even completely eliminate them. He cites the “Australian industry report” prepared by the Department of Industry (2014, p44) which declared bookkeeping and auditing clerk positions as having the highest risk of being automated by the technology. Yermack (2017) first identifies that blockchain-based accounting system by definition must allow shareholders, customers, creditors and other stakeholders of a corporation to compile their own financial statements at any time and eliminates the need to rely on quarterly reports.

One of the cornerstone notions when dealing with a real-time accounting systems with potential daily updates is the problem of time-lag between the financial reports.
Understanding the current situation with time-lag implications is especially important considering that a blockchain system will eliminate them completely. We discuss those implications as well as current theories revealing the consequences of untimely reporting, the factors influencing whether the company publishes them in time and what are the reasons for the managers holding discretionary power over the reports to publish or not to publish them in due time.

The literature analysis shows lack of focused research beyond discussions of possible benefits and general ways of implementation of the technology in accounting. Industrial literature by accounting companies outlines the importance of the technology and suggests the solutions under development, but the research by Hans Byström (2016) seems to be first of its kind. It aims at identifying clear material effects on a very narrow issue of imprecision of solvency-prediction models due to lag between the financial statements, the elimination of the lag is one improvement which will be provided under the blockchain regime and practically all the literature in the area clearly recognizes that. The future research needs to be more focused on this kind of narrow issues and specific implications of the blockchain as industrial reports and blockchain literature provide a good guidance into what blockchain can do and which aspects of it should be thoroughly investigated by the academia.

In this research, we test the impact that the blockchain-based accounting system can have on measures provided by two famous and widely used bankruptcy prediction models Z-scores and Merton’s distance to default.

The Z-score model was invented by Edward Altman in 1968 and is still enjoys great popularity in the literature and among practitioners (Bemmann 2005, p69). The model uses five financial ratios weighted by coefficients, in this research we will use data provided by quarterly reports daily stock price to calculate the ratios.

The Merton’s model (1974) also relies on the information from the firm’s balance sheet and its market stock price using Black and Scholes’ (1973) option-pricing framework to solve for the asset value and stock volatility. Knowing that equity holders have a residual on firm’s assets it makes their claim a long position in the call option on the firm’s assets. The asset value and its volatility then combined into a risk-measure – distance to default.

The two models use the information from financial statements and the stock price the information which will be affected by an implementation of a blockchain-based accounting system. Currently it is possible to calculate Z-Score and Distance to default only quarterly but with a blockchain system it will be possible to calculate daily measures. The choice of the two models for our research is justified by the fact that the accessibility of the accounting data will be widely affected by the new system and they are essential for the models and by the aim to compare the results founded in the research by Byström (2016) to our results of analyzing a company from a different sector. The research gap between general theoretical ideas on the blockchain and actual empirical evidence of the benefits resulting from its implementation is clear due to the technology being new and most of the actual products being in its beta-test phase. Nevertheless, we can attempt to simulate some of the effects of the technology and identify its material impact on one or another aspect of accounting and financial relationships. Now we can formulate the research questions.
1.2 Research question

1 What is the potential material impact on credit risk management models if the financial data are available daily rather than quarterly?

1.3 Target audience and purpose of the research

We consider the primary target audience of our research to be auditing companies as the auditing industry together with banking have expressed the greatest interest in the blockchain technology by investing funds into various start-up companies which try to develop solutions mainly in the area of interbank transactions and cloud accounting systems. The literature search showed that most of the articles on the subject are basically industry thoughts on the matter. The biggest benefit from blockchain accounting as we could see in the reports by Deloitte, Ernst and Young and others is the data transparency and constant availability. Since we aim to explore the impact which stems primarily from these two properties of the technology in the field of bankruptcy prediction and credit score modelling the findings can be potentially used by banks and auditors in their pursuit to benefit from this expensive, complex and potentially disruptive technology. Understanding of specific blockchain’s effects on widely used by financial entities technics must further contribute the technologies adoption and create an important piece of knowledge that can be used in a comprehensive guideline for companies wishing to implement it in their practices and also for professionals who will be directly involved with the technology. Even though our estimations of future theoretical daily credit scores can be significantly different from real ones they can be used to graphically show the blockchain’s impact on rather dated models which weren’t even developed to specifically include daily available accounting information. The results of our modelling are supposed to induce further deliberations on how to specifically recalibrate the old models to embrace a new accounting paradigm or even develop new models to fully benefit from constantly available and automatically audited financial data. We consider analysis of the current theoretical framework of blockchain accounting to be one of the main purposes of the research as there is no comprehensive description of all the implications and ways of the technology being used in this area, although disjoint ideas are in abundance. The importance of theoretical framework analysis stems from the fact that we use it to deduce local repercussions for credit risk management. Another important aspect that we consider in this research is the ethical side of not only blockchain itself but the accounting systems with fully disclosed financial information in particular. A number of ethical controversies arise from the technology, while some were already considered in the literature others weren’t even mentioned. We aim to identify them for future users to take them into account.

1.4 Subject choice

The authors of this paper are two master’s students in financial management at Umeå University with long outstanding interest in the latest financial technologies, namely the Blockchain, and a wish to explore the new opportunities for the financial sector arising from implementation of these technologies in banking and accounting since these are areas of our primary expertise and are most likely to be affected by the development of new application
based on the blockchain. To illustrate the immediate material impact from the most straightforward implementation of the blockchain technology – a blockchain-based accounting system we decided to analyze how such a system will affect two widely used bankruptcy-prediction models – Altman’s Z-score and Merton’s models. We consider it important to contribute to understanding and promotion of the technology as Blockchain technology is potentially the biggest game-changer for the financial industry in the nearest future, new projects, start-ups and research groups sponsored by big players of the industry are appearing all around the world. It is important to identify, among all the hype around, specific, focused solutions for long outstanding problems and understand the issues to overcome before the full implementation of the technology. We wish to make a contribution into academical understanding of the technology’s effects and test the findings of on the very few research projects that deal with not general theoretical framework but with focused material impacts of blockchain in accounting and further expand it by replicating the research on a company representing a different industry.

1.5 Delimitations

The main delimitation of this research project is that we do not assess the real impact of blockchain-based accounting systems on bankruptcy prediction models as no working real-time accounting system satisfying all the characteristics implied by the blockchain has been implemented so far but rather, we try to model as close as possible in the absence of a real system the theoretical material effects of daily available data.

Second delimitation is that we use only two bankruptcy prediction models in our statistical modelling for the purpose of comparing the results and discuss which model will be affected stronger. There are many other models that can be suitable for the same purpose but the analysis of all the models and their ranking is well beyond the scope of this research.

Third delimitation is that the bankruptcy prediction models that we use in our modelling were not designed to integrate the full scope of daily available accounting data but quite the contrary to mathematically circumvent the deficiencies of financial statements and produce a fairly accurate default probability measure. It is very likely that new credit score models will be proposed once the first real-time accounting has been set in place, therefore the real daily credit scores measures produced with these specially designed technics can be very different from those that we try to model.
Chapter 2 – Scientific method

The description of scientific research methodology starts with the choice of research philosophy. The philosophy defines the views of the researcher on knowledge and the way it is produced, approaches, strategies and technics (Saunders et al. 2009, p107).

2.1 Ontological assumption

Ontology is a branch of metaphysics concerned with the nature and relations of beings as defined by Merriam-Webster dictionary (Merriam-webster.com, n.d.). Researchers concern themselves with their ontological position to define their research in terms of two aspects of ontology - objectivism and subjectivism. Objectivism reflects notions which are considered to be external to social actors concerned with the existence of the notions, subjectivism describes phenomena which are created and influenced by actions of social actors concerned with existence of the notions (Saunders et al 2009, p110). Therefore, positivists hold the position of objectivism and interpretivists hold the subjectivism views (Collis&Hussey 2014 p47).

In this research, we take the objectivist ontological assumption as we believe that the technological system in question possesses its properties and will be used in a way which is independent on the actors such as the management of the company and external users. The results which can be potentially brought by the system are of quantitative nature and can be precisely measured and extracted at any time.

2.2 Epistemological assumption

“Epistemology is concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate” (Maynard, 1994 p10). There are two main epistemological stances: first, positivism which regards only observable and measurable phenomena as valid knowledge. Positivists conduct their research in a way that allows them to be an external actor and to not affect the research subject. Second epistemological stance is interpretivism where the researcher minimizes distance with the research subject. For example if the research is of social nature then the researcher would like to participate in the activity being studied and try to understand the process from the subjects perspective (Collis&Hussey, 2014 p47), (Saunders et al. 2009, p116). In addition to the two main epistemological stances researchers recognize realism which is close to positivism in its interpretation of is knowledge and emphasizes collection and comprehension of data from positions of direct realism which states that what we see and sense is the correct reflection of reality and critical realism which points out the difference between the notion we observe and the sensation of the notions. Critical realism emphasizes the importance of a mindful comprehension process which occurs after the observable notion was conveyed through our senses while the direct realism skips that step (Saunders et al 2014, p114,115).

In our research, we hold the epistemological aspect of positivism as the nature of the main research question is quantitatively measured by means of statistical analysis and the results cannot be affected by our views or views of the company’s stakeholders. Figure 1 below
produced by Saunders et al (2014, p106) helps to design a study by going from general (philosophies) to more specific aspects of the research. In our case, having identified the ontological and epistemological stances as positivist we proceed further to identify our approaches, strategies and specific techniques.

2.3 Approach to research

There are two main approaches or styles of reasoning in a research – Inductivism and Deductivism. Inductivism refers to generalizing a number of observations into a theory, thus going from specific to general. Deductivism implies narrowing down general laws to a specific testable hypothesis which may or may not confirm the result predicted by the general hypothesis (Adams et al 2007 p29). As outlined by Saunders (2014 p124), deduction is largely associated with positivism and induction with interpretivism.

The theoretical approach which we use in this study is one of a deductive nature. The definition of deductive research as provided by Collis&Hussey (2014 p49) is a study where a theoretical framework is developed and then tested by an empirical observation. The deductive approach is justified in our case by abundance of general ideas and assumptions about potential benefits of a blockchain regime associated with the ability of a blockchain regime to alleviate the issues associated with the reliability of financial statements and the quarterly time lag in financial statement analysis in general and thus in solvency prediction in particular but lack of actual empirical observations of this ability.

2.4 Research design

As defined by Creswell (2009, p41), research design is a type of inquiry with qualitative, quantitative or a mixed method approach that provide specific directions for procedures in a research design.
Quantitative designs are used for examining relationships among variables which can be measured and statistically analyzed. Qualitative designs explore social problems by studying individuals or groups and often is of an inductive nature where researcher draw general conclusions from collected data. Mixed-method approach integrates both qualitative and quantitative data for a deeper comprehension of the research problem (Creswell 2009, p32). In accordance with our positivist epistemological assumption and objective ontological assumption only quantitative approach to the research deems to be possible, basing on the hypothesis from a general theoretical framework that transparency and live availability of financial statements should improve the credit-score modelling we collect solely quantitative data and analyze them statistically to test the assumption and identify the material impact.

Going further within the research onion we choose a case study as our research strategy. As defined by Robert K. Yin (1994 p12, 13) a case study represents an empirical investigation of a phenomenon within a real-life context. Table 1 below helps to identify what kind of research strategy is applicable in a particular case.

Table 1 – Relevant Situations for Different Research Strategies (Yin, 1994 p6).

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Form of research question</th>
<th>Control over behavioral events</th>
<th>Focuses on contemporary events?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
<td>How, why</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Survey</td>
<td>Who, what, where, how many, how much</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Archival analysis</td>
<td>Who, what, where, how many, how much</td>
<td>No</td>
<td>Yes, No</td>
</tr>
<tr>
<td>History</td>
<td>How, why</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Case study</td>
<td>How, why</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

In our case, we do not aim to control the environment of the research but rather to conduct an analysis of the effects of one variable on the whole system. Our goal is to understand not only the abstract economic impact of the technology but do so in a context of multi-sectoral, technological corporations and the two most popular credit risk models to possibly identify the processes being involved as prescribed by Morris and Wood (1991, cited by Saunders, 2014 p146). We do so in a real-life context and study the effects of the variable in terms of its impact on credit scores of only one company and then draw general conclusions and hypothesis applicable to a broader range of models and companies in accordance with the deductive nature of our research.

The case study method is useful as it allows to explore a broad range of questions about a phenomenon including why, how and what and therefore the method is highly suitable for an explanatory and exploratory research (Saunders, 2014 p146). As we can see the older guideline represented in table 1 doesn’t include the question “what” as recommended for case study research and therefore under Yin’s recommendations our research can be described as a case study crossing with archival method. However, in a modern sense as Saunders (2014,
p146) states a case study has broader applications and allows to answer “what” question as well as those recommended by Yin. The nature of our research is such that the real-life context is the best way to illustrate the potential impact of blockchain systems. In an experiment, we could use hypothetical financial statement to do the same but it would be much less useful as we do not model real effects due to the absence of a real working model. Moreover, usage of a real company’s financial statements allows to draw conclusions in a context of a particular company although it cannot by generalized on other companies. Finally, we can suggest that even a hypothetical daily credit score modelling can allow an interesting analysis of companies that went into trouble due to opaque accounting reports and intricated schemes to hide losses, here we imply that for instance Enron financial statements can be used for the same modelling to analyze if a blockchain system could help to detect the accounting fraud or at least identify the company’s troubles earlier. We do not do such an analysis in our case study as it is beyond the scope of our research but our example can be used in future research to analyze different companies specifically to see if a blockchain system can solve one or another issue associated with financial reporting problems of those companies. Thus, we consider a case study superior to an experiment in the context of this research and with future research in mind as it allows a broader future applications for analyses similar to ours and exploring the same issues.

Exploratory research is used to find out what is happening; to seek new insights; to ask questions and to assess phenomena in a new light (Robson 2002:59 Cited by Sauders et al, 2014 p139). One of the main principles of an exploratory study is a thorough literature search and that it allows to be flexible and adaptive while conducting the research to include new insights and thoughts occurring to us as researchers (Saunders, 2014 p140). Which, in a foresight, will prove to be useful as one of our main findings will come from the literature review as well as results of the case study.

Explanatory study is conducted with a focus on establishing causal relationships between variables and explain them in the context of the study (Saunders, 2014 p140). By its application in this research the case study method is Explanatory as it is designed to explain the causation effect of the variable imbedded into a real-life framework and Exploratory as the variable introduced may not have a clear single effect on the phenomena researched and the literature analysis is used widely to get new positions and insights into the problem in order to explain those effects as prescribed Yien (1994, p15) and in coherence with the definitions above.

2.5 Literature search

By conducting the literature review we tried to identify the existing theoretical framework used in development of blockchain solutions for banking and accounting. It helped us not only to understand the current state of the academical research in the area but also what are the major advantages that the industry hopes to obtain from the technology. The literature search highlighted the points to focus the research on. We tried to conduct the literature search primarily in peer reviewed journals provided by the databases from Umeå University library searching tool, Google scholar and the library itself. In addition to peer reviewed journals, we used a number of industrial reports which are in some cases ahead of academical literature in creating a comprehensible theoretical guidance for the technology due to lack of
academical research concerning not only the technological aspects but also frameworks of implementation. We tried to minimize the use of more popular media sources but we argue that their use is necessary due to peculiarities of blockchain development which is covered much more extensively and up-to-date by specialized technological media. Nevertheless, we used only the most reliable and specialized sources to cover the hypothesis and ideas surrounding the technology. The key words used in the literature search include: blockchain, real-time accounting, credit risk, bankruptcy prediction. In the process of literature search we identified the main academical and industrial figures involved in the research concerning blockchain-based accounting and those who shaped the theoretical framework for financial use of the technology. The literature search was of particular importance for us as we do not try to directly expand the theoretical framework and develop new general ideas of the technological improvement of auditing practices which are already in abundance but rather to test existing hypothesis in accordance with deductive research approach to fulfill the lack of empirical evidence of those technological improvements.

2.6 Ethical considerations of the research

Research ethics refers to clear formulation of research theme, purposes, the way it is designed, and how the data was collected, stored and analyzed (Saunders et al 2014, p184). The two main paradigms of research ethics should be considered and stated for a reader to be able to understand how the ethical considerations were taking into account. The first ethical position is Deontological viewpoint which states that no aim of a research, however noble it is, cannot justify loose ethical principles in the way the research is conducted, no tempering with data and deceitful ways of their obtaining are acceptable (Saunders et al, 2014 p184). Second, Teleological position exist which states that a virtuous purpose is in itself ethical even if the means of achieving it are questionable, the main point is that the benefits of the aim must overweight the harm from unethical means. A controversy arises from Teleological position as the researcher should measure the benefits against the harm equally for all affected parties which is very difficult to do in practice (Saunders et al, 2014 p184).

We hold the Deontological view and clearly describe the procedures of data collection and analysis. The financial data used for statistical analysis are solely those publicly available and contain no insider information. The data obtained through statistical analysis were thoroughly tested to contain only declared parameters. We state the authors of all ideas and theories used in this research and acknowledge their contribution.

We also recognize that when dealing with such a new and exciting topic as blockchain it is very easy to indulge into irrational exuberance and downgrade the perils. The blockchain community including even prominent researchers has a certain reputation of being overly enthusiastic. To avoid the influence of any overly optimistic preconceptions of one author of this research we allocate the parts designated for criticism to another researcher who is not predisposed to any illusions of the technology and can assess the downsides in an unbiased way.

We carefully studied and follow the Umeå University ethical code of conduct and consider research ethics a top priority.
Chapter 3 Theoretical framework

In this chapter, we discuss the origination of blockchain technology how it has been developing, we give definition to blockchain accounting and describe already existing solutions in the area. We link the blockchain solutions with the existing process of credit risk management and focus more on risk identification stage. We also describe credit risk and measures of probability of default produced by the two models Z-score and Merton’s distance to default which are widely used for credit risk identification.

3.1 The blockchain

Blockchain is a distributed database of records or a public ledger of all transactions or digital events that have been executed and shared among participating parties. Each transaction in the public ledger is verified by consensus of a majority of the participants in the system (Crosby et al 2015). A broader definition to blockchain is given by Swan (2015 p10), she defines blockchain as a giant spreadsheet for registering all assets, and an accounting system for transacting them on a global scale that can include all forms of assets held by all parties worldwide. Lazanis (2015) gives a similar definition of blockchain as public, distributed, ledger capable of storing and confirming transaction occurred in its network. He also notes that public blockchain means that it is not owned by any entity but rather the control over the network is distributed among its users. The process of verification of the transaction is conducted by users called miners who use the power of their computers or specially designed devices to solve mathematical equations required for transaction confirmation, by doing so they earn a reward in the form of bitcoin (or any other cryptocurrency) which is determined in advance (Lazanis, 2015). The difficulty of equations is growing with the growth of mining computational power to keep the time needed to write the data into a cryptographically sealed block constant.

The history of blockchain concept starts in 1999 when the technological solution was proposed to solve the problem of time-stamping easily modified digital assets such as audio files, pictures and text documents to track when a file was created and when it was changed. The solution was described in an article “How to time stamp a digital document” (Haber, Stornetta, 1991). Nevertheless, the first practical implementation of the technology was created by an unknown person or entity under a pseudonym Satoshi Nakamoto in 2009 when he launched the first electronic cash system known as Bitcoin which uses blockchain as an underlying mechanism to track and verify the transaction of this digital cash. He described the blockchain concept and bitcoin in his article “Bitcoin: A Peer-to-Peer Electronic Cash System” (Nakamoto 2008). Since then, the blockchain technology has matured and much more advanced applications than bitcoin have been created. To better comprehend different kind of solutions in this area we give a classification of blockchain based technologies as proposed by Swan (2015):

**Blockchain 1.0** – The currency and services associated with money transfers such as payment mechanisms and remittance services. Currently, there are hundreds of different types of cryptocurrencies with bitcoin remaining the biggest by market cup. The currencies
may have different features such as being tied to a fiat currency or commodity but their nature stays the same – they are used for payments and transfers of digital property.

**Blockchain 2.0** – is a layer of smart-contracts which are more sophisticated than just a currency. Smart-contracts can represent shares of stocks, bonds, options, mortgages and smart property. When the 1.0 concept represents decentralization of money the 2.0 concept is a decentralization of markets. All the technologies aiming at decentralization of relationships of different counterparties such as clearing houses, banks, companies are covered by this concept. Some interesting examples are peer-to-peer lending services Btc-jam, Bitbond, Crowd-funding platform Koinify, bitcoin prediction markets Augur, Fairlay. A potential accounting system on blockchain whose implications we explore in this thesis is, therefore, covered by the 2.0 concept as it is supposed to represent a smart-contract system where the transactions and automatically paid bills are executed and recorded.

**Blockchain 3.0** – is a blockchain applications system beyond financial markets and covers government, art, culture and science. Examples of 3.0 applications are blockchain voting systems, Decentralized Domain Name system – namecoin, anti-censorship applications like Alexandria and Ostel, and many other applications using immutability and transparency properties of blockchain to promote freedom, democracy and fair allocation of wealth.

To illustrate how important the technology is deemed by many researchers we present figure 2 produced by Swan (2016).

![Figure 2 – Disruptive computer paradigms (Swan 2016, p12)](image)

As other four computer paradigms revolutionized the world blockchain is expected to do so on even larger scale by seamlessly connecting financial world and providing great benefits by decreasing risks and enabling better allocation of resources (Swan, 2016 p11). The amount of investments coming from different types of financial institutions into blockchain-related start-ups also supports the idea of great importance of the technology for the financial world. According to PWC expert Seamus Cushley, just in nine last months of 2016 companies invested $1.4 billion into blockchain (Kennedy, 2016).

### 3.2 Blockchain in finance and accounting

The idea to use blockchain databases and infrastructure for accounting purposes stems from the nature of blockchain being a ledger for bitcoin transactions which means that it is an
actual accounting system serving to write, store and publish the transactions data occurred in bitcoin. Since blockchain can hold currency transactions without any trusted third party intermediary, note that currency transferring is one of the most heavily regulated areas of financial relationship, it can in the same way hold transactions of any type of property: shares, bonds, mortgages and others. Potentially, with more companies using blockchain systems in their transactions it will be possible to aggregate them into financial statements at any time. Lazanis (2015) was first to coherently describe the possibility of blockchain accounting by conventional companies. He emphasizes that blockchain eliminates the need for trust in any intermediary such as bank or insurance company if a company voluntarily publishes its transactions on blockchain. Yermack (2015) also states that accounting as we know it puts too much trust into the integrity of bookkeepers and auditors who in turn can be and sometimes are susceptible to corrupt behavior. Now, to verify accounting information GAAP requires auditors to obtain sufficient and appropriate evidence to support the integrity of written events which unsurprisingly results into huge costs of auditing. In their pursuit to reduce costs of auditing for their clients auditing firms were pressured to do the minimum, and find ways not to actually test the transactions but only sample above certain dollar amounts and in a very predictable approach as testifies Ellen Masterson, former global head of audit methodology at PwC in an interview to Frieswick (2003). However, the cost of public reliance on false financial information can be times more as high-profile scandal such as Enron testify (Tyra 2014). In the Enron case the accountancy firm was found guilty of obstructing justice by destroying critical accountant information (News.bbc.co.uk, 2002) Luckily, under a blockchain regime, consumers of financial information wouldn’t need to rely upon the judgement of auditors on integrity of financial statements but could with a high degree of certainty aggregate timely financial statements and make their own non-cash adjustments, for example, depreciation and inventory evaluation. To illustrate the scale of losses that companies suffer from human-induced accounting mistakes or intentional modification of data we present the findings of Bloomberg BNA’s survey of accounting professionals (Bnasoftware.com 2014): in 2013 US businesses suffered $7billion of IRS penalties due to inaccurate reporting with top 2 mistakes being:

1. Closing the books before all required, accurate data has been collected
2. Modifying asset information from past years

These kind of mistakes or sometimes fraudulent activities would be impossible under a blockchain regime, since it is impossible to change the data once it was written and the data is updated in real time.

In the absence of a comprehensive definition of real-time blockchain accounting we need to give the definition by ourselves. Real-time blockchain accounting system is a software solution which enables transactions of currency, financial derivatives, and other digital documents between two or more counterparts, stores the transaction data in cryptographically protected blocks whose integrity is verified through the process of mining, and allows the composition of financial statements at any time. For companies and their stakeholder to obtain all the benefits provided by the technology it is necessary that a real-time blockchain accounting system possesses the following properties:

1. Transparency - the transactions must visible in real time as it is the case with bitcoin
2. Immutability - there mustn’t be a programming possibility to change any data once they were entered, to ensure this, the mining power mustn’t be controlled by the company using the system.

3. Accessibility – the data must be easily accessible to a broad range of stakeholders.

Bitcoin network is somewhat a golden standard in terms of these properties but it is possible that private companies using the technology may want to restrict access to their accounting information since great transparency comes at a cost, it may content sensitive information that can give an advantage to the competitors. The right balance between transparency and competitive protection of data is yet to be established.

To explain the notion of blockchain-based accounting some researchers use the term triple-entry accounting which is described as an enhancement to conventional double entry accounting where the accounting entries of the involved parties are cryptographically sealed by a third entity (the blockchain). The seller books a debit for cash received, the buyer books a credit for cash spent but these entries do not occur in separate books but rather occur as a transaction between accounts in the same public ledger, thus creating an interconnected set of accounting records. Since the blockchain is immutable to any data amendment it is impossible to falsify or delete the written accounting entries (Tyra 2014). Interestingly, the notion of triple-entry accounting was first time described in 2005 three years before blockchain was invented. Ian Grigg (2005) described a possibility of using cryptographically protected digital receipt to verify transactions occurred between different counterparts and stored by a third party and showing if any details in the records were changed or deleted. With the advent of blockchain that processes can become automated, cheap and even more reliable as the need for a third party holding the receipts in a centralized manner is superseded by a decentralized ledger.

Another term which is used in connection with blockchain accounting is the World Wide Ledger (WWL), the term that doesn’t have a strict definition but is frequently used in blockchain-related literature. As explained by Tapscott (2016) the WWL is an ultimate implementation of a verifiable, auditable and searchable blockchain accounting system where international corporations publish all their transactions and make them available for regulators, managers and key stakeholders. A quote from an interview with Simon Taylor provided by Tapscott (2016) sharply describes the need for regulations which stems from opaque reporting: “We do a lot of regulatory reporting where we’re basically saying, here’s everything we’ve done, because what we’ve done sits inside a system that nobody else can see.” Therefore, a transparent WWL should streamline the work of regulators, accountants and auditors. In figure 3 below you can see a graphic representation of blockchain accounting system as proposed by Rückeshäuser (2017 p24). The system a full peer-to-peer network between corporations using blockchain accounting in their practices and thus committing monetary transactions among themselves solely through the blockchain in the form of tokenized currency, this allows all the transactions to registered and verified in the network. The system is also assumed to provide full transparency to the shareholders and regulators allowing external audit of the accounting entries. Proof of Work validation means that the transactions were validated through an implied mining process.
3.3 How blockchain-based accounting will transform the auditing profession

The role of an auditor is to be an independent third party to verify that the information in a company’s financial statements is accurate. The stakeholders of the company put their trust into the auditors’ judgement. Considering that the blockchain can render the element of trust unnecessary and automate the process of confirmation of the transactions occurred in the company’s ledger it is natural to assume that the auditing profession will be affected (Lazanis 2015). In an interview presented in Don Tapscott’s book “Blockchain Revolution” (2016), Eric Piscini, head of Deloitte’s cryptocurrency center, acknowledged the ability of blockchain to significantly affect the business model of auditing companies saying: “That’s a disruption to our own business model, right? Today we spend a lot of time auditing companies, and we charge fees accordingly. Tomorrow, if that process is completely streamlined because there is a timestamp in the blockchain, that changes the way we audit companies.”

Currently, auditors have to perform a variety of procedures to verify the integrity of accounting entries, they may check invoices, confirm a sale transaction with the buyer and so on (Lazanis 2016). These procedures result into hefty cost, consume a lot of time and ultimately do not guarantee that there is no discrepancy in the accounting information. Therefore, the main implication of blockchain-based accounting on the process of auditing is greatly reduced time and costs of performing auditing. Knowing for sure that all the transactions written in the accounting system indeed occurred and the amounts stated are correct allows not to spend time on manual confirmation of the accounting entries allowing auditors to spend more time on more important areas such as complex transaction entries and internal control mechanisms. It is a reasonable assumption that the technology will reduce the role of auditors and will make their work more efficient but the complete elimination of the profession may happen only in distant future. To embrace the opportunities provided by the technology and not to stay out of business in the future the big four accounting companies are developing solutions that will allow them to transform and improve their practices and keep their positions by becoming the first providers of blockchain software in the market.
3.4 Overview of the blockchain solutions under development

To once again emphasize that the technology researched in this paper is not just a theoretical concept but a rapidly developing sector of financial solutions we present an overview of the most prominent projects and software that can already be employed by companies or will be available in the nearest future.

3.4.1 Rubix by Deloitte
Rubix is a blockchain development team established by Deloitte for development of client specific application based on blockchain. One of the application developed by Rubix is PermaRec – a triple-entry accounting system which allows Deloitte to record transactions between their clients and quickly audit them in a way described in chapter part 3.2. (Tapscott 2016). Other Rubix applications include dStock app for blockchain corporate voting and Rubix check network for bank transfers.

3.4.2 Harmony by Factom
Harmony provides a blockchain-powered document catalog for mortgage industry. The Harmony catalog allows quick document assembly and immutable storage which results into money and time savings for compliance audit and convenient interaction with loan documents and data from multiple sources, the system reduces audit costs and risks and legal costs associated with lending disputes (Factom.com, 2017).

3.4.3 Balanc3
Balanc3 is an application solely focused on triple-entry accounting and built on open-source technology provided by Ethereum Foundation. The application contains features allowing different levels of transparency with ability to restrict access to financial data, it can allow external access for all stakeholders or leave it only for management and other internal users. Balanc3 includes all the characteristics of a real-time blockchain accounting system and fully satisfies the definition that we provided previously. Unlike other software it is aimed not only at multinational corporations but also for small-scale businesses providing a blockchain solution to invoicing, accounting, storing documentation and processing payments (Balanc3.net, 2017)

3.4.4 Tierion
Tierion is a blockchain cloud service that allows companies to create digital time-stamped receipts necessary for triple-entry accounting together with a verifiable record of transactions. The system can be used not only for accounting purposes but also for legal records, inventory management and medical records (Tierion.com, 2017)

Apart from the companies mentioned above there is a range of companies that develop broader software for inter-banking transactions which often include accompanying accounting systems, such companies include Hyperledger, Consensys and Ripple.
3.5 Limitations of the technology and problems on the way to implementation

3.5.1 Issues associated with business models and regulatory framework.

Despite blockchain being actively developed and receiving tons of attention and investments there still are problems to overcome on the way to revolutionizing financial world. The first problem is a variety of business model challenges. Many traditional business models may not be compatible with blockchain, and those which can integrate blockchain still need to prove being sustainable (Swan 2016). While some business models have a clear revenue model and relatively simple implementation process for example Ripple - a network providing blockchain transactions on the inter-bank level or Balanc3 – a pure triple-entry accounting system. But more complex applications such as Decentralized Autonomous Organizations have very intricate business models with no empirical evidence of their effectiveness.

The second challenge is uncertain legal framework and government regulations. There are several issues concerning regulations of blockchain technology. First of all, since blockchain solutions require some kind of cryptocurrency to operate for purposes of rewarding miners or for recording transactions (as you can remember for blockchain to correctly track inter-company transfers the transaction must be conducted in the blockchain not just the record of an external transaction) it is necessary to adjust the regulatory framework to recognize Bitcoin and other cryptocurrencies as a legal mean of exchange. The first move that will set an example can be The New York Bitlicense concerning all kind of virtual currencies including blockchain-based ones. The Bitlicense sets the requirement for companies using blockchain such as KYC (know your customer) which is especially important for consumer protection and compliance as cryptocurrencies often imply pseudonimity (Swan 2016). For regulators to fully encompass blockchain international treaties must be develop to regulate new kind of international deals, and accounting practices resulting from the technology’s implementation. It can prove to be very difficult as different authorities deal with blockchain in drastically diverse ways. For example, US Internal Revenue Service recognizes bitcoin as a financial asset and calculates taxes on its value appreciation while China banned Bitcoin and doesn’t allow banks to exchange it or use it as an investment (Tapscott 2016), according to Bitcoin.se in Sweden Finansinspektionen recognizes Bitcoin as a means of payment and requires cryptocurrency exchange services register and comply with the same requirements as other similar financial institutions (Bitcoin.se, 2012).

Another issue is the adjustment of taxation practices to encompass peer-to-peer sharing economy. It is will be hard to track deals made in the pseudonimity mode. It is already a difficult task for tax authorities to correctly tax Airbnb, Uber and OpenBazaar services and their users. A proposition was made to shift from income-based taxation to consumption-based variant which will require a major overhaul of the current taxation system (Swan 2016). As we mentioned earlier, not all companies will like a high degree of their records transparency where their competitors will receive valuable financial information in real time. However, this problem can be partially solved by restricting access to the data to management, regulators and key stakeholders. Tapscott (2016) argues that privacy is a privilege of individuals, not corporations, and that the companies have a responsibility to the society to publish all their deals openly and timely.
A broad issue arises from the fact that blockchain is a potential “job killer”. Blockchain accounting systems are designed in a way to replace tedious tasks of bookkeeping and manual verification of transactions, this may result into a full automation of the work currently done by millions of accounting clerks. This problem is already recognized by authorities, for example, in a mentioned above report by Australian Department of Industry (2014) naming accounting clerks profession as one the most likely to be replaced by a technology. While the problem may be in a reasonably distant future it should be considered.

Often, general public strongly associates blockchain with the most famous cryptocurrency – bitcoin, this fact means that the scandals aroused around bitcoin can be projected on the blockchain as the underlying technology and stem its development with sometimes redundant regulations and aversion of businesses to use it. Most of the negative events tainted bitcoin’s reputation come from its characteristic of pseudonymity. While it is easy to track transactions to the recipient it is extremely difficult to establish the person behind one or another bitcoin wallet. It allowed creation of services like Silk Road – an anonymous marketplace for illegal goods including stolen credit cards, drugs and weapons. A strong regulatory framework, especially know-your-customer requirements are necessary to prevent illegal use of the technology (Swan 2016). But there is another prospective, some believe that on a later stage of the technology’s development criminals will be discouraged to use as the use of cryptocurrencies leaves a permanent trace of illegal transactions unlike cash (Tapscott 2016).

3.5.2 Technological challenge
There are quite a few technological challenges to overcome on the way to mass adoption of blockchain, while most of them are beyond the scope of this paper, one must be mentioned. High energy consumption is required to maintain the network through the process of mining. It is estimated that bitcoin network maintenance consumes around $15million worth of electricity (Swan 2016). This is the cost of decentralization and automation, and it should be compared to the expenses currently occurring due to human-induced mistakes and costs of labor. Ultimately the trade-off doesn’t seem to be difficult (Tapscott 2016).

3.6 The problem of time lag between the financial statements
One of the cornerstone issues that we discuss in this thesis is the quarterly time lag between the financial statements published by corporations. The time lag will be completely eliminated if a company chooses to use a real-time blockchain accounting system and allows the general public or at least the key stakeholders to observe the transaction in real time. The implications of the quarterly lag have been discussed in several studies so far although not in the framework of blockchain accounting. Nevertheless, it is important to understand what kind of conclusions investors draw from timing of financial statements publishing to predict the implications of its absence.

Timely published financial reports both quarterly and annual are important to a broad range of stakeholders and for a well-functioning financial market as a whole because they provide probably the most important layer of information about companies’ financial health and future perspectives. Several researches show that in cases of delayed reports the investors response negatively as the delay is often interpreted as a sign of accounting or management
problems and also may indicate that the management is trying to temper with information. For example, the delay in annual reporting both inside and outside the regulatory grace period results into the average -1.96% drop in stock price of the company, and the delay in quarterly reports results into even higher -2.93% drop, moreover the stock returns tend to decline in the following several months as a consequence of late reporting (Bartov, DeFond, Konchitchki, 2015). There can be different reasons for delays in financial reporting apart from “technical” ones such as high difficulty of accounting or poor financial management there are reasons where the management exercises their discretionary power to delay the reports. A study conducted among French corporations show that delays are negatively correlated with bad news about the company’s financial performance as the management tries to reduce possible litigation costs by disclosing losses quickly whereas delays are positively correlated with increasing leverage of the company as growing indebtedness is often seen by investors as reducing future earning potential, notably, delays are negatively correlated with trading high trading volume and market attention as they put a higher pressure on the company to disclose the financials earlier (Aubert, 2009).

In future, it is possible that open to stakeholders and/or regulators blockchain accounting data may become a requirement for listed companies as it provides the most relevant information which will further increase the effectiveness of financial markets. Even if it will not be a requirement but rather a recommendation it is safe to assume that companies experiencing a higher pressure from its shareholders would opt for a higher disclosure or face consequences in form of a lower market equity value. Even though, we support the statement expressed by Tapscott (2016) that privacy is for individuals and, not for corporations (even more for those publicly listed) we recognize that there can be downsides of higher degree of transparency. An important downside is so called short-termism where the management tries to meet the earnings expectations for the stock price not to fall by saving on safety or refusing potentially profitable long-term projects. A suggestion has even been made to move from quarterly reporting to a semiannual to counter the short-termism effects (Hasselback, 2015). A transparent blockchain accounting system can exacerbate those effects and here we again return to a trade-off between benefits of greater transparency and its potential negative consequences which are yet to be established.

3.7 Credit risk and credit risk modelling

One area which will be undoubtedly affected by the blockchain accounting systems is credit risk modelling. To understand the implications of a reliable, timely and transparent source of financial information for the way credit risk is assessed we need to understand what credit risk is and how financial models account for different factors in evaluation of a company’s creditworthiness and probability of default.

As defined by Hull (2015), Credit risk arises from the possibility that borrower, bond issuer, and counterparties in derivative transactions may default. In a similar way credit risk is defined in the Basel regulatory framework as the potential that a borrower or a counterparty will fail its obligations in accordance with the agreement (Basel committee, 2000). Quite naturally, credit risk management is of highest importance for financial institutions lending money to companies, and for companies and individuals buying debt issued by other companies. Apart from direct counterparty risk in the process of lending money, credit risk
arises in dealing with many kinds of financial instruments, such as futures, options, bonds, a variety of financial derivatives, but also in interbank or intercompany transactions together with foreign exchange operations.

With the advent of blockchain-powered accounting systems we can expect a major shift in the way credit risk is managed. Now when we covered the basics of blockchain we can analyze the current risk management process step by step and make assumptions on how the blockchain will affect every step.

3.7.1 The credit risk management process
The process of credit risk management consists of several steps as summarized in figure 4 provided by Weber et al. (2008, p152)

![Credit risk management process](image)

Figure 4 – Credit risk management process

The process starts with risk identification which implies assessment of the borrower’s probability of default. A bank or any other lender tries to evaluate the company-borrower’s financial situation and assign it a credit rating. Here we should note that terms default, insolvency and bankruptcy while often used interchangeably in the literature can also be defined differently. Technical default and insolvency indicate a company’s inability to meet its current obligations, there is also a minor difference between default and insolvency in a sense that technical default occurs when the debtor violates conditions of borrowing agreement and can suffer legal actions, technical default and insolvency do not necessarily lead to the company’s liquidation and can be temporarily conditions. Default and insolvency can be used in a bankruptcy sense together with the bankruptcy term itself meaning a chronicle inability of the company to meet its obligations and where its total debt exceeds its assets valuation, to put it simply, where the company is worth more dead than alive (Altman&Hotchkiss, 2006 p5,6). In this paper, we use the three terms as equivalent. The risk identification process involves using different types of financial and statistical models such as Altman’s Z-score and Merton Distance to Default which we will describe in details later. The main implication of the blockchain-based real-time accounting system on the stage of risk identification seems to be a timely availability of financial information which is not just available daily instead of quarterly but is also reliable to such extent which is now only guaranteed after a through auditing process has been conducted. Later in the paper, we will show what can be a potential material impact on credit risk models in our case study of Ericsson corporation.
As the second step, the lender tries to evaluate the possible cost of the borrower-company going bankrupt and quantify the expected loss using the probability of default measured in the previous step and the loss given default in per cent (Weber et al. 2006). Loss Given Default is expressed as a proportion of the exposure in case of the borrower’s default (Hull 2015, p341) where the Exposure at Default is the total amount that a lender is exposed to. All three measures are used in calculations of the required capital for financial institutions to hold under the Basel model. Needless to say, that with a blockchain-based accounting systems the regulators will be able to evaluate whether the lender satisfies the capital requirements almost automatically. Here opens an area where an experienced auditor is needed to compile and use the provided by the blockchain information and issue the judgement on the lender’s position. But with the technology maturing, the process can be automated to the degree where a blockchain 2.0 smart-contract can be developed to trigger a warning or sanction event if the lender is dangerously close to violation of the required capital.

Then comes the pricing step where the lender includes the identified costs into the credit conditions. The credit conditions and the cost of borrowing depends on the potential costs of losses and thus the borrower is charged a premium according to the strength of its ability to pay back the loan (Weber et al. 2006). The system is familiar to everybody who tried to take a loan from the bank, the worse your credit rating the higher the risk premium you are charged. Truly great possibilities of improving this stage come from the blockchain. While it eliminates a significant part of the counterparty risk by establishing a transparent network of transactions with possible smart-contracts which can for example track changes in the borrower’s financial position and change conditions of the lending agreement accordingly, the blockchain also allows a more accurate assessment of the lender’s credit score for a more precisely established premium. Especially important it may be for personal loans of private individuals where the widely-used FICO takes into account a variety of factors such as credit history, current outstanding loans and their length, but according to some researchers and professionals the system is far from accounting all the relevant factors into the credit score. According to Marc Andreesen – a co-founder of a $4.2 billion venture capital company investing into new decentralized solutions, the FICO system is flawed as it doesn’t account for a huge chunk of relevant information provided by so called Big Data something which Pay Pal credit score system does. It generates a credit score in real-time taking into account credit card bills and history of e-bay purchases (Effinger, 2014). The blockchain can unite the two systems and account for the both sources of information if a person allows it access to his digital identity profile (Tappscott, 2016) – something that is already in development, Bitmark system, for example. In the same way, corporate credit ratings can be improved by including new types of information.

The last two stages are monitoring and working out. In the process of monitoring, different changes affecting the conditions of the lending agreement are tracked and necessary adjustments are made. We already mentioned that this process can be largely automated by smart-contracts. The working out stage comes if there is the need for the lending institution to interfere to prevent the loss of the loan and help the borrower going insolvent to find ways to repay the debt. This area is likely to stay in human accountants and lowers’ expertise as it is quite difficult to automate this process but a transparent system and immutable records should facilitate the process.
Note that the first stage of the credit risk management is useful not only for lenders but also for the management of the company and its potential investors. Timely identification, evaluation and analysis of credit risk help management to make right decisions which can improve its financial performance and increase competitiveness, while investors need to evaluate the company’s financial health during the process of bond pricing analysis and making the decision about making investments into the company’s equity. We focus the later part of this study on two widely used by corporate and private lenders and investors bankruptcy prediction models – Altman’s Z-score models and Merton Distance to default.

3.8 Altman’s Z-score model

Up to date, Altman’s Z-score model is one of the most popular and recognizable quantitative bankruptcy-prediction model, especially in its variation for private companies. Numerous accounting and financial analysis books use the model to demonstrate the transformation of miscellaneous accounting data and ratios into an easily understandable equation which produces a clear credit score for further evaluation (Moody’s Investors Service, 2000, p. 71). Edward Altman developed his renowned model from previously used univariate ratio analysis which was extensively describe by Beaver (1968). Beaver’s works provided a good ground for developing a multivariate discriminant analysis model as he established that the use of several ratios rather than only one could improve the precision of a prediction model. Altman identified five financial ratios out of 22 potentially useful ratios as having the highest prediction power when combined together (Altman & Hotchkiss, 2006 p241). Figure 5 shows the ratios with assigned weights from the original work by Altman (1968), note that for companies that are not publicly listed Market Value/Total Liabilities ratio is replaced with Book Value of Equity/Total Liabilities.

\[
Z = 1.2 X_1 + 1.4 X_2 + 3.3 X_3 + 0.6 X_4 + 1.0 X_5
\]
\[
X_1 = \frac{\text{Working Capital}}{\text{Total Assets}}
\]
\[
X_2 = \frac{\text{Retained Earnings}}{\text{Total Assets}}
\]
\[
X_3 = \frac{\text{Earnings before Interest and Taxes}}{\text{Total Assets}}
\]
\[
X_4 = \frac{\text{Market Value of Equity}}{\text{Book Value of Total Liabilities}}
\]
\[
X_5 = \frac{\text{Sales}}{\text{Total Assets}}
\]
\[
Z = \text{Overall Index or Score}
\]

Figure 5 – The Z-score model

Working Capital/Total assets ratio – this ratio assesses the ability of the company to meet its accounts payable or in other words its liquidity. The ratio is the least important contributor to the final Z-score (Altman & Hotchkiss, 2006 p242).

Retained Earnings/Total Assets – the ratio partly measures the leverage of the firm, the lower the ratio the bigger part of the company’s assets is financed through debt rather than retained earnings. There are several caveats with the use of this ratio, first, it may be significantly higher for new companies, so a qualitative assessment of the company’s business strategy is required, and second, the ratio can be skewed in case of the company’s restructurings and high stock dividends (Altman & Hotchkiss, 2006 p242).
EBIT/Total assets indicates the company’s ability to generate earnings with its assets before other obligations than those associated with the actual generation process. Despite the ratio depending on the earnings which may be tampered with Altman argues that it is at least as reliable as the cash flow analysis (Altman&Hotchkiss, 2006 p242).

Market Value of Equity/Total Liabilities – this ratio adds an important market value dimension to the analysis and measures how much of its market value the company can lose before it goes insolvent. There is a clear similarity with the Merton’s model in reasoning – the company is useless when the liquidation is preferable to continuing business. Note, that for privately-held companies and non-manufacturers the market value be replaced with book value of equity.

Sales/Total assets measure the company’s efficiency in generating sales with its assets and a low ratio may indicate problems on management or production side. The ratio varies across industries and thus the company’s ratio must be compared to those of other representatives of the same industry.

When it comes to the analysis of the final Z-score, originally, Altman proposed three categories of the final Z-score. Companies with the Z-score lower than 1.8 are in danger of going bankrupt, 1.81-2.99 the range where additional analysis is needed to establish the company’s prospects, and the score higher than 2.99 indicates strong financial health. Later, basing on a range of firms analyzed throughout 2000-2004 period Altman provided an extended interpretation of the final Z-score as compared to bond ratings. In figure 6 published in Altman&Hotchkiss (2006 p246) you can see the comparison which provides a better ground for Z-score interpretation.

<table>
<thead>
<tr>
<th>Average Annual Number of Firms</th>
<th>Average Z-Score</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>66</td>
<td>6.2</td>
</tr>
<tr>
<td>AA</td>
<td>194</td>
<td>4.73</td>
</tr>
<tr>
<td>A</td>
<td>519</td>
<td>3.74</td>
</tr>
<tr>
<td>BBB</td>
<td>530</td>
<td>2.81</td>
</tr>
<tr>
<td>BB</td>
<td>538</td>
<td>2.38</td>
</tr>
<tr>
<td>B</td>
<td>390</td>
<td>1.8</td>
</tr>
<tr>
<td>CCC</td>
<td>10</td>
<td>0.33</td>
</tr>
<tr>
<td>D*</td>
<td>244</td>
<td>-0.20</td>
</tr>
</tbody>
</table>

Figure 6 – Average Z-scores and S&P bond rating

Throughout the years since its invention the model was tested numerous times and still enjoys a great popularity. Critics of the model mainly point out that it was designed to evaluate primarily manufacturing companies and that the model does not include qualitative aspects such sustainability of the business model, legal issues, management and others which in our opinion is just a problem of the models interpretation as it never was claimed that the Z-score model is a comprehensive tool for bankruptcy prediction but rather a quantitative instrument
which incorporates a variety of the most important financial ratios and it must be used in a
broader framework together with taking into account other aspects of the company analyzed.
But what is more important in the scope of this research is that it relies on the accuracy of
the information provided in the financial statements where a lot of possibilities for tampering
with sales, hiding losses and liabilities lie, for example through a system of special purpose
vehicles as it was the case with Enron. Poor quality of financial statements can greatly
contribute to the reduction of the model’s accuracy and this is exactly the issue that can be
solved through transparent and reliable accounting system. We will show in our case study
the importance of daily updated financial system for the bankruptcy prediction models and
discuss the issue of poorly audited financial statements in credit score modelling in more
details.

3.9 Merton Distance to Default Model

The Distance to Default model for bankruptcy prediction is one of the most popular models
around. It was developed by an American economist Robert C. Merton (1974) basing on a
European option pricing model developed a year earlier by Merton, Black and Scholes. The
logic behind the model is that knowing owners of the company’s equity have limited liability
and residual claim on its assets after the holders of the debt. In this sense, the company’s
equity is similar to a European call option where the strike price of the option is the amount
of the company’s debt and thus the option pricing model can be used to evaluate the
probability of the company going bankrupt. The measure of the model is called Distance to
Default and where “distance” is measured in the quantity of standard deviations between the
company’s current value and the value of its debt (default point).

To find the Distance to Default one need to know the observable inputs: Market value of
equity, Volatility of equity return, Book value of liabilities, time to maturity of the company’s
liabilities, and the inputs that are not directly observable: Market value of the assets,
Volatility of the Assets’ return.
The unobservable inputs can be found through the original Merton (1974) formula:

\[ V_E = V_A N(d_1) - e^{-r(T-t)} DN(d_2) \]  \hspace{1cm} (1)

Where:
- \( V_A \) - market value of assets of the firm
- \( N \) - cumulative normal distribution
- \( D \) - total amount of debt of the firm
- \( r \) - risk free interest rate
- \( T - t \) - time to maturity of debt of the firm

\[ d_1 = \frac{\ln \left( \frac{V_A}{D} \right) + (r + \frac{1}{2} \sigma_A^2)(T - t)}{\sigma_A \sqrt{T - t}} \]

\[ d_2 = d_1 - \sigma_A \sqrt{T - t} \]

\( \sigma_A \) - volatility of asset returns of the firm

In turn, \( \sigma_A \) volatility of assets return is found through formula:
\[ \sigma_E = \frac{V_A}{V_E} N(d_1) \sigma_A \]  
(2)

Where \( \sigma_E \) is volatility of the equity returns of the firm.

Finally, after solving the first and the second equations we can find distance to default using this formula:

\[
DD_{\text{Merton}} = \frac{\ln \left( \frac{V_A}{D} \right) + (r - \frac{1}{2} \sigma_A^2)(T-t)}{\sigma_A \sqrt{T-t}}
\]  
(3)

Since its inception in 1974, the original Merton model has been reviewed in numerous studies and several problems have been pointed out among with possible modifications. For example, the fact that some of the inputs are not directly observable may contribute into the probability of mistakes or misevaluations being made. For example, the Market Value of Assets and the Volatility of Assets return are derived through equation (1) where the Market Value of Assets is linked with the Market Value of Equity, and in the same way the Volatility of Assets return is linked with Volatility of Equity return. Byström (2003) points out that empirical observations demonstrate the assumption of Assets return being normally distributed may not be the case as it often features fat-tailed probability distribution and volatility clustering. Another important assumption of the original model is that constant leverage ratio is used while several empirical studies show that companies try to adjust the leverage ratio to reflect changing value of the company and keep the default risk constant (March 1982), (Auerbach 1985).

To take into account all the above mentioned empirical observations Byström (2003) proposed a somewhat simplified version of the original model which uses only observable inputs and incorporates expected future leverage of the company rather than a stationary one. In our case study, we use the simplified version for several reasons: first, imagine a variety of smart-contracts inbuilt into a blockchain-based accounting system, some of them will certainly be programmed to calculate the default probabilities using existing models like Z-score and Merton, for those smart contracts to operate most efficiently only automatically obtained accounting and market information should be used and as few unobservable measures as possible should be used. Second, even though the constant debt assumption of the original model may be alleviated with daily-updated financial data it can also lead to mistakes as it is used in connection with the unobservable Market Value of Assets measure. Third, it is one of the likely future domains of human accountants to take into account information provided by automatic smart-contracts and test it through a qualitative procedure. For example, human accountants see a warning signal from a default risk tracking smart contract, to assess this machine-provided signal they can conduct a manual analysis and calculate the Market Value of assets not only through a more thorough equation (1) but also by assessing its cash flow potential and intangibles. Intangibles are very hard for a machine to evaluate, for example even a big proponent of triple-entry blockchain accounting Don Tapscott expresses doubts that the situation will change: “How does one reconcile non-transaction-based accounting measures, particularly the recognition of intangible assets? How are we going to track intellectual property rights, brand value, or even celebrity status—think Tom Hanks? How many bad films must this Oscar winner make before the blockchain
impairs the Hanks brand value?” (Tapscott, 2016). Thus, no need for machines to speculate by mathematically deriving Market assets values, better leave it for humans.

Returning to the simplified Merton model, Byström reduces the original formula to:

\[
DD_{\text{Modified Merton}} = \frac{\ln\left(\frac{1}{L}\right)}{\sigma_E (1-L)} = \frac{\ln(L)}{(L-1) \sigma_E }
\]  

(4)

Where leverage \( L = \frac{D}{V_E + D} \)

To derive the simplified formula a number of assumptions were made:

1. The drift rate of assets \( (r - \frac{1}{2} \sigma_A^2)(T - t) \) is small. The drift rate reflects a trend in price of stocks or any other assets and in practice is difficult to establish, moreover in most situations it is small relative to the first term of equation (3) \( \ln\left(\frac{V_A}{D}\right) \) and often is assumed to be zero.
2. \( N(d_1) \) factor is close to 1. Despite a common misconception \( N(d_1) \) factor is not the probability of option exercise it is rather the factor by which the present value of contingent receipt of the stock exceeds the current stock price (Nielsen, 1992). According to Byström (2016), \( N(d_1) \) is significantly different from 1 only in extreme situations when \( V_A \) is close to \( D \) and the Assets volatility is high.
3. To calculate the leverage ratio \( L \) the book value of liabilities is used as in case of insolvency it is the book value that must be paid out.

Despite being simplified, the model produces identical to the original model default measure and encompasses dynamic volatilities and leverage ratio (Byström 2016). Moreover, it is easier to adapt for automatic usage as a type of a warning smart-contract as it uses only observable measures and leaves speculations about the market value of assets to more proficient in this matter human analytics.
Chapter 4 – The case study set-up

As we outlined in chapter 2.3, our research method is a case study motivated by the nature of the research question and the need to explore the effects of the variable in a real-life context to provide a better illustration of the effects induced by the variable on a real company. The case study basically answers the question “what could the credit scores have looked like if a real-time blockchain accounting system had been implemented by the company in 2016?”.

The purpose of the case study is to model the hypothetical intra-quarterly fluctuations of credit score measures and present them in graphs which allows to illustrate the significance of their daily volatility in a clear way. While those hypothetical fluctuations may differ from ones induced by a real system once it has taken place the real-life context allows us to get closer to depiction of future credit scores. The assumption is that the real future intra-quarterly credit scores are unlikely to fluctuate higher than it is implied by a volatility assessed from actual quarterly scores. To draw the graphs, we collect financial data necessary for calculation of Z-scores and Distances to Default from actual financial statements published by Telefonaktiebolaget L. M. Ericsson. In particular, we use the quarterly reports of the corporation throughout year 2016 to calculate four measures of Z-scores and Distances to Default. One needs book values of Total Liabilities, Total Assets, Current Assets and Liabilities, EBIT, and Sales from the reports. In addition, the Stock prices and Number of Shares Outstanding on each respective date of the quarterly report to calculate the Market cap for the Z-score model. For the Merton model the stock prices throughout the entire year are required to calculate the volatility of equity returns. These financial data are shown in tables in the case study chapter before each respective calculation.

It is possible to conduct the same analysis for any publicly-listed company or even a private company although an adjustment for both credit scores models will be necessary. To conduct our case study, we chose Ericsson as it satisfies all the requirements for modelling potential intra-quarterly fluctuations, such as being publicly listed and provides quarterly financial statements. In this sense, Ericsson is a convenience choice, and is quite similar to the companies used in Byström’s (2016) case study. Less important factors for choosing Ericsson over thousands of other appropriate companies are that we are reasonably familiar with the company’s business and that it is one of the pioneer companies in blockchain development.

It is global company in the sector of telecommunications and software with its own blockchain-based projects. The fact that the company conducts research and development of blockchain technologies makes it a likely candidate to implement a blockchain accounting system in practice. Another factor is that it is listed on Nasdaq stock market which was first to implement the blockchain in its practices by developing its Linq service for launching IPOs of new corporations (Castillo, 2016). This kind of cooperation between the companies further contributes to the assumption of future quick adoption of the technology.

Here it is important to note that the findings applicable to Ericsson cannot be fully generalized to other companies, meaning that the scale of intra-quarterly fluctuations will differ depending on real quarterly fluctuations of credit score measures and some other factors
including volatility of their equity and possibly characteristics of the industry the company operates in.

To simulate the intra-quarterly, daily fluctuations of each credit risk measure we estimate the Standard Deviations of real quarterly measures during year 2016 and use the square root of time ($\sqrt{63}$ assuming 21 trading day a month) rule to scale back to the potential daily volatilities of the measures assuming that the movements are independent. The square root rule for time scaling is used to produce volatility or standard deviation for longer or shorter time periods than those used in actual estimations (financetrain.com). While it can be a rough evaluation of real volatilities that will be shown once the first blockchain based accounting system has started being used we consider it appropriate for the purposes of this paper. One way to improve the estimation is to calculate a drift (trend) term of the credit scores but it is very difficult to do in practice and does not guarantee a better estimation of intra-quarterly volatilities. After all the measures and volatilities have been calculated we generate normally distributed random numbers around the real scores and their respective means with standard deviations estimated in the previous step. Normal distribution of the random numbers guarantees the realistic estimation of the theoretical measures. We use IBM SPSS Statistics 24 for this task. The functions used are “Random Numbers” and “RVnormal”. Then we test back the numbers generated using “descriptive statistics” function to make sure that each set of numbers is normally distributed and contains means and standard deviations that were set.

To graphically illustrate the impact of daily measures availability we put them on a graph together with the actual quarterly credit scores. The method that we use in this case study is in accordance with Byström (2016) paper where he conducts the same analysis for Groupon and Apple corporations.

4.1 Quantitative data collection

There are two types main types of data used for quantitative or qualitative research – primary and secondary data. The primary data are collected specifically for the purpose of the research while secondary data were initially collected for another research or some other purposes, secondary data can include both already processed and raw data (Saunders et al. 2014 p256). The secondary data can come in a variety of forms such as documentary, multiple source, and survey (Saunders et al. 2014 p259). The documentary data include written and non-written materials. The financial reports and filings are therefore classified as secondary written raw materials most often provided by the companies on their websites and/or on the websites of the respective authorities such as SEC or other financial regulators. It is worth mentioning that financial reports aggregators such as Yahoo finance despite collecting the financials from these primary reports provided by corporations can processed in one way or another and often cannot be considered raw materials.

In our case study, we use secondary data extracted from Ericsson financial reports as it is the most reliable financial information that can be obtained in a reasonable time in the scope of our research. We use the 2015 Annual report, quarterly interim reports throughout year 2016 and the annual report 2016. We can be assured that the company provides accurate information as not only annual but also interim reports were audited by an independent
external auditor in this case by PWC. Each financial report that we used contains auditor’s review. The financial reports can be found at the company’s website (Ericsson.com, 2016).

The second type of data that we used are daily prices of Ericsson’s shares. We used aggregator of share prices provided by Financial Times engine. The reason that we didn’t use the data provided directly by the stock exchanges is that the Financial Times aggregator provides easy access to the stock prices in different currencies and allows to directly export the data into processing tools such as excel or SPSS. It is a convenience choice which nevertheless doesn’t affect the accuracy of information extracted as the Financial Times tool doesn’t process the data in any way but simply aggregates them from the stock exchanges. Moreover, the Financial Times clearly states in terms and conditions section that the data provided are historical and not real time and rounded up to two digits (markets.ft.com, 2016). This is an acceptable accuracy for the purpose of our research and we do not aim to use real-time updated data and use the historical ones throughout year 2016.

The time period of one year was chosen over a longer period as we consider it a sufficient period for the illustration of theoretical intra-quarterly credit scores fluctuations. It is sufficient because we do not try to model real fluctuations but only potential ones as is defined by the limitations of our research. Note, that currently it is impossible to try to predict the real impact as no working blockchain accounting system has been implemented. The purpose of the case study is to model with reasonable accuracy the intra-quarterly fluctuations implied by the practical design and to reflect upon them under the established theoretical framework. The practical design that we described above was developed by Byström (2016) where he uses it for the same purposes as ours only on smaller case without a broad discussion of the system’s implications beyond the two credit scores models. In this research, we expanded discussion to the whole credit management process and reflected upon not only the benefits but also the perils of such a system.
Chapter 5 – A case study

Despite the negative effects of constantly updated ledgers if blockchain accounting systems are implemented they will provide an important source of information for credit score modelling and will certainly not be ignored by investors, stakeholders, and other counterparties of corporations that choose to disclose their accounting information in a real-time manner. It is possible that more advanced credit score models will be developed in the future to deal specifically with real-time accounting information and incorporate new kind of ratios in the first time, currently existing models will be used. For specially designed models to appear the effects of real-time blockchain accounting on existing bankruptcy prediction models should be thoroughly studied. Even though there is no company using such an accounting system up to date it is possible to model the first obvious effects reasonably accurate. First, for the purpose of illustrating the effects, and second to induce further research if the effects can be considerate significant. We model these theoretical effects and then discuss the results and analyze their implications.

5.1 The Z-score intra-quarterly fluctuations modelling

In Table 2 below you can find all the necessary financial information for calculating quarterly Z-scores and the Z-scores themselves for 2016 and the final Z-score of 2015. The financial statements providing the information can be found at the official website of Ericsson corporation (Ericsson.com, 2016). Market capitalization is calculated as the stock price multiplied with total shares outstanding, the stock prices were downloaded from Financial Times (markets.ft.com, 2016). Earnings Before Interest and Taxes (EBIT) is calculated as Operating Income minus Operating Expenses. Working Capital is calculated as Current Assets minus Current Liabilities.

| Table 2 – Financial data for Z-score calculation (million SEK) |
|----------------|----------------|----------------|----------------|----------------|----------------|
| Total Assets   | 284 363       | 280 325       | 277 387       | 275 718       | 283 347       |
| Total Liabilities | 136 997     | 134 681       | 140 696       | 141 706       | 142 855       |
| Working Capital | 102 435     | 103 649       | 88 829        | 88 365        | 81 006        |
| Retained Earnings | 0           | 0             | 0             | 0             | 0             |
| EBIT           | 10 752        | 3185          | 2763          | 341           | -280          |
| Sales          | 73 568        | 52 209        | 54 108        | 51 076        | 65 215        |
| Market Cap.    | 267 804       | 264 875       | 209 193       | 202 204       | 174 838       |
| Z-SCORE        | 1,98          | 1,84          | 1,50          | 1,43          | 1,30          |

Here we show the way the December 30, 2015 Z-score was calculated:
The necessary financial ratios for Z-scores in accordance with formula shown in figure 4:

\[ Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 0.99X_5 \]  

(5)

\[ X_1 = \frac{102\,435}{284\,363} = 0.36 \]

Where Working capital is calculated as Current Assets minus Current liabilities = 189\,525 – 87090 = 102\,435

\[ X_2 = \frac{0}{284\,363} = 0 \] (no retained earnings were stated)

\[ X_3 = \frac{10752}{284\,363} = 0.378 \]

Where EBIT was calculated as Operating Income minus Operating Expenses = 26\,669 - 15917 = 10752

\[ X_4 = \frac{267\,804}{136\,997} = 1.955 \]

Where Market Capitalization is the stock price multiplied with the number of shares outstanding = 82.3 * 3254 = 267\,804

\[ X_5 = \frac{73568}{284\,363} = 0.259 \]

Plugging the numbers into the Z-score formula:

\[ Z = 1.2*0.36 + 1.4*0 + 3.3*0.378 + 0.6*1.955 + 0.99*0.259 = 1.98 \]

In the same way were calculated the four Z-scores with quarterly data of year 2016.

To produce the Standard Deviation and the Mean of the Z-scores for year 2016 we use the formula for Standard Deviation:

\[ \sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i - \bar{x})^2 } \]

(6)

Where:
\[ \sigma \] - Standard Deviation
\[ N \] – the number of samples
\[ x_i \] – individual x values
\[ \bar{x} \] – the Mean of the individuals values

In our case:
\[ \bar{x} = 1.98 + 1.84 + 1.5 + 1.42 + 1.3 = 8.04 / 5 = 1.608 \]

Subtracting the mean for individual values and taking them to the degree of 2:

\[(1.98 - 1.608)^2 = 0.1383 \]
\[(1.84 - 1.608)^2 = 0.0538 \]
\[(1.50 - 1.608)^2 = 0.0116 \]
\[(1.43 - 1.608)^2 = 0.0316 \]
\[(1,30 - 1,608)^2 = 0.0949\]

Summing up the results and dividing them by N to find Mean of Squared Differences (Variance):

\[\sigma^2 = 0.1383 + 0.0538 + 0.0116 + 0.0316 + 0.0949 = 0.33 / 5 = 0.066\]

\[\sigma = \sqrt{0.066} = 0.257\] which is the Standard Deviation of Quarterly Z-Scores.

To scale down the quarterly Standard Deviation to the daily one we divide it by square root of 63 which is the number of trading days in quarter:

\[\sigma_{daily} = 0.257 / \sqrt{63} = 0.257 / 7.937 = 0.0324\]

Now, to model the hypothetical intra-quarterly fluctuations we generate 252 Random Normally Distributed Numbers separately for each respective quarter taking into account their means and Standard Deviation = 0.0324.

We presented the results in the form of graphs featuring both the hypothetical intra-quarterly Z-scores and Actual Quarterly ones, where the black line represents Quarterly updates and the orange line represents generated daily fluctuations. Vertical axis shows the range of Z-scores and horizontal axis shows the dates of real quarterly credit scores estimation.

![Figure 7 – Z-scores with quarterly and daily accounting data.](image)

To compare we present a graph in figure 8 produced in the same way by Byström (2016 p12) for Apple corporation.

As we can see, both graphs show fairy substantial fluctuations, although Apple exhibits larger fluctuations due to a significantly higher volatility of Z-scores, the range of Z-scores over one year for Apple 5.2 – 3.2 and for Ericsson 1.98 – 1.3. The hypothesis which stems from this fact is that for companies with higher volatility of credit scores a blockchain-based accounting system will have a bigger impact in terms of shareholders and lenders scrutiny. We will discuss the implications of that in chapter 6.
4.3 Merton Distance to Default intra-quarterly fluctuations modelling

Table 3 below features all the necessary components for calculating Distances to Default in accordance with the simplified “spread sheet” formula (4). The reasons for using this model rather than the original one were provided in chapter 3.8.

Table 3 – Financial data for DD calculation.

<table>
<thead>
<tr>
<th></th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Book Value of Debt (D)</td>
<td>134 681</td>
<td>140 696</td>
<td>141 706</td>
<td>142 855</td>
</tr>
<tr>
<td>Market Capitalization ($V_E$)</td>
<td>264 875</td>
<td>209 193</td>
<td>202 204</td>
<td>174 838</td>
</tr>
<tr>
<td>Quarterly volatility of stock returns ($\sigma_E$)</td>
<td>0,173</td>
<td>0,225</td>
<td>0,118</td>
<td>0,255</td>
</tr>
<tr>
<td>Distance to Default (DD)</td>
<td>9,473</td>
<td>6,762</td>
<td>12,761</td>
<td>5,685</td>
</tr>
</tbody>
</table>

Daily Volatility of stock returns was calculated in Excel spreadsheet using Log returns to take into account compounding effect which is customary to use in Black&Scholes framework, it then was converted into quarterly volatility using the square root of time rule. The stock prices were downloaded from Financial Times (markets.ft.com, 2016).

Here is the way the Distance to Default was calculated for Q1 in accordance with formula (4):

$$DD = \frac{\ln(L)}{(L-1) \sigma_E} \frac{1}{\ln(0,337)} \frac{1}{0,173} = 9,437$$
Where $L$ is leverage calculated as 

$$\frac{D}{V_E+D} = \frac{134681}{264875+134681} = 0,337$$

In the same way were calculated DDs for each quarter of 2016. To model hypothetical intra-quarterly fluctuations of DDs we use the same method as for Z-scores by normally distributed random numbers around actual DDs and their means with quarterly standard deviation estimated from actual Distances to Default which is equal 2,793 quarterly and 0,344 daily.

The result of the modeling is presented below in figure 8.

![Figure 9](image-url)  
**Figure 9** – Hypothetical daily and actual quarterly fluctuations of Merton DDs

To compare here is the graph produced in the same way by Byström (2016 p12) for Merton DDs of Apple. Note that Byström used the original Merton formula while we used the simplified version (4). Nevertheless, the graphs are supposed to provide only an illustration of hypothetical fluctuations and the two formulae produce identical results.

![Figure 10](image-url)  
**Figure 10** - Hypothetical daily and actual quarterly fluctuations of Merton DDs, Apple (Byström, 2016, p12)
Chapter 6 – Results and discussion

6.1 The findings and their meaning in the blockchain accounting framework

As noted by Byström (2016 p8) even though the dynamic of modelled daily DDs and Z-scores looks similar on both graphs one of the two models most likely to be affected by implementation of a real-time blockchain accounting system is the Altman’s Z-score model. The reason is that the basis of the most important inputs of the model is a variety of financial ratios calculated from accounting reports. While we already have daily updated stock prices to use in credit score analysis the daily provided ratios will add an additional dynamic dimension to the model. Currently, Z-score results can be significantly affected by poorly comprised financial ratios which is especially pertinent when unaudited quarterly reports are used for analysis. And it is unlikely that the regulators will start requiring auditing interim financial reports and there is practically no incentive to do so for the management as studies show that 18% average increase in auditing costs doesn’t provide any material impact neither on quality of interim reports nor subsequent earnings (Bedard, Courteau, 2013 p4). Nevertheless, the situation will be changed with blockchain accounting systems. The daily fluctuations of credit scores are valuable not only for reasons of their timeliness and reasonably high potential volatility but also because they contain an automatically audited financial information without any added costs. Even considering that the quality of automatic assessment of intangibles may not be satisfactory the costs for human conducted auditing will decrease dramatically inducing an overhaul of costs against benefits ratio of interim reports auditing.

Considering that the significance of daily scores fluctuations is defined by the standard deviation of its quarterly credit risk measures it safe to assume that for riskier companies with high volatility of components used in one or another bankruptcy prediction model new blockchain accounting systems will have more implications. As you can see if you compare figures 7 and 8 the larger the standard deviation of quarterly scores the larger the daily fluctuations. But these implications can be equally likely negative as well as positive depending on the source of the riskiness. If the source is irrationally risky behavior of the management then the stake holders will benefit from an increased ability to scrutinize the activities of the management and greater involvement in the company’s managing processes. Otherwise the increased transparency can put an additional and undesirable pressure on the management. In figures 9 and 10 both companies are relatively safe in terms of the number of standard deviations from the bankruptcy threshold but for companies approaching the default line the fluctuations are likely to increase making blockchain accounting an important tool for earlier identification of financial troubles which can lead to a more effective process of managing the companies during their financial storms both for the companies themselves and for their creditors allowing to cut losses and/or steer it away from the troubled waters.

Another notable benefit hiding in those daily updated financial statements relevant to evaluation of a company for an investment or a lender is the ability to comprise specifically designed balance sheets and income statements. While it may sound as a convenient tweak it is more important than that. The process is currently used and known as reformulation of financial statements. The reformulation is done to focus on different aspects of the company’s
financial activities and eliminate the “the noise” of financial statements prepared under GAAP and IFRS regulatory frameworks, for example through separation of operating and investment activities (Penman, 2013 p235). The reformulation process is costly and time-consuming but can be done in seconds through a transparent blockchain ledger.

But the benefits come at a cost. When looking at the graphs, you can think about investors and lenders monitoring the changes in their counterparty company’s credit stance. The larger the fluctuations the more pressure will be exercised upon the management in the form of dropping share prices and need to explain every significant movement. This fact can greatly contribute to the problem of short-termism, something that has not been discussed extensively under a blockchain framework. Economic short termism is defined as decisions and outcomes that lead towards actions pursuing the goals that are optimal for the short term but inadequate in the long run (Laverty, 1996 p826). The factors causing short-termism problems are the pressure from capital markets and the management systems valuing short-term goals over the long-term ones. Studies show the market pressure cause indeed plays a big role in exacerbating the short-termism problems, and the decrease in market pressure contributes into the company valuing long term investments (Laverty 2004 p950). The frequency of financial reporting is also deemed to contribute to the problem. To meet public expectations over quarter to quarter results the management may decrease research and development and marketing expenditures making numbers in the short term and damaging future development (Herz, 2016). It seems reasonable to assume that with transparent blockchain accounting the situation can become worse despite of all the benefits of transparency and reliability of the reports. The solution to mitigate this potential problem hides in better interpretation of the financial results fluctuations. The managers should cultivate the culture of valuing the long-term projects and communicate the purpose of their decisions to the stakeholders. They should embrace transparency instead of trying to cook the numbers and meet every irrational expectation of the shareholders. Only under these circumstances when the management is accountable and clearly communicate their actions a synergy effect is possible from implementation of blockchain accounting practices.

6.2 – Discussion and overview of benefits, dangers and ethical aspects

Table 4 below contains all the benefits and perils associated with blockchain accounting systems that we discussed earlier and two that we only mentioned, namely cyber security issues and the necessity of mass adoption. The adoption of blockchain accounting practices is required for all counterparties. The whole point of a blockchain ledger is that it updates and stores all the transactions occurred inside the company and outside with various counterparties. But it can only do so if the transaction entry is the transaction itself, in other words all the transactions must occur in the form of token transfers inside the blockchain which is only possible if all the counterparties implemented the blockchain system. In isolation, the blockchain loses most if its benefits and is able to write and store merely intra-company transactions. Naturally, the transactions must be committed in a cryptocurrency denominated in fiat currencies used by the counterparties and be easily exchangeable for those fiat currencies. The obvious solution is developing regulated crypto-exchange services which is not an easy task. So far, crypto-markets have been suffering lack of transparency and regulations which lead to collapse of a major crypto-exchanger MtGOX with hundreds of millions of dollars disappearing in a security breach (Elgot, 2015). These facts present a
major adoption challenge that can be overcome through gradual implementation of the technology by the most common intermediary – financial institutions. Luckily, the banks and other financial intermediaries are pioneers in doing so which gives hope that mass adoption of the technology will be possible for other companies quickly and in a standardized manner.

Table 3 – Benefits and disadvantages of blockchain-based accounting systems.

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater transparency</td>
<td>Cyber security concerns</td>
</tr>
<tr>
<td>Immutability to changes</td>
<td>May contribute to economic short-termism</td>
</tr>
<tr>
<td>Constantly updated</td>
<td>High energy consumption</td>
</tr>
<tr>
<td>Provides dynamic risk measures</td>
<td>Requires adoption of blockchain accounting practices by all counterparties</td>
</tr>
<tr>
<td>Decreases cost of auditing</td>
<td></td>
</tr>
<tr>
<td>Can provide specially designed reports</td>
<td></td>
</tr>
<tr>
<td>Automates the accounting process</td>
<td></td>
</tr>
</tbody>
</table>

Practically all the benefits and some of the dangers of the technology for the accounting field are recognized in the industry reports, most notably in Deloitte’s (2016) report where they discuss the technology and how it can make the notion of triple-entry accounting a reality. Here we should note that even though currently the notion triple-entry accounting is mostly used in connection with blockchain it may mean only that the accounting entries are time-stamped. Therefore, all the benefits described above will come only with the next stage of blockchain accounting development, something that we called the World Wide Ledger in chapter 3. While the industrial reports do not really describe the implications of the technology on credit risk management in details we identified that existing miscellaneous ideas and proposals concerning blockchain accounting are applicable to every stage of credit risk management process from chapter 3.6.1. The identification stage is influenced by described above credit score modelling effects, the pricing stage by enhancements in the solvency evaluation processes which will use the “big data” advantages, and the controlling stage by great transparency and automatization through different smart-contracts.

The cybersecurity issues are somewhat controversial topic when speaking about blockchain. By its nature, the blockchain is supposed to solve many issues concerning security and immutability of digital assets but at the same time is prone to many itself. One of the security issues that blockchain is supposed to solve is system integrity. System integrity is defined as the accuracy and consistency of data over its entire life-cycle (Gault, 2017). When you here in the news that credit cards data were stolen from a bank or a merchant in most cases it
happened because the system software integrity was compromised by using malware. Note that in some cases Integrity and Confidentiality in terms of security are used interchangeable when in reality they are not. Figure 11 below shows the difference.

Currently, the integrity of system components in any organization from national security agencies to banks and other financial institutions is protected through a public key system available to the administrators of the network. In the long run the probability of a security key being compromised is not neglectable. The trusted administrators are responsible for verifying the integrity of the system’s components which is a difficult task to do, the average time for identification of a security breach is 200 days (Gault, 2017). With a blockchain based system this task is done automatically through the mining process and can be checked in minutes by anybody who has a copy of the blockchain.

![Figure 11 – security integrity and confidentiality (Gault, 2017)](image)

So, is blockchain safe? It is relatively safe in terms of data integrity issue described above but has some specific issues. First of all, the ownership of blockchain encrypted assets is verified by a key. If a key was stolen the thief will be able to get unhindered access to the assets and transfer them unrecognized by the system but it is important to understand that this is not really a blockchain security issue but rather a personal one (Berke, 2017). Also, a big problem arises if the key was just forgotten as there is mechanism of the key recovery in the blockchain. It presents a tricky situation for companies using a blockchain-based accounting system. Imagine a situation when an identification key was forgotten for an account storing tokens representing a physical asset such as barrels of oil, without a recovery mechanism it is impossible to prove the ownership of the asset but the physical object must be stored somewhere unlike a digital one (bitcoins for example) and often have a limited shelf life. However, if the accounting system is based on a private blockchain it is possible to reverse the transaction or get access to an account with forgotten key through a process of “splitting” the chain of blocks and make it start before the unfortunate event occurred (the process is also known as “forking” in blockchain jargon) (Berke, 2017). But splitting is a very difficult, controversial and irreversible process that will result into large expenditures and freeze the network for some time. There is a good but sad example of such a misfortune. The first decentralized venture capital fund that was going to become the first decentralized
autonomous organization governed directly by its shareholders through an intricate system of programming laws collapsed due to a mistake in its code, the underlying Ethereum blockchain had to split to prevent millions of dollars losses for the participants resulting into a huge dip in the price of the Ethereum cryptocurrency (Castillo 2016). The once ambitious project now stands as a dire reminder of the dangers arising from code mistakes. Here we go to another security issue, the code of any blockchain accounting system must be thoroughly tested and desirably for several years of testing period as any mistake can bring enormous losses not only for the user company but to its counterparties. Finally, as you can remember the integrity of data stored in blockchain is ensured through the mining process where the computational power of numerous miners used to write and encrypt the transactions information, it is impossible to change the data once they were written unless one takes control over more than 50% of the miners’ computational power. It is immensely difficult to do in practice as the power is decentralized among many different miners from large companies with specially designed “mining farms” to users using the power of their computers. But with the growth of competition for rewards providing by a blockchain network to the miners the centralization of computing power will grow with mining facilities being transferred to countries with cheap electricity up to date miscellaneous Chinese miners already control around 70% of mining power for bitcoin (Coleman, 2016). At a point in future we can find ourselves in a situation where slightly more than 50% of the power used in one or another blockchain is controlled by some huge mining corporation which will put the users of that blockchain at the mercy of the mining corporation.

6.2.1 Ethical aspects of blockchain
Blockchain is strongly associated with decentralization of power in almost any of its numerous applications from bookkeeping to the idea of digital governmental representation. Decentralization of bookkeeping in particular means that the management of corporations will seize to have the ultimate authority over the accounting entries going into the blockchain which can prevent accounting fraud and manipulation with the data ex post. Many unethical and illegal activities will become too hard or impossible to commit. For example, most incentive systems for the management link a certain part of the manager’s compensation to the share price performance by granting stocks or options to the manager. The options incentive scheme is known to contain possibilities for extracting personal gain at the expense of the shareholders. Backdating the options to choose a date when the price was the lowest is illegal but not unheard of (Brealey et al, 2011 p540). Under a blockchain regime backdating is practically impossible. Another aspect contributing to solving some ethical problems is high level of transparency of the blockchain ledgers exposing vital information about the company to its shareholders leading to greater accountability of the management. As noted by (Tapscott, 2016) the blockchain brings a new level of business Integrity consisting of Honesty (with employees, partners, shareholders and public), Consideration (fair exchange of benefits or detriments), Accountability and Transparency, with shareholders making judgement on the fairness of their CEO’s bonuses and making sure that budget organizations are running at minimum. Blockchain can shift the power towards employees, shareholders and the public in general which we consider a significant ethical improvement in business.

By improving the reliability and transparency of data and releasing enormous resources currently necessary for bookkeeping and auditing blockchain-based accounting can give a boost to Integrated Reporting. Integrated Reporting is defined as “concise communication
about how an organization’s strategy, governance, performance and prospects lead to the creation of value over the short, medium and long term” (Integratedreporting.org, 2013 p7). Integrated Reporting allows to solve the issue of disjointedness of financial reporting and gives a better insight into the company’s strategy and its societal and environmental impact (Barth et al, 2016 p5). The assessment of all aspects of corporations necessary for integral reporting is the area that can be solely done by human experts and auditors which is basically the answer to the question “what all auditors will do after blockchain has taken over their work?”.

However, the same characteristics that give the blockchain its benefits contain the dangers of ethical nature. First of all, immutability and transparency properties may sound good when applied to the corporations but may become a nightmare when applied to private persons. All the financial information about private individuals will be stored in the same way as corporate entries when individuals will be interacting with the companies. Personal privacy may be in danger. If you look again at figure 11 you can see the two types of security issues, while blockchain improves system integrity it may at the same time exacerbate the privacy issue. The current proposal to tackle privacy problems with multiple types of digital identity – different identity for different types of interactions that contain only the necessary information (for example credit history and current indebtedness when interacting with banks) is very difficult to implement in practice and in the long run the breaches in privacy are very likely.

Another issue ethical issue is associated with pseudonymity property of the blockchain, while it can be tackled with Know-Your-Customer regulations in the corporate world very little can be done with the case of public blockchains such one powering bitcoin. Difficulties with tracking bitcoins to its real-life users and the possibility to use anonymously gave birth to ugly cases of bitcoin usage for guns and drug trading and even assassination markets. For example, the notorious SilkRoad internet marketplace which offered a broad range of drugs and weapons in exchange for bitcoins. SilkRoad was ultimately brought down by the FBI and the man behind it arrested, the assets seized during the arrests are estimated at $28 million with annual sales that were happening at the marketplace estimated to be $22 million (Greenberg, 2012).

There cannot be a universal recipe to tackle the ethical problems coming from the blockchain – the technology where decentralization is the cornerstone of its benefits. But at least a good regulatory framework and deeper understanding of its danger can help to reduce them. As it has been happening with the internet with the technology maturing new effective methods of its proper usage will be developed together with solutions to its problems.
Chapter 7 - Conclusion

Returning to the research question established in chapter 1:

1. What is the potential material impact on credit risk identification models if the financial data are available daily rather than quarterly?

Through our simple case study, we show the theoretical daily fluctuations of credit scores using two of the most popular bankruptcy prediction models Altman’s Z-scores and Merton DD model. Having done the analysis, we can say that the material impact is largely confined within the boundaries set by the standard deviation of quarterly measures, or in other words, we can say the material impact is the fluctuations themselves but how big are they is defined by the daily volatility of the measures which in the absence of a real blockchain accounting system can only be deduced from the quarterly volatility. The material impact with all its implications will be higher for troubled companies with high volatility of the credit scores. The implications for companies that are most likely to be affected by the technology can be both positive such as greater transparency of financial health and early identification of troubles, and negative such as a greater pressure on the management to meet the expectations of the stakeholders as soon as possible. This we consider our first contribution into credit risk modelling under the blockchain regime together with discussion of the blockchain’s influence on every stem of the credit risk management process in chapter 3.6.1.

Concerning current theoretical framework for blockchain accounting, through analysis of the literature including industrial reports, scholarly articles and books we established that the blockchain in accounting while being extensively covered technologically with numerous examples of focused accounting solutions misses important points of consideration. Current theoretical framework covers reliability, immutability, decentralization and relative cyber-safety aspects of the technology as its most valuable characteristics for usage in accounting. However, while it considers technological challenges of blockchain’s implementation the societal impact is covered in somewhat overly-positive manner. One of the most important negative consequences that has been missed in the literature is a very likely increase in economic short-termism problem. The identification and discussion of this problem under a blockchain accounting framework is our main contribution into improvement of the current theoretical framework.

We tried to cover all the benefits and disadvantages of the technology’s implementation in accounting in table 3 but we recognize that the list is far from being comprehensive and future research especially focused on societal impact is needed. We also recognize that our analysis of the material impact may differ from what is to come in reality as the models we used were not designed to include high-frequency daily updates of accounting information.

These are large topics for future research. First stems from the fact that no bankruptcy prediction model was designed to deal with constantly updated ledgers and thus the resulting daily volatility of their measures has no clear interpretation. The subject must be thoroughly researched with the aim of better comprehension of newly available data where a startling amount of these data can be misunderstood and hurdle the work of management and
regulators. Second, new credit scores models should be developed to incorporate the daily updates and provide a meaningful interpretation. One of the main requirements for these models should be their direct integration in blockchain accounting systems presumably in the form of smart-contracts tracking the financial health of the company. Otherwise the cost of constant manual scrutiny can be comparable to the current cost of accounting and outweigh the benefits. The measures and signals produced by the smart contracts must be easily available for human auditors and provide the basis for further manual investigation and do not try to assess the qualitative factors by making far-fetched mathematical assumptions.

We fulfill the purpose of our research by comprising fragmented theories and ideas of the blockchain’s usage in accounting and credit risk modelling, we discussed most of the implied blockchain characteristics relevant to improve accounting and auditing practices and outlined the ideas applicable for each stage of credit risk management. While it is not enough for creating a practical guidance for the technology’s implementation in accounting it can be used as a foundation to build upon. One of the main implications for practical usage of the technology is that specially designed models should be used to gain the full advantage of daily available data and that the users should bear in mind the ethical issues arising from great transparency of the system which can lead to exposure of sensitive information including private information of the company’s clients and employees.

While the blockchain technology seems to be a great solution for problems long-haunting auditing, accounting and corporate governance including poor quality of financial statements, astronomical costs of auditing both in terms of money and time, lack of shareholders’ control over their company and insufficient security of financial data a company wishing to implement it should proceed carefully. As the first stage of the technologies introduction into the company’s practices we would suggest using it for internal bookkeeping and gradually expand it onto external transactions processing. The financial sector as a whole is in a dire need for not just another tweak but a truly revolutionary overhaul. However, the danger of overlooking troubles and not doing enough research or being overly positive on societal impact can come from the property of being revolutionary and “new computing paradigm”. We are talking about the enormous buzz around the technology and a somewhat “cult” status of blockchain, the title containing the word “blockchain” in a press release collects a lot of media attention and the same word in a job description is more likely to attract top-class professionals than words "ledger", "reconciliation", "settlement" or "notarization" (Arceiri, 2016). You may have already noticed an uncanny resemblance of blockchain buzz to the dot.com crisis with tons of media attention, revolutionary paradigms and skyrocketing prices of associated securities with one bitcoin being valued around $2000 dollars and Ethereum being valued at $133 per unit (compare it to around $7 in December 2016) (Poloniex.com, 2017). It is very easy in such conditions to forget about precautions and indulge into overstating of the blockchain abilities. Considering the nature of this research limitations further research is needed to analyze the impact of blockchain accounting on other credit score models as we use quite a small sample - only two out of many, it would help to identify the best model to incorporate daily available and technically audited financial data and ultimately help to develop special smart-contract-like models. This can be comprehensively done when the first blockchain-powered system has been implemented but even now further research can lay good ground by taking into account all possible repercussions - technological, environmental, societal, and monetary alike.
Chapter 8 – Quality of the research

Here we describe the quality criteria applicable to our research and clarify the generalizability of our results as well as reliability and replicability.

8.1 – Reliability and replication

According to Adams et al. (2007 p235) reliability is defined by consistency of the research measurements or the degree to which an instrument measures the same way when it is used under the same conditions with the same subject. As it stems from the definition, reliability is verified through replication, meaning that if the results can be reproduced in a consistent way the study is reliable. Note that reliability doesn’t evaluate validity of the study but only its consistency (Adams et al. 2007 p235). In our study, we carefully describe every step of how to the intra-quarterly fluctuations were modelled and in the same way it can be done by anybody. One wishing to reproduce the same fluctuations for Ericsson or any other company can follow our description or the one provided by Byström (2016). The difference between our method and the one that Byström invented is that we use a simplified version of the original Merton model. The fluctuations were produced through generating random numbers with previously estimated means and standard deviation which means that the daily credit score fluctuations represented by those numbers will not be the same when one generates them again but they will certainly be consistent in terms of normal distribution which will allow to draw the same conclusions. Moreover, the method is easily modified if one wishes to add accuracy through estimating a drift rate for credit scores or in any other way.

8.2 – Validity and generalizability

Validity refers to the strength of the researcher’s conclusions, inferences or propositions, in other words the degree to which the researcher measures what is supposed to be measured and the accuracy of the measurements (Adams et al. 2007 p237). There are four common types of research validity. Internal validity examining the causal relationship between the programme and the outcome; external validity asking about the ability to generalize the results to other settings; Construct validity asking if there is a relationship between how the researcher operationalized concepts in the study to the actual causal relationship that he/she is trying to study; Conclusion validity refers the degree to which conclusions we reach about relationships in our data are reasonable (Adams et al. 2007 p237). Term generalizability is therefore commonly interchangeable with the term external validity (Saunders et al. 2014 p158).

Internal validity is ensured in our research design as the daily credit score fluctuations are modelled with and fully depend upon the inputs assessed through the variability of quarterly measures. In other words, the answer to the question if there is the causal relationship between volatility of quarterly measures and daily ones is yes as the daily measures are not real ones but produced through the quarterly. It is important to understand that we do not try to establish the causal relationship but assume them as it is the only method that is currently available to produce the theoretical daily measures for illustrational purposes which we emphasize throughout the study. Coming to generalizability of our study, the findings in
terms of the modelled fluctuations and their scale are only applicable to the company we used and for illustrational purposes and others (for example to produce a certain advice to the company or analyze if a system in question would help in one or another situation regarding a particular company) new individual modellings are necessary. To be able to generalize, the assumption that the daily measures will fluctuate depending on the company’s industry, riskiness and other factors must be tested in further research when we have a real working blockchain system. To better describe the construct validity, consider the following quote from Trochim (2006) “When we claim construct validity, we're essentially claiming that our observed pattern -- how things operate in reality -- corresponds with our theoretical pattern”, we cannot observe that our theoretically produced measures correspond to those that will be in reality as no real blockchain accounting system is in place. We emphasize it in the delimitations of our research. Finally, the nature of our case study is such that we don’t study causal relationship between the two variables but rather assume them to produce one from another for, once again, illustrational purposes, therefore the conclusion validity is not applicable here.
References


48