UNIVERSITY OF LJUBLJANA FACULTY OF ECONOMICS

MASTER'S THESIS

OBJECTIVE AND SUBJECTIVE INFORMATION PROCESSING IN FINANCE

Ljubljana, December 2017

MARJANA SUBOTIĆ

AUTHORSHIP STATEMENT

The undersigned Marjana Subotić, a student at the University of Ljubljana, Faculty of Economics, (hereafter: FELU), the author of this master's thesis entitled Objective and Subjective Information Processing in Finance, prepared and written under the supervision of PhD Aljoša Valentinčič, Full Professor,

DECLARE

- 1. this master's thesis to be based on the results of my own research;
- 2. the printed form of this master's thesis to be identical to its electronic form;
- 3. the text of this master's thesis to be language-edited and technically in adherence with the FELU's Technical Guidelines for Written Works, which means that I cited and/or quoted works and opinions of other authors in this master's thesis in accordance with the FELU's Technical Guidelines for Written Works;
- 4. to be aware of the fact that plagiarism (in written or graphical form) is a criminal offence and can be prosecuted in accordance with the Criminal Code of the Republic of Slovenia;
- 5. to be aware of the consequences a proven plagiarism charge based on this master's thesis could have for my status at the FELU in accordance with the relevant FELU Rules;
- 6. to have obtained all the necessary permits to use the data and works of other authors which are (in written or graphical form) referred to in this master's thesis, and to have clearly marked them;
- 7. to have acted in accordance with ethical principles during the preparation of this master's thesis, and to have, where necessary, obtained permission of the Ethics Committee;
- 8. my consent to use the electronic form of this master's thesis for the detection of content similarity with other written works, using similarity detection software that is connected with the FELU Study Information System;
- 9. to transfer to the University of Ljubljana free of charge, non-exclusively, geographically and time-wise unlimited the right of saving this written final work of studies in the electronic form, the right of its reproduction, as well as the right of making this written final work of studies available to the public on the World Wide Web via the Repository of the University of Ljubljana;
- 10. my consent to publication of my personal data included in this master's thesis and in this declaration when this master's thesis is published.

Ljubljana, December 2017

Author's signature: _____

TABLE OF CONTENTS

Π	NTRODU	JCTION	1						
1	FROM	I (MODERN) TRADITIONAL FINANCE TO BEHAVIORAL FINANCE	2						
	1.1 Tra	ditional Finance View	3						
	1.2 Beh	navioral Finance View	6						
	1.3 Cor	nplementary or Orthogonal Relationship	.11						
2	ORIF	TIVE AND SUBJECTIVE MEASURES FOR FUTURE FORECASTS							
-	AND INVESTING REHAVIOR								
	2.1 Info	prmation-Processing Model	. 15						
	2.1.1	Classical Approach to Cognitive Science	. 15						
	2.1.2	Connectionist Approach to Cognitive Science	. 16						
	2.1.3	Hybrid Structure of the Organization of the Mind	.17						
	2.1.4	Neural Network Models in Finance	. 18						
	2.2 Cor	ncept of Information	. 22						
	2.3 Fin	ancial Reports as Objective Information Carriers	. 23						
	2.3.1	International Financial Reporting Standards	. 24						
	2.3.2	Financial Reporting Process	. 25						
	2.3.3	Numerical Cognition and Numerical Values	. 26						
	2.4 Fac	e Perception and Business Leaders as Subjective Information Carriers	. 27						
	2.4.1	Facial Appearances of Business Leaders as Carriers of Subjective Information	. 28						
	2.4.2	Research Methods for Assessing the Subjective Information Carriers	. 28						
	2.4.3	Personality Traits and Leadership Theory	. 31						
	2.4.4	Emotions and Assessment of Subjective Information	. 33						
	2.4.5	Hybrid Approach Combining Analytic and Holistic Views	. 35						
3	COMB	BINATION AND INTERPRETATION OF OBJECTIVE AND							
	SUBJE	CCTIVE INFORMATION	. 36						
	3.1 Ent	repreneurs as Subjective Information Carriers in Case of Insufficient Objective							
	Info	prmation	. 36						
	3.2 Infl	uence of Financial Literacy on Assessment of Objective and Subjective							
	Info	prmation	. 38						
	3.2.1	Question of Financial Literacy	. 39						
	3.2.2	Financial Literacy in Relation to the Objective and Subjective Information-							
		Processing	. 42						
	3.2.3	Role of Social norms for Information Processing	.43						
4	DISCU	USSION	. 46						
6		STON	40						
U	UNCLU	5101,	. 49						

REFERENCE LIST	
----------------	--

APPENDIXES

LIST OF FIGURES

Figure	1. Nu	ımber	of	sources	including	keywords	Behavioral	Economics	and	
	Neuro	pecono	mics	from 20	02 to 2016.					5
Figure 2. Number of sources including keywords Behavioral Finance and Neurofinance										
	from	2002 to	o 201	16	••••••					8
Figure 3	. Numł	per of s	ourc	es includ	ing keywor	ds Agent Ba	ased Models,	Network Ana	ılysis	
	and F	inance	fron	n 2002 to	2016				1	. 1
Figure 4	4. Num	ber of	sou	rces incl	uding keyw	ords Neura	l Networks a	and Finance	from	
	2002	to 2010	5						2	20
Figure 5	. Numt	per of s	ourc	es includ	ing keyword	ds Financial	Literacy from	n 2002 to 201	64	0

INTRODUCTION

In the field of behavioral finance, research is built upon the foundation of different disciplines, researching human behavior while incorporating important insights from the traditional financial field (Ackert & Deaves, 2010). The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2017 was awarded to Richard H. Thaler for his contributions to behavioral economics, thereby acknowledging his work on limited rationality, social preferences, and lack of self-control in the field of behavioral economics (Nobel Media AB, 2017). In the light of fast-paced technological developments, the possible creation of a bubble in relation to the emerging cryptocurrencies – Fry & Cheah (2016) present sophisticated modeling of financial bubbles and crashes, or as Trueman (1994) presents the notion of observed herding behavior in analysts' forecasts –, or the prospect theory that presented a critical view and alternative to the expected utility theory of decision-making process under risky conditions (Kahneman & Tversky, 1979), are introduced as possible explanations for developments in financial markets.

The objective of the master's thesis is to propose a new framework for understanding the interplay between these different fields. New theoretical and research thoughts about the relationship between the traditional and the behavioral finance are discussed through the lens of understanding objective and subjective information processing and presenting general models of information processing of human mind (some of the models of human mind presented in Bermúdez, 2014). Information is classified as objective or subjective, where the objective information is financial information extracted from the financial reports, and the subjective information is information extracted from the facial features of the business leaders. It is important to emphasize that such discussion might not give definite answers, what is more, it might raise even more questions.

This thesis is conducted with the use of theoretical-analytical review of professional literature, scientific discussions, and studies in the field of finance, behavioral finance and cognitive science, contributed by foreign and domestic experts. Through the acknowledgment of "what was" and "what is" the state at the moment, it presents a discussion of the current situation in both fields, their relationships and implications in the theory and field of behavioral finance and investing literature. The literature is analyzed within the analytical approach and with the use of descriptive and compilation method of research to combine different insights from various fields.

The thesis opens with a brief presentation of traditional and behavioral finance, complexity theory, while also exploring the relationship between fields. Assumptions from fields are presented in order to present a theoretical framework and to shift from traditional to behavioral finance. The second part presents the general human mind processing approach, whereas general models for information-processing process are presented from the field of cognitive science: classical model, connectionist model and hybrid structure of the mind

organization. Afterwards, the concept of information is presented with approaches of objective information processing for future forecasts and investing, based on information from financial reports, and subjective information processing for future forecasts, based on information from facial appearances of business leaders, while presenting important studies for both approaches. In the third part, the importance of subjective information is presented within the asymmetric information environment, namely within the environment which lacks objective information, that is the field of entrepreneurship. This is followed by a discussion on financial literacy and its importance for the information-processing process.

1 FROM (MODERN) TRADITIONAL FINANCE TO BEHAVIORAL FINANCE

Financial decisions are inevitable in everyday life, and are perceived as complex. They impose a great responsibility on every individual to make the most optimal decision, otherwise the cost of the suboptimal financial decision could have certain consequences for the individual and the society as a whole (Agarwal, Driscoll, Gabaix, & Laibson, 2009; Estelami, 2008).

In the traditional financial theory, together with the central efficient market theory, which peaked dominance in the academic world in the 1970s, the center of discussion in the economic theory was the rational expectations revolution. Under assumptions of rational expectations, the prominent finance model aimed to bind together the finance and the whole economy in one elegant theory. In the first years, the theory seemed to have presented a huge accomplishment in the field with various empirical results, providing support for the theory, and plausible explanations for certain anomalies (Shiller, 2003).

In later works, numerous observed anomalies raised further questions, since the theory focused mainly on objective market situations, but failed to explain anomalies or questions about sources of volatility in markets (Shiller, 2006). Some of the explanations about the stock market data on aggregate level or individual trading behavior could not be easily understood within such theory (Barberis & Thaler, 2003).

Consequently, possibilities for looking for new explanations emerged and a shift in discussions was made in the 1990s from econometric analyses of time series in prices, dividends and earnings, towards models that would include also human psychology and its relations to financial markets, towards development of behavioral finance (Shiller, 2003).

De Bondt & Thaler (1995) advocate that such shift did not present the complete story occurring, since economists from previous generations greatly acknowledged the importance of the flawed nature of human decision-making process.

At this point, for better understanding of the concept of paradigm used throughout the thesis, the concept of paradigm is here understood as it was firstly introduced and later rethought and

restructured by Kuhn (1970) for natural sciences (and philosophy) as "what members of a scientific community share, and, conversely, a scientific community consists of members who share a paradigm" (p. 176). In such understanding (Kuhn, 1970), paradigm enscribes all sets of concepts, theories, research methods, postulates, values and standards for problem solutions situations of legitimate contribution to certain scientific field, where the scientific community is in agreement of these sets (hence, paradigms are seen as "constitutive of science" (p. 110)), where the researchers who base their research on shared paradigms are "committed to the same rules and standards for scientific practice" (p. 11). Kuhn did not see the concept of paradigm as completely suitable for social sciences. However, in the later time, Handa (1986) introduced the idea of social paradigm, taking into consideration the social institutions and circumstances that shaped or could change a paradigm. According to Kuhn (1970), a paradigm shifts present extraordinary episodes of research leading to emergence of anomalies that cannot be explained by present sets of the research framework, hence new sets of commitments, practice, and a new basis for practice of science occur. According to Handa (1986), a shift in the framework occurs when there is a change in the way individuals and groups perceive reality, where it furthermore changes also the sets of experience, evaluations and beliefs, and frameworks for maintainance of social interactions and social institutions.

The discussion between traditional and behavioral finance having such concept allows to clearly present their standings, especially since behavioral finance in itself extracts large portions of insights from other fields and disciplines, as Ackert & Deaves (2010) point out at some period in time, therefore, the future theory will be also shaped by research findings from behavioral finance.

In this chapter, we take into consideration the traditional and behavioral finance views with their underlying assumptions. This is followed by a presentation of the impact of the complexity theory ideas on the field of finance, and concluded with a proposition of a possible relationship between them as an orthogonal relationship.

1.1 Traditional Finance View

The basis of traditional financial models lies in economics, with the dominant paradigm of neoclassical economics, where individuals and firms act as a self-interested agent with an objective to optimize as best as possible with the given resources and constraints on them, where in the set of alternatives they are informed about the probability distributions of all outcomes and they maximize the expected utility (Simon, 1955).

One of the central theories of the traditional finance view is an efficient market hypothesis, assuming that markets constantly reflect complete information in prices, where in the market there are rational investors collectively and uniformly evaluating information, the consequences are efficient and fair prices of securities (Peters, 2003). In this framework, capital markets also perform a critical service. It is assumed that resource allocation is done in the best way possible through efficient and well-performing markets, understanding that a

notion of such definition of efficient markets inherently depends on information (Ackert & Deaves, 2010). With the assumption that investors in such efficient financial markets process information correctly, and that the efficient market price incorporates all information, there cannot exist a strategy that would allow for excessive risk-adjusted average returns (Barberis & Thaler, 2003). Risk measure in such framework is understood as a quantitative measure, building on aggregate-level data from the participants in the financial market, within the macroeconomic assessment and building on the assumption of linear relationship between risk and return (Ricciardi, 2008).

Further assumptions in the traditional finance are based on the idea that individual psychological processes are not playing a role in the investment decision-making process (Nofsinger, 2011). Individual decision-making is assumed through the lens of neoclassical economics. Firstly, individuals are assumed to have rational preferences about possible outcomes in the future; secondly, individuals maximize their utility, while firms maximize their profits; and thirdly, individuals can make independent decisions based on all relevant information (Ackert & Deaves, 2010). Hence, the presence of assumptions of rationality, people are rational agents, making rational decisions, deciding for choices in respect to maximizing expected utility; and assumption of people as rational agents that are making unbiased future forecasts when predicting the outcomes about the future, while with the emergence of new information such agents follow Bayes' law for updates of their beliefs. In coherence with the efficient market hypothesis, if there was a not fully rational agent, rational agents would correct such influence on security prices within a long-term perspective through the process of arbitrage (Barberis & Thaler, 2003).

Financial concepts that are still crucial for the field of finance in present time must be acknowledged (Hens & Rieger, 2010). It is important to acknowledge that traditional finance with underlying assumptions about complete rationality and neglecting psychological or neuroscientific insights brought many important theories (e.g., modern portfolio theory, arbitrage theory, etc.). Nevertheless, when considering traditional finance approach with underlying assumptions of brain processing as analogical to digital computers (and with underlying assumption of full rationality), such assumptions cannot fully hold (Nofsinger, 2011). Such analogy without the strict assumption of rationality, building on advances of Alan Turing and consequent idea of computational models and information processing in mind, was present also in the field of cognitive science, where the conclusions are not straightforward and assumptions about the information-processing process are still being questioned and updated within limitations that research in this field possesses (Bermúdez, 2014).

Since possibilities for looking for new explanations in the financial sphere emerged, and building on observed data from the market that provided unexplained anomalies (Barberis & Thaler, 2003), the shift in discussions was present in the 1990s from econometric analyses of time series in prices, dividends and earnings, towards models that include human psychology and its relations to financial markets and development of behavioral finance (Shiller, 2003). In

relation to the risk measure, within the traditional finance view, the risk is seen as a quantitative measure, where with the emergence of behavioral finance the consideration and incorporation of qualitative characteristics of such measure emerge (Ricciardi, 2008). In support of emergence of such field and based on the notion of many empirical research evidence, Thaler & Sunstein (2008) argue that, as one of the fields of human information processing, human forecasting and decision-making processes are flawed as on the contrary to assumptions of the traditional finance view.

However, the shift is not present only in the field of finance, it is also seen in the economics, with the emerging field of neuroeconomics, providing new account for the theory of choice, incorporating also advances from the neuroscientific and psychological insights, where the definitions present and approaches taken among different authors are still heterogeneous (Fumagalli, 2010).

A certain rise of importance of the fields of behavioral economics and neuroeconomics in discussions is seen in Figure 1, with the rise in the number of sources that include keywords – behavioral economics or neuroeconomics – in the text in the last 15 years. Numbers of sources were gathered from the academic database of the Digital Library of University of Ljubljana (DiKUL), where the sources included were scientific articles, books and e-books, conference proceedings, theses and dissertations published during the observation period from 2002 to 2016 for each year (table with exact numbers for Figure 1 can be found in Appendix A, Table 1).



Figure 1. Number of sources including keywords Behavioral Economics and Neuroeconomics from 2002 to 2016

A similarly increasing trend is also evident from the results of three studies by Geiger (2017), taking into account the limitations of such studies (namely the use of respective terms in the paper). Results of studies, carried out during the time period from the mid-1990s to the year 2013, present a straightforward, uprising trend for publications, including term behavioral economics, with higher frequency among top journals. In relation to the central economic terms (e.g., monetary policy, general equilibrium, and others), these frequencies are still lower for the overall period, but this difference is smaller if taking into account only years from 2010 to 2012, which is also consistent with the findings presented in Figure 1. Regarding the study of citation counts, the same author reports that Simon (1955) has been cited at the level of quotation of important works of Milton Friedman, while Kahneman & Tversky (1979) have been cited in approximately two thirds of quotations of any work published by John Maynard Keynes.

1.2 Behavioral Finance View

Hens & Rieger (2010) understand behavioral finance as a subfield of finance, mainly emerging from the critique of a rational investor that should follow expected utility theory. They argue that the classical approach to the rational decision theory, in light of empirical observations, shifted to a more descriptive approach which they name "behavioral decision theory" (p. 11) that consequently leads to the emergence of behavioral finance. Behavioral finance can be more specifically understood as a field with underlying assumptions of not fully rational investors, where the behavior of irrational investors cannot be corrected by rational investors and can importantly impact prices on the long-term (Barberis & Thaler, 2003). Hence, the scope of behavioral finance is already present in situations where there is an emergence of observation which needs to be addressed as deviation from perfectly rational behavior. In some views, such assumptions lead to lack of clear distinction of problems inside and outside the scope of behavioral finance, resulting consequently in the possible integration of the behavioral view into classic theories with an emphasis on improving the understanding of financial markets (Hens & Rieger, 2010).

A wave of behavioral finance gathered its momentum especially with an emergence of numerous anomalies to which an efficient market hypothesis could not sufficiently provide an explanation (Shiller, 2003), and the establishment continued with Simon's bounded rationality theory (1955) and with Kahneman & Tversky's prospect theory (1979). Notions following the bounded rationality softened the strictness of assumption of individual rationality (Barberis & Thaler, 2003). The bounded rationality theory takes into account cognitive and computational limitations of the individual complex decision-making process, deviating from assumptions of neoclassical paradigm (Simon, 1955).

Further support for the fallacies in the human complex decision-making process is presented by the prospect theory, where on the notion that individuals underweight certain outcomes in relation to certain probabilities and produces consequent aversion effect, while also presenting framing effect of inconsistent choices under different choice architectures, they developed a model with decision weights and assigning value to possible gains and losses with focal reference point that varies with every individual (Kahneman & Tversky, 1979). A further shift to establishment of behavioral finance followed with subsequent empirical research and as a critique to the expected utility theory and assumptions from the traditional finance and neoclassical economics. Consequent research presented new insights that investing decisions and forecasts were sometimes made based on the intuition of the investor (Harteis & Gruber, 2008), and were flawed by cognitive biases such as overconfidence and attribution bias (Daniel, Hirshleifer, & Subrahmanyam, 1998), home bias (Coval & Moskowitz, 1999), illusion of knowledge and illusion of control (Nofsinger, 2011), role of emotions (Montier, 2007), and other phenomena, based on the psychological and neuroscientific findings.¹

Interest in the field of behavioral finance in the discussion in the academic sphere presented an upward-rising trend in the period of 2002–2016, as presented in Figure 2, while the discussion within the field of neurofinance was still very rare. In this thesis, neurofinance is understood as described by Ascher, Da Silva, Da Veiga, & Souza (2016) to be a field providing answers for the behavior of financial decision-makers with tools of neuroscience, but still as authors state "at stage of an embryo" (p. 12). It applies the same logic and data acquisiton for data collection, observational units and logic behind the graph as in Figure 1. Numbers of sources were gathered from the academic database of the Digital Library of University of Ljubljana (DiKUL), where the sources included were scientific articles, books and e-books, conference proceedings, theses and dissertations published during the observation period from 2002 to 2016 for each year (table with exact numbers for Figure 2 can be found in Appendix A, Table 1).

Similar trend, as presented in Figure 2, is noticed in the field of behavioral finance in results of the study made by Huang, Shieh, & Kao (2016), observing the period 1995–2013, and providing similar conclusions of emergence of articles studying behavioral finance.

With advances in the fields of neuroscience and cognitive science for understanding the human mind and with advances and establishments in behavioral economics and behavioral finance, regulators and international organizations attempt to incorporate new insights in their policy making processes. The World Bank aims to present idea of importance of taking into account processes of mind and processes of the influence of society in their World Development Report (The World Bank Group, 2015). Especially in the fields that are dealing with policies and interventions of human individual and collective behaviors.

¹ At this point further biases will not be presented and discussed since they are not the main objective of the current work. For more information about biases in investing see e.g., Nofsinger (2011) and Montier (2007).



Figure 2. Number of sources including keywords Behavioral Finance and Neurofinance from 2002 to 2016

In their report they present various findings ranging from different disciplines (neuroscience, behavioral economics, cognitive science, anthropology, and other fields) in order to spark a discussion and present ideas based on these principles. Following such notion, they also aim to inspire and nudge for development of new approaches to understand behavior, consequently following design and implementing new policies, among others also economic and financial policies. They propose that such behavioral insights can provide further insights for development of some standards or policy measures as well as for financial and investing behavior (The World Bank Group, 2015; Montier, 2007; Ackert & Deaves, 2010).

Following notions proposed by the World Bank's World Development Report (The World Bank Group, 2015) and considering the interplay between the macroprudential regulation with an objective to be used to counter risk within the financial system and the behavioral finance, some argue that the understanding in the behavioral research of the interplay on the micro level is still too rudimentary (Gray, 2016).

As important as these considerations are, observing actions taken by the regulator, such argument seems to not be supported by the regulator, e.g., the European Union. While drafting the legislation for the risk disclosure part in the Key Investor Information Document (KIID) for Undertakings for Collective Investment in Transferable Securities (UCITS) funds in Europe, the European Union as a regulator, as part of considerations, acknowledged also insights from the supporting behavioral study (Decision Technology Ltd, 2010), proposing insights from the combination of fields of behavioral economy and behavioral finance.

On the notion of their supporting study, they considered different designs of the simple risk measure that would communicate simplified decision framework and riskiness of the investment (European Commission, 2012). Such implications of the insights are important also for respective fields to further develop and for the regulator to consider also insights from multiple different interdisciplinary fields, providing new insights for the human behavior.

The 2008 financial crisis, also known as the global financial crisis, presented an abundance of challenges for individuals, local companies and banks, national banks and national financial systems, and most importantly for global financial system (Taylor, 2013). There are many explanations for the causes of the 2008 financial crisis, ranging from asserting the presence of a trading and moral hazard (Dowd, 2009), greed and dishonesty, absence of appropriate risk management measures, to claiming financial instruments to be too complicated and complex, and indicating a lack of financial literacy among people (Shiller, 2012).

Responses from the regulators varied. Some proposed and researched the financial literacy among people (Lusardi & Mitchell, 2014). Others proposed better risk management services and adoption where lack thereof (Saunders & Allen, 2010). Some adopted regulatory frameworks for making a clear distinction between proprietary trading and retail services and transactions in banking environments, e.g., the Dodd-Frank Act in the United States of America (Schäfer, Schnabel, & Weder di Mauro, 2015), the Liikanen Report in the European Union, and the Volcker Report in the United Kingdom (Viñals et al., 2013)).

On the other hand, following the notion that it seemed none of the traditional and standard economic and financial theories were neither able to predict or explain the near collapse during the recent global financial crisis, some assessments of risks and methods called for revision (Borio & Drehmann, 2009; Rajan, Seru, & Vig, 2015).

Building on present notion, Battiston et al. (2016) argue that in financial regulation and economic policy an interdisciplinary approach should be considered. In such argumentation they are following previously mentioned notions (taking into account still limited use of such models and results), hence interest for the complexity theory, and subsequent ideas and concepts: tipping points, networks, contagion, feedback, resilience is increasing.

Mantegna & Stanley (2004), based on the assumptions of complex system from physics, present a notion of similarity between the characterization of the financial markets and complex systems in relation to the concept of being an open system. Financial markets characterized as open systems can be described then as having many subunits present with the underlying assumption of the nonlinear interaction between units and the feedback rule presence (Kuhlmann, 2014).

Specifically in such analogical understanding, there are many agents, as subunits, that interact in the markets with system having a relatively stable rule of governance, while the continuously monitoring process of the time evolution is present at chosen time scales (Mantegna & Stanley, 2004).

Battiston et al. (2016) argue further that following ideas from the network science approach of tipping points and the early detection of warning signals in the financial markets could be used even with present challenges in the financial and economic field to extrapolate results from the natural sciences (Kostanjčar, Begušić, & Stanley, 2016). They present the notion of "too-central-to-fail" (p. 818) as, in their view, being almost more important than the notion of "too-big-to-fail" (p. 818).

These two notions were also attempted to be already regulated with the Dodd-Frank Act in the United States of America (Schäfer et al., 2015), the Liikanen report in the European Union, and the Volcker report in the United Kingdom (Viñals et al., 2013), together with the assumptions and models of Battiston et al. (2016), following the notion of understanding financial markets through the lens of network science. However, they also acknowledge that understanding interconnectedness between banks (that would serve as a map of links between banks as nodes) is limited due to the fact that banks are not willing to disclose hidden data because of confidentiality.

One of the important ideas arising from such theory is the notion of the Agent-Based Models that could, as computer models, represent behaviors of individual agents and interactions, building on the decision rules, following agents' observations and actions. Tedeschi, Mazloumian, Gallegati, & Helbing (2012) presented a study following such notions, where they have with the use of agent-based models presented the study on systemic risk and sharing risk within the interconnected market of interbank system, where higher degree of banking interconnectedness presented an increase in bank's financial fragility. and formed higher degree of systemic risk and of bankruptcy cascades.

Such ideas and framework has also shown an upward trend in the discussions, as presented in Figure 3 with number of sources including keywords Agent-Based Models, Network Analysis and Finance. For the data collection, observational units and logic behind the graph, it applies the same logic and data acquisiton as in Figure 1. Numbers of sources were gathered from the academic database of the Digital Library of University of Ljubljana (DiKUL), where the sources included are scientific articles, books and e-books, conference proceedings, theses and dissertations published for the observation period of 15 years from 2002 to 2016, an observational unit being each year (table with exact numbers for Figure 3 can be found in Appendix A, Table 1).

Figure 3. Number of sources including keywords Agent Based Models, Network Analysis and Finance from 2002 to 2016



1.3 Complementary or Orthogonal Relationship

Two paradigmatic waves, traditional and behavioral are present in the field of finance, as discussed in the first two parts of this chapter. In the field of financial economics, Hens & Rieger (2010) see the behavioral finance as a subfield, providing an explanation where the empirical observations deviate from the classical theory. De Bondt & Thaler (1995) agree to some extent that assumptions and results of modern finance can be in some situations adequate, with the importance of integrating the behavioral aspects in the field as well.

Further, Barberis & Thaler (2003) argue that it can be possible to coherently approach to asset pricing with the incorporation of human behavior considerations, and as Schiller (2006) argues, even though the two waves are assumed to not be compatible, they have always been intertwined, consequently the most important further advances will incorporate both views and approaches where the incorporation is still in progress.

It is important to emphasize the discrepancy between the research methods, many times seemingly allowing for the criticism of the behavioral part of the research, as Ackert & Deaves (2010) point out, and with further notion by the same authors that traditional finance aimed for the proximity of the field to the natural sciences framework, modeling the observations as viewed universe, behaving and adhering to rules of observed society which is to some extent still evident with the notions of advances of understanding financial markets as an open system, as understood and presented by Mantegna & Stanley (2004). In the field of traditional finance, research methods are connected to two possible approaches in gathering the empirical evidence for the support or falsification of a theory on financial markets. One

approach is to study data from financial markets (keeping in mind noisiness of such data, uncontrollable factors, and the question of availability of some private data), while another approach is to conduct surveys and controlled experiments, building on the assumptions of neoclassical economics and traditional finance (Hens & Rieger, 2010).

In the field of behavioral finance such clear distinction of the research methods approach is not present, since field is extracting information from various disciplines researching human mind and connected phenomena, with the establishment and validation of tool of laboratory experiments as of use in empirical economic analysis, also for the study of alternative market behavior, with the jointly awarded The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2002 for contributions to integrating insights of psychological research to the economic research field and establishment of laboratory experiments (The Nobel Foundation, 2002). Therefore, one of the future challenges of the behavioral finance, as it is for the neuroeconomics field (Fumagalli, 2010), is to provide a consensus about to some extent unified research framework and methods for the field.

Similarly, Barberis & Thaler (2003) present a notion of competing behavioral explanations, with one scientific way of comparison of alternative theories with empirical tests. However, as Fumagalli (2010) points out the discrepancy between the research methods of economics and neuroscience, by analogy similar considerations can hold also for behavioral finance.

However, as it holds for every discipline, validity of results rests on the assumptions and advances made, and as in relation to the research framework, Ackert & Deaves (2010) acknowledge in their view that behavioral finance field lacks the unified research framework, similiarly as Fumagalli (2010) presented for neuroeconomics. Rocha, Vieito, Massad, Rocha, & Lima (2015) have with the use of electroencephalographic activity measurement (EEG) presented findings in gender differences when investing. They came to conclusions that different neurons activate on the cortical level in the brains of males and females when making (equally successful) financial decisions, while acknowledging the limitations of such studies managing to record only brain activation on cortical level, and not the deep brain structures, modulating limbic system process (e.g., such as processes of emotions).

In the midst of these different data obtained, the question that remains is if the integration of the different research fields is possible; that is such that would actually lead to some extent interdisciplinary nature of the finance, or in the small correction of traditional finance and accepting the behavioral finance findings to the point they can still be integrated within the paradigm of the traditional finance, as proposed by Hens & Rieger (2010). In order to increase the level of credibility of behavioral measures to be also incorporated with the traditional financial measures, there is still a current gap that needs to be filled in order to successfully combine both measures. Taking into account only financial reports as carriers of crucial information, they are processed internally and externally with different aims in mind, but having a crucial impact on the financial agent itself, differences are present in management and financial accounting for decision-makers (Atrill & McLaney, 2007).

When discussing further developments in the financial field, we should also address the ideas in relation to the complexity theory and propose implementation of the ideas (Mantegna & Stanley, 2004). In relation to such ideas, some further advocate the emergence of "econophysics" and "sociopysichs", referring to the further interdisciplinary approach of the economic science and finance, and taking into account also dynamic aspects of systems and social systems (Chakrabarti, Chakraborti, & Chatterjee, 2007). Some ideas within such fields are tipping point, networks, contagion, feedback, resilience (Battiston et al., 2016), following present similarities between the characteristics of the financial markets and complex in relation to the concept of being an open system. The understanding of the financial markets under such presentation can be seen as presented in a more active area of the pricing of the derivative instruments (Bouchauda & Potters, 2003), with an attempt to develop theoretical models by grasping all the essential characteristics of the real financial market (Bak et al., 1993; Bouchand & Cont, 1998; Levy, Levy, & Solomon, 1995; Stauffer, 1998).

Based on such understanding, physics can provide an advanced step for the foundations of the financial theory. Taking that step presents also a paradigmatic shift, incorporating dynamic dimension of financial markets (Mantegna & Stanley, 2004). Since real markets depend also on people and everyday circulation of instruments and symbols of monetary value, a further step into understanding of the financial markets and related phenomena can be provided by behavioral finance paradigm, for the modeling of human behavior, and as in relation to the traditional finance, presented also by De Bond & Thaler (1995).

In the following chapters, the presented notion will be further developed and a possible orthogonal relationship between paradigms of finance will be presented, with the assumption of further possible development, based on idea of the complexity theory (Mantegna & Stanley, 2004; Battiston et al., 2016) and advances in behavioral finance. Inspired by the empirical research conducted by Rule & Ambady (2008), supported with findings that an objective company performance can be forecasted from the facial features and first impressions of the business leaders, we present objective and subjective measures for future forecasts and investing behavior with some additional thoughts to the debate about the relationship between the traditional and behavioral finances. Focusing on the subjective measures (such as financial reports) for the forecast of companies' success, the debate reflects also the first purpose of the thesis as the paradigmatic debate between the traditional and the behavioral finance.

2 OBJECTIVE AND SUBJECTIVE MEASURES FOR FUTURE FORECASTS AND INVESTING BEHAVIOR

In this chapter, the objective and subjective measures for future forecasts and investing behavior are discussed. Subjective measures and information are primarily understood from the point and through the lens of finance discipline and cognitive science discipline with approach and assumptions, as discussed further in the chapter. According to Bourgine, Le Moigne, & Walliser (1992), interdisciplinary research between the finance and the cognitive science discipline is possible, bearing in mind that the objective of both disciplines is to understand and conceptualize emerging phenomena of the behavior on the aggregate level, deriving from individual level, analyzing information, information interactions, and knowledge that is shared.

The approach, adopted to shed some light on certain questions, is based on the foundations of the financial theories and theories of cognitive science, more specifically the starting point of our idea is based on one of the basic underlying principles of the cognitive science, understanding cognition as information processing (Bermúdez, 2014), and the information-processing approach as a central principle of cognitive psychology (Eysenck & Keane, 2010). However, developments from simple models to intricate information-processing models with strengths and weaknesses are not presented for the whole cognitive understanding and modeling.² To simplify, the relationships in the information-processing models have three components: input information, information-processing process and output information (Lindsay & Norman, 1972).

Input information can be any information from the outside world, perceived through perception: visual system, auditory system dimension, dimension of vision, while some also argue for the dimension and influence of the embodied cognition to be the input information of an inner experience, known as in relation to the embodied cognition paradigm³ (Varela, Thompson, & Rosch, 2016). However, such information can also arise in combination with the memory processes that produce certain information or any other relevant process, producing information that is relevant for specific information process (Eysenck & Keane, 2010; Bermúdez, 2014). Output information can be understood as certain outer action, inner experience, or any other set of action – inner or outer – by an individual actor (Bermúdez, 2014; Varela, Thompson, & Rosch, 2016). For the purpose of the thesis, we assume two classes of information for the input information: objective and subjective, with the forecast information about the future performance of the company as the output information, following Rule & Ambady's approach (2008).

Before discussing the objective and the subjective information processing and their implication for the forecasts and investing behavior, the presented information-processing process follows the classification of information processing through the lens of the models of cognition (Bermúdez, 2014):

 $^{^2}$ In the thesis, relationship between disciplines and integration challenge within cognitive science are not discussed, as it is out of the scope of the topic and focus of the thesis; similarly also the discussion about the specific models, with following variations of such models of cognition: for more information on topics see, e.g., Bermúdez (2014) and Markič (2011).

³ Embodied cognition and phenomenology will not be discussed fort the scope of the thesis, as they provide another range of also methodlogical approaches that within the research of cognition will not be discussed within the thesis. For further information consult Varela, Thompon, & Rosch (2016) and Markić (2011).

- models of cognition based on classical approach to cognitive science (with central notion of symbolic paradigm and physical symbol system hypothesis and language hypothesis);
- models of cognition based on connectionist approach to cognitive science (with central notion of connected neural networks);
- hybrid structure of the organization of the mind.

2.1 Information-Processing Model

Information-processing models can be understood through the lens of classical cognitive science (with the central paradigm, symbolic paradigm) or through the lens of connectionist approach, inspired by the new advances in the neuroscience approach and advances in artificial intelligence, with the underlying understanding of the neural networks (Bermúdez, 2014). First part explains approach through the lens of the classical cognitive science, and the second part briefly explains approach through the lens of the connectionist approach, notwithstanding the notion that the latter seems to have a slight advantage in the explanation of the working of cognition (Markič, 2011).

2.1.1 Classical Approach to Cognitive Science

In models of the classical cognitive science, the crucial and central idea is the analogy between the mind and the digital computer with symbolic paradigm. Following the notion of the hypothesis of the physical symbol system as proposed by Newell & Simon (1976), processes of the information processing are processes based on the manipulation of the physical structures that consequently serve as symbols. The core of the information processing under the physical symbol system hypothesis is that information processing in the problem solving domain is understood as the transformation of the symbol structures, according to certain rules or algorithms (Markič, 2011), while the hypothesis, further developed by Fodor, stating the language of thought hypothesis (Bermúdez, 2014), where the central idea is that the most basic symbol structures in the mind which carry information are in fact sentences with the internal language of thought, hence the information-processing processes in mind are the processes that are transforming sentences expressed in and based on the language of thought.

Both hypotheses present a distinction between the syntax dimension of the information and the semantic dimension of the information (Bermúdez, 2014). For the classical cognitive science approach with the classical cognitive architecture concept, there is an assumption that symbolic structure actually reflects the actual physical structure in the brain, where the combinatory structural representation acts as a duplicate in structural relations between the physical characteristics in the brain (Fodor & Pylyshyn, 1988).

Through the lens of the classical cognitive science approach, for the behavioral finance field, the question is if we can understand money and financial concepts as symbolic representation connected with certain mental architecture, presented also in the connection with certain

structural relation with certain physical characteristics in the brain. In connection to the information concept, as discussed further in the thesis with the classification of objective and subjective information, we understand objective information processing to be in structural relation to the higher cognitive processes (among others reasoning and relational reasoning) that in the field of cognitive neuroscience have been understood as a neural substrate in the brain regions of prefrontal cortex (Rushworth, Chau, Schüffelgen, Neubert, & Kolling, 2014). Such assumptions seem to be closer to the traditional finance approach, however all finance and investing decisions cannot be connected only to the higher cognitive processes. There is a range of studies reporting anomalies in financial decision-making process, presenting different biases for investing (Montier, 2007), e.g., a home bias (Coval & Moskowitz, 1999).

There are not only biases that play a role in investing, since also emotions (Montier, 2007), also in decision-making (Phelps & Delgado, 2009), and brain regions involving the dopamine neural circuit when evaluating the value (Glimcher, 2009) indicate that investing is not only the objective domain of the information-processing process. Classical symbolic models explain well the domains of modeling of higher cognitive functions, but as a critique to the paradigm, they do not do well in the domain of all cognitive functions, such as, e.g., recognition of the visual and audio patterns and spatial cognitive functions (Markič, 2011), whereas the spatial cognitive functions have been related also to the numerical cognition processing (Wiese, 2003).

The critique provided by Dreyfus (1972) that such models are too rigid and are not adequate in modeling of everyday and uncertain situations is in a broad sense connected also to the possible critique of understanding the financial field development in a sense that symbolic manipulations, where with the development of more sophisticated computational models we could successfully model everyday investing situations and financial decision-making, is not adequate. Further critique to such approach in information-processing models lead to the emergence of the connectionist approach that will be further presented and discussed.

2.1.2 Connectionist Approach to Cognitive Science

Following the advances in neuroscience techniques and insights, the connectionist approach provides a clear distinction between the structural and functionalistic understandings of the human mind. The idealized model of how neurons work inspired connectionist approach and the neural network modeling, assuming the neural networks in the brains (Markič, 2011). Bermúdez (2014) advocates that for the understanding of cognition, there will be needed the understanding of the interplay between the workings at the level of organization on the large-scale brain areas and individual neurons, taking into account that the brain is complex and very complicated set of interlocking and interconnected circuits, with the most fundamental characteristics of the connectivity.

Hence, in the connectionist model, the fundamental characteristic is a simple, idealized neuron as a unit (or node) that is intertwiningly connected with many links to other neurons,

units. Every unit in such configuration has a certain activation level as a value, and units are affecting other units by exciting or inhibiting other units, consequently a network is formed (similar working is also on the level of neurons, according to the Hebb's rule), with possibile hidden layers. Connectionist networks can have different architectures, differentiated based on different topologies (structures and layers), the function of the activation, output function, and the underlying learning rule. In such networks, the representation of the concept is saved in the activation pattern, in a distributed way, across the network (Markič, 2011; Eysenck & Keane, 2010).

The main advantages (not all of them will be presented, since they relate in a more general way to the functioning and understanding of the human mind) of such models should be presented. More so, since neural networks are (in contradiction to the physical symbol system hypothesis models) capable of a learning process in sophisticated ways (Bermúdez, 2014), whereas Markič (2011) recognizes that learning from experiences is one of the main advantages of the connectionist approach. The principle of learning from experience is important for the field of finance and investing, since in investing, investors in their analysis for the future forecasts evaluate also past data, business, financial data and past behavior of the companies (Penman, 2010; Damodaran, 2002). Furthermore, learning and evolution is one of the domains that is also of interest to both, the economics and the cognitive science in order to be able to develop predictive strategies for the respective fields (Bourgine et al., 1992).

2.1.3 Hybrid Structure of the Organization of the Mind

By combining the modularity hypothesis of the mind, the physical symbol system hypothesis and the subsymbolic neural network approach, Bermúdez (2014) proposes a hybrid structure of the organization of the mind and concludes that both understandings of the human mind are neither exclusive, nor exhaustive. If the mind is understood as having a hybrid architecture with the combination of both approaches, one works better for certain information-processing tasks, while other tasks are performed subsymbolically better for other information-processing tasks.

Through the understanding of agents' mental representation as integral part of the information process, where a mental representation is a representation in the human mind that is internal about certain piece of information (Eysenck & Keane, 2010) and can be seen as a symbol or stored in the subsymbolic neural network (Bermúdez, 2014) from the field of cognitive science of economics, Bourgine et al. (1992) recognize a possible interdisciplinary opportunity on the notion of common field with economics, where agents' expectations as understood in economics are schemes presenting their representations.

Similarly, the financial field could take a similar step in perhaps combining both approaches more successfully. Some tasks could be understood by the analogy with the symbolic manipulation information processing, while other tasks and influences of other phenomena could be understood with integrating the subsymbolic neural network approach.

2.1.4 Neural Network Models in Finance

Neural networks, with underlying architecture as presented in the connectionists approach, as computational methodologies performing multifactor analysis, and applied in various fields, such as military, robotics, machine monitoring, control systems, medical imaging, medical decision-making support system and finance, present very promising results, while also establishing themselves in a viable, multipurpose way, having a high degree of robustness in multifactor mathematic models, while applying successfully the model in the predictive, classifying, function estimating, complex decision-making, pattern-recognizing behavior and completion problem (Dayhoff & DeLeo, 2001).

In the field of finance, the argument for neural networks lies in assumptions and capabilities, allowing the system to learn and react in time, in comparison to the classical econometric models. In such sense, network models approximate the behavior in financial market, with underlying assumptions of an agent as financial decision-maker, reacting in a linear and proportionate strand to the assumptions of asymmetric and nonlinear reactions to exogenous variable changes (McNelis, 2005).

For forecasting purposes, the neural network approach was for the first time researched and applied (although not yet in the financial field) in 1964, with presented limits at the time, and later numerous and growing research considerations and applications for forecasting (Zhang, Patuwo, & Hu, 1998). McNelis (2005) argues that with development and applications of neural networks, financial decision-makers in financial markets acquired substantial computational power with the methods for more accurate recognition, forecasting and predictions in the environment, characterized as volatile, complex and multidimensional. Furthermore, he acknowledges that in the financial field, we can take a step further from the methods with assumptions of underlying linearity and normality, and linear or log-linear models to the models of neural networks, with underlying assumptions.

Following such notion in connection to the cognitive and brain science studies, neural networks are becoming also a key component of the implicit epistemology in the empirical finance. However, as already pointed out, in such applications in the field of finance, in comparison to the hard sciences (e.g., physics), we are constrained and limited in separation in statistical processes of diagnostics and forecasting from the goals of the researchers, decision-makers and players in the market. Inherently, the underlying social forces also modulate financial markets (Bikas, Jurevičienė, Dubinskas, & Novickytė, 2013).

Bahrammirzaee (2010) in his comparative survey of applications of artificial intelligence in finance further acknowledges that, at the time of research, applications of methods of artificial intelligence present the most popular tool used in financial markets.⁴ As one of the further

⁴ For the purpose of present discussion, detailed presentation of different models of neural networks is out of scope.

claims for the popularity of such tools, Hamid & Habib (2014) recognize the ability of underlying models to detect complexity of interdependent and increasingly interconnected characteristics of financial markets and their variables (also underlying correlations of numerous variables).

However, Dunis, Laws, & Sermpinis (2009) acknowledge skepticism of such applications among practitioners due to the inevitable numerous limitations and some contradicting current empirical evidence for the forecasting power of such models. An additional burden lies in the fact that, before applying models of neural networks, one needs to know the models thoroughly, accept the underlying assumptions and acknowledge model uncertainty, while models themselves can possess certain, even relatively high, degree of complexity (McNelis, 2005).

In the study with application of neural networks for the trading behavior in the Euro Member Countires to the United States Dollar exchange market, in the 1-day-ahead forecasting and trading task at the European Central Bank fixing rate, Dunis et al. (2009) tested stability and robustness of neural network models. Authors compared three different neural network designs (Higher Order Neural Network, Mulitlayer Perceptron and Reccurent Network), comparing also results with traditional statistical or technical methodology. Based on their research, they conclude that two neural network architectural models (namely multilayer perceptron and higher order neural networks) provide better results and perform other models in their forecasts of annualised returns, with stability and robustness over time.

In an attempt to provide additional input of the importance of the neural networks for finance, the graph in Figure 4 presents an increasing trend of the occurrence of keywords Neural Network and Finance in the academic field. Data collection, database and units of observation are the same as in Figure 1, Figure 2 and Figure 3, and the same logic of reasonsing applies in acquisition of the data. Numbers of sources were gathered from the academic database of the Digital Library of University of Ljubljana (DiKUL), where the sources included are scientific articles, books and e-books, conference proceedings, theses and dissertations published during the observation period of 15 years from 2002 to 2016, the observational unit being each year (table with exact numbers for Figure 4 can be found in Appendix A, Table 1).



Figure 4. Number of sources including keywords Neural Networks and Finance from 2002 to 2016

Dunis, Laws, & Sermpinis (2011), in another research, similarly comparing and benchmarking three different neural network designs (Higher Order Neural Network, Psi Sigma Network and Reccurent Network), reported some of the models as being successful (Multi-Layer Perceptron, the Softmax and the Gaussian Mixture model) at the time of the research. Their findings were similar to the previous ones; the proposed models of neural networks were as successful as the already reported successful ones. However, when applying in the analysis process more sophisticated trading strategies, the Gaussian Mixture models outperformed all other neural network models.

Similarly, when analyzing the volatility of the The Standard & Poor's Index futures price, Hamid & Habib (2014) concluded that artificial neural network models provided superior forecasts for volatility in comparison to the implied and realized volatilities. Sermpinis, Laws, & Dunis (2013) researched in their study the use of neural network design models, with benchmarking it to forecasting the 21-day-ahead realized volatility of the The Financial Times Stock Exchange 100 Index futures returns, and evaluating forecasts in terms of statistical accuracy and trading efficiencies. In their results, they acknowledged the higher order neural networks as outperforming other model designs, according to statistical accuracy and trading efficiency.⁵

These results for the financial field present promising results for further applications. It should be noted that for the input data, neural network model used mostly for training historical

⁵ Further discussion and explanation of the mentioned specific architectures of the neural networks is out of the scope of the present discussion.

trading from the financial markets (such as the study made by Sermpinis et al. (2013), where they used derived option premia, cumulative profits, trades, buys/sells, profitable trades, average profit per trade). Such data presented and reported in numerical values and in combination with the numerical cognition, are classified as fitting in the class of objective information-processing process.

According to McNelis (2005), the hidden layer used is in fact the difference that distinguishes neural networks from other approximation methods, in also efficiently modeling non-linear statistical processes. In his explanation of the hidden layer, the hidden layer is where the input variables undergo transformation by a special function – logistic or logarithm-sigmoid transformation. Bermúdez (2014) further acknowledges possibility of numerous hidden layers, meaning neural networks understood as a single layer or multilayer network. Hidden layers are in his understanding simply layers that have hidden units within the neural network and receive inputs only from other units and cannot be achieved or seen by the influences from the outside of the model.

In the financial field, Bahrammirzaee (2010) acknowledges that hidden layers present a very important role for the successful application of the neural network models. However, he argues that the issue in application lies in the fact that it is very tough, although crucial for the process to determine the optimal number of hidden nodes and hidden layers. Nevertheless, artificial neural networks are in his view further seen as black-box methods, where there is no specific form in explaining and analyzing the underlying relationship between inputs and methods, while there is currently no specific statistical method present to be able to test artificial neural networks. Furthermore, one notion arising from the characteristics of the hidden layer of the artificial neural network is that it is not exactly understood what activation functions and connections hidden layers make in the specific data application (Bermúdez, 2014; McNelis, 2005).

Bahrammirzaee (2010) claims that the hybrid model has possibility and capability of combining capabilities of different systems and that numeric nature exhibited in the artificial neural network models is superior to the nominal nature of traditional symbolic manipulation techniques. Moreover, he claims that in the neural network model there is a data sample that networks use for the training phase of the information-processing process, where they can use and add also additional ones, without reprocessing the older ones. Same author in the application of the artificial neural network model in specific financial applications concludes that in case of credit evaluation, portfolio management and financial prediction planning (to name a few domains: corporate financial distress predictions, financial investment decision support, stock market prediction, stock price forecasting, earnings management prediction, bankruptcy prediction, budget allocation, stock trend prediction), there were mixed results between the single techniques and hybrid approaches. However, results in the above presented studies still follow the notion when comparing the traditional and statistical methods in favor of the artificial neural networks – single techniques, expert systems or hybrid approach.

In application to the financial domains, however when choosing the input, it is as in traditional models important to think about the parameters used as inputs (e.g., time horizon, type of variables, data, etc.). To point out one notion arising from the characteristics of the hidden layer of the artificial neural network, the characteristics and value of the activation functions and connections in hidden layers are not exactly clear and known, and therefore it makes it difficult to fully understand in order to successfully make a specific data application (Bahrammirzaee, 2010; McNelis, 2005; Bermúdez, 2014; Huang, Keung Lai, Nakamori, Wang, & Yu, 2007; Chen & Sutcliffe, 2012).

Neural network models originating from the biological models of the imitation of the brains (Bermúdez, 2014), with growing importance in the discussion with the finance or with the use of financial datasets, leads to the discussion of the application of the methodology of the neural network models for the financial field. The current chapter presents some of the characteristics of the neural network models, the notion of successful application of such models in the various fields, while further discussion presents specific considerations, when discussing the application to the financial field. In finance, when discussing forecasting techniques, different studies presented and empirically supported the notion that neural network models outperform traditional statistics and econometrics models. Some of the benchmark studies and its applications presented support to the notion that the characteristic of the hidden layer(s) and the good preparation of the input data can play a key role for the successful application of the specific model.

2.2 Concept of Information

Following the proposed assumption of information-processing models, we present the concept of information to be able to incorporate it with the understanding of the cognition model and later the output information interpretation.

The information is assumed in the thesis through the lens of the discipline of information science. Capurro & Hjørland (2003) take a point of view that the concept of information is used by almost every scientific discipline within its own context and in relation with specific phenomena. Robinson & Bawden (2014) present the notion of numerous present concepts of information and attempt to find a common ground between the concepts (and the usage of thereof) in various disciplines.⁶

There are two crucial roles of information in market economies: ex ante role, helping investor in the evaluation of investment opportunity and underlying returns, and ex post role, allowing investors to successfully develop and shape mechanisms of monitoring invested resources, such as corporate governance mechanisms (Beyer, Cohen, Lys, & Walther, 2010). In line with the outlined objective of the thesis, the concept of the information is understood and in the

⁶ Discussion of the various concepts of information across different disciplines is out of the focus and the scope of the present thesis and will not be included.

thesis assumed as the information that has an influence on the judgments and future forecasts for investing behavior.

Discussion of face perception as subjective information, in comparison to financial statement information as objective information, was motivated by the study done by Rule & Ambady (2008). In their research experiment, they came to a conclusion that first impressions (especially impressions of chief executive officers (hereafter CEO(s))) have relevance for the future forecasts about the performance of their company. Based on such notion, facial appearances of business leaders and perception of their faces are carriers of subjective information, through the lens of the proposed concept of information as subjective information for the discipline of finance.

2.3 Financial Reports as Objective Information Carriers

Financial reports are reports providing information about the financial related transactions and matters for the business entity, that can be broadly speaking conducted under two main strands in accounting: management accounting and financial accounting (Atrill & McLaney, 2007). Accounting information need to be prepared with having in mind a clear picture for whom (since there can be various interest groups having an interest in the certain business entity) and for what purpose the information is being prepared. One of the main differences in the strands is the specific user group to which information prepared are addressed. In the management accounting the information is primarily addressed to the managers, while in the financial accounting the information can be addressed to various user groups (stakeholders, external investors, governments, regulators, antitrust authorities, financial market authorities, banks, etc.), and can have an aim of more general purpose. Other differences between the two main strands in accounting are (briefly stated) in the dimensions of: nature of the reports produced, level of details, regulations about reporting, reporting interval, time horizon and range, quality of information (Atrill & McLaney, 2007).⁷

The thesis focuses on the financial reports that are produced in the financial accounting. Financial reports produced in such manner are referred from this point on as financial statements. Financial statements are the primary information, published by the company itself, reporting the numbers of the business, and seen as providing a translation of economic factors into accounting numbers (Penman, 2010).

Furthermore, in the process of such translation, financial accounting is still a process involving judgments that are guided by the fundamental principles, governed by the corresponding standards (Subramanyam & Wild, 2009), such standards being International Financial Reporting Standards, International Accounting Standards, and other standards that are governed and published by the country regulator or organizations themselves. On the

⁷ Further explanation about the both fields, clearer distinction and studies will not be discussed; for more information see Atrill & McLaney (2007) and the book series Studies in Managerial and Financial Accounting.

notion of such regulatory prepositions and concepts, advocating also for the increasing quality and comparability of the financial statement information (taking into account also limitations presented by the results of presented studies about the improvement or lack thereof of quality of information in financial statements), assumption of financial statements as objective information carriers is made. Penman (2010) also further in the accounting domain presents good accounting and bad accounting (that can be also in some cases supported by the regulator prepositions in relation to the valuation processes), also for valuation purposes. For the purpose of the present thesis, we do not distinguish between the good or bad accounting, as distinguished by Penman (2010).

2.3.1 International Financial Reporting Standards

In the European Union countries for promotion of the convergence of the accounting standards in the global space and providing a way for consistent and comparable financial reporting across the European Union, International Financial Reporting Standards (hereafter IFRS) are obligatory for listed companies, while the non-listed companies and small business follow different requirements as specified by the European Union rules (European Comission, n.d.). The IFRS Conceptual Framework aims to present concepts that serve as a foundation upon which financial statements should be prepared, since the preparation has uncertainties underlying the notion of preparation based on estimates, judgments and models. The general-purpose objective is to make such statements useful in valuations and investing decision-making process, while identifying also the qualitative characteristics for the information that are most useful in financial reporting. Such characteristics are (without determined hierarchy in application of qualitative characteristics): fundamental qualitative characteristics (relevance and faithful representation) and enhancing qualitative characteristics (comparability, verifiability, timeliness and understandability) (Bakker et al., 2017).

Building on these notions, we assume financial information from financial statements, assuming the good accounting practices, as an objective information carrier. In taking a stand also in the support of the influence of the IFRS for the quality of the information, Chen, Tang, Jiang, & Zhijun (2010) conclude in their study on the sample of 15 Member States of the European Union that improvement in the quality of the information after the adoption of IFRS can be associated with the adoption of IFRS, not with the general business environment, changes in managerial incentives, and other factors. Similarly, Daske & Gebhardt (2006) report about a significant increase in the quality of financial statements after the required adoption in the European Union, and in connection to the enhancing quality of the comparability.

Brochet, Jagolinzer, & Riedl (2013) argue that the mandatory IFRS adoption indeed improves comparability, and leads to capital market benefits. Christensen, Lee, Walker, & Zeng (2015) report in the case of a sample of German companies the indication that incentives for reporting matter and that determining the quality changes around the voluntarily adoption of IFRS *per se* consequences in improvement in accounting quality, but not so much when the

adoption was not voluntarily incentivized. Findings presented by Cascino et al. (2014) show that when developing such standards, there can be no prototypical user group defined to lead such development. They follow with the notion that capital providers use information from different sources in different manners and for different purposes, while also their demand for information systematically differs across their group.

2.3.2 Financial Reporting Process

Building on the previously presented models of information processing, the quality of input information, in this case financial statements, is very important, but it can be biased as presented with the results from studies that will be presented (Beyer et al., 2010). When comparing financial statements between different companies (e.g., profits, sales, income, profitability margins), following the notion of Penman (2010) that the financial statements are reporting the numbers of the business, seen as providing a translation of economic factors into accounting numbers, the important emphasis is on the numbers, and here the field of numerical cognition can provide some further insights.

Considerations of presented studies for information quality in financial statements and consequences for the assumptions of the financial statements as objective information carriers we next discuss possible biases in the financial reporting process. Beyer et al. (2010) present the notion of endogenous development of corporate information environments for financial reporting with different sources of information that consequently have an effect on such an environment: corporate disclosures, information inferred from actions, information generated by the third parties, information publicly disclosed by stakeholders (even in cases where such generation is made on private account), and same sources of information from the competitor or related company.

In regard to the idea of endogenous information environment, Nan & Wen (2014) present effects of accounting biases as pervasive and to have an impact on the quality of the information in the financial statement and on financial and investment decisions for the firm. When producing a financial report, reports tend to be influenced by managers as follows from findings of Graham, Harvey, & Rajgopal (2005) who conducted a survey with 401 financial executives and in-depth interviews with subsequent 20 financial executives in order to research and provide key factors modulating decision in relation to reported earnings and voluntary disclosure. They conclude that when managers think about information they communicate to other parties in the ecosystem, they focus on a short-term need to achieve or exceed earnings benchmarks, following also voluntary disclosure, phenomena that from the manager's point of view leads to reflection in stock price. Furthermore, they continue that companies tend to rather present information voluntarily and in a clear and understanding matter for investors, however such disclosure still has limitations in relation to the sensitive information and setting practices, which would be difficult to maintain.

In relation to the biases in financial reporting, Bazerman et al. (2002) provide interesting considerations in relation to biases in the information-processing process of accountants in the corporate audit environment. In relation to the self-serving bias, authors name possible explanations from structural aspects of accounting that could lead to the creation of opportunity for emergence of such bias and consequent influence on the judgment over the dimensions of ambiguity, attachment, approval, familiarity, discounting, and escalation. In relation to the accounting standards, they conclude that eliminating all biases within certain system is a difficult task.

Arnold et al. (2000) were researching the decision-making of accountants with a high level of experience and specialization in the complex environments and in relation to the effect of experience and order on recency bias. They have concluded that experience and expertise does not mitigate such biases even in complex environment. These findings (among many other biases and empirical research in accounting domain that will not be specifically further addressed at this point) indicate influences of accountants for the financial statements.

In relation to the cross-cultural accounting research, Patel & Millanta (2011) argue for the controversial nature of accounting in relation to the theoretical conception of culture. In their research, the authors focused on the bias towards responding in a socially desirable way in connection to its underlying component, "holier-than-thou" perception bias. In the sample of accountants from the multinational, international accounting firms from India and Australia, they came to the conclusion that those accountants within cultural groups presented such bias, but it was eliminated on the cross-cultural scale.

Heidhues & Patel (2012) present a study in the domain of differences in the process of professional judgment in two countries of Continental Europe – Germany and Italy. Based on their findings, they conclude that accountants from Germany exhibit more conservative behavior, though presenting a lower level of uncertainty avoidance in comparison to the accounting behavior of accountants from Italy, thus presenting a notion of cross-cultural differences in materiality judgments (as in line with IFRS), when provided a specific case scenario. Such results as an indices provide an insight into cultural effects playing a role in the financial reporting process.

2.3.3 Numerical Cognition and Numerical Values

Numbers, reported in the financial statements, correspond to a specific category of the business financial information as the objective information, e.g., profit reporting. Numerical cognition with underlying concepts: numerical quantity, numerical rank and numerical label (Wiese, 2003), can further explain the objectivity of such numerical information. Numerical cognition, as referred to in this thesis, is understood as cognitive mental architectures, allowing numerical skills of different numerical functions (number reading, basic calculations, etc.), and processing of numbers, where they are inherently dependent on the mental representation in the cognition, numerical representation (Campbell, 1994; Dehaene,

1992; Wiese, 2003; Zhang & Norman, 1995; Ashcraft, 1992). Such representations are dependent on the systemic acquirement of the numerical representations (Dehaene, 1992; Campbell, 1994) and vary between cultures; it is not a universal cognitive process (Gordon, 2004).

The numerical quantity concept relates to the understanding as non-referential counting words and as a connection between the set and present numerical tool. On the notion of numerical quantity, the cardinality of a set of objects can be connected with the number words (understanding also cardinal concepts as mental representations, underlying the notion of cardinal number assignments (Wiese, 2003)). The concept of numerical quantity, referred to also as numerosity, is important as it allows the understanding of the quantity of how many, as empirical characteristics of sets of object or events.

The second concept of the numerical rank relates to the serial order of objects or events and it entitles us to understand in which position it stands in observed series. Following the notion of such concepts, numbers are understood as representations in the brain, where the neural correlates for representation and processing of numbers in the brains are found in the prefrontal, posterior parietal lobes and intraparietal sulcus areas of the brain (Nieder & Dehaene, 2009). Our assumption based on these concepts is that in connection to the second concept of the numerical rank, it is important which number is higher in the serial order of numerical values stated. In this sense, objectivity of the certain number used as objective information from the financial statement, and comparing only numbers between companies in the serial order for numerical value, is clear.

2.4 Face Perception and Business Leaders as Subjective Information Carriers

In a short period, the human mind can store in memory a lot of information about the human face, even though different faces can have similar characteristics (Bahrick, Bahrick, & Wittlinger, 1975). Attributions, quickly established from the faces, and the first impression are rapidly formed and with very little effort being presented with a stimuli of a face, even a time span of 34 milliseconds is enough to form a first impression, impressions that are not changing even with the longer exposures (longer than 200 milliseconds) (Todorov, Olivola, Dotsch, & Mende-Siedlecki, 2015). In the general field of perception, in comparison to, e.g., process of object recognition in human mind, face recognition is seen as a unique, expert knowledge process (Eysenck & Keane, 2010). Therefore, such process was selected for the following discussion in comparison to the financial statement information as objective information.

In relation to the face recognition, there have been two strands of explanation: analytical and holistic view. Zhao et al. (2003) propose also the third strand of approaches, named hybrid approach, that uses both holistic and local features. The analytical view, mostly supported by

the studies done with eye tracking, claims that faces are being scanned according to the local features, allowing for extraction of the most diagnostic information for the face individualization. On the other hand, the holistic view, the prevailing approach in research supported mostly by the behavioral studies, while acknowledging the local features, states that the mutually independent relationship in their perception and representation is not present and concludes that faces are processed holistically or as configural processing where there is interactivity and integration present across the whole face (Van Belle, De Graef, Verfaillie, Rossion, & Lefèvre, 2010; Eysenck & Keane, 2010). In the holistic processing approach, two influential theories are proposed: domain-specifity hypothesis and expertise hypothesis based on previous studies. Zhao & Bülthoff (2017) present a notion of dual-route hypothesis, where the object-based (bottom-up processing) and experience-driven (top-down processing) processings influence holistic processing of the faces.

2.4.1 Facial Appearances of Business Leaders as Carriers of Subjective Information

CEOs are recognized as the influencers of people's perception of a firm. Love, Lim, & Bednar (2017) intended to empirically test such notion, relating the leaders to the corporate reputations (where they assumed that reputation is a subjective evaluation of the firms' overall quality and following the notion that corporate reputations are valuable intangible assets of the firm). In their study, they have found that in cases where the quality of the leader is uncertain, evaluators look for other information about the leader (e.g., media coverage). However, they claim that prominence quality information alone is not enough to enhance reputation of the firm, the distinction between a prominence quality and the case of how established the CEO is, should be taken into account. Based on their study, they also acknowledge a role of the intuitive idea of the first impressions, where people construct first impressions of the capabilities of the leader, as to some extent distinct from their views on the firms itself and its performance. Following such notion, we must acknowledge the formation of first impressions of the CEOs for the company and such relation to the intangible value of the firm, namely reputation.

2.4.2 Research Methods for Assessing the Subjective Information Carriers

In the chapter of financial reports as objective information carriers, with objective information extracted from the financial statements, presented through the lens of numerical cognition (Wiese, 2003), we argued that such numerical values can be understood through the approach of classical cognitive science, physical symbolic system hypothesis, and information-processing is simply manipulation of symbols. Such approach in finance is closer to the traditional finance approach and paradigm, where the financial and economic agents are understood through the strong assumption of rationality.

On the other hand, in relation to the research methods for assessing the subjective information carriers, facial features and emotion recognition clues, we present different research methods that form part of it, and are closer to behavioral finance. Presented research methods

(although not an exhaustive list) are eye-tracking and brain imaging research method, namely functional magnetic resonance brain imaging.

Eye tracking method. In relation to the face perception and emotional recognition as subjective information, extracted from the faces of the CEOs of the company, eye-tracking method can shed a light on the features of the face and on the gaze of participants when extracting information from the faces. Eye tracking methodology builds on the following ideas: working of visual system with the neural underlings in the human brain; underlying concept of visual attention and visual search, allowing for the presence of four basic characteristics – color, size, orientation, presence/direction of motion; structure of the eye and psychophysical information; and different linear models of eye movements (building on eye movements understood as, e.g., saccades, fixation) (Duchowski, 2007). In relation to the face processing, eye movements in the study were used by Bombari et al. (2013), when researching the emotion recognition though the lens of the role of featural and configural information.

Brain imaging research method. First article using the imaging technique of magnetic resonance was published in 1991 by Belliveau et al. Further development lead to development of functional magnetic resonance imaging (hereafter fMRI), a non-invasive method with an objective of understanding and localizing functional areas in relation to the brain function, presenting a powerful tool for conducting imagining research (Ulmer, 2010) and specifying the workings of the brains in space and time. Imaging the fMRI technique is based on the interconnections of the cerebral blood flow, energy demands in brains and activity of neuron calls providing a contrast for emergence of the picture. Such phenomena are observed in relation to behavior in the magnetic field of the hemoglobin in human blood, more specifically in relation to the blood oxygenation level dependent (BOLD) contrast. During the fMRI imaging, there is a time sequence of the pictures of the brains, where a new picture is made every 2-3 seconds, while during the imaging, an individual is carrying out a certain task. Interchangeably, periods of activation and rest are present during the imaging. Differences in the activation of the signals in the brains, based on such periods of activation and rest are hence calculated and presented with a specific statistical process. In the field of neuroscience, fMRI imaging techniques allows observing activation patterns of certain regions of the brains during the task, taking the limitations that the current state of the apparatus, for the design of the experimental task, presents (Bear, Connors, & Paradiso, 2007; Matthews & Jezzard, 2004; Kim, Jin, & Fukuda, 2013).

Both of the presented research methods for the analysis of the subjective information processing have their strengths and weaknesses. At this point, a detailed discussion about underlying strengths and weaknesses is not presented. Combining both presented research methods, provided important insights, sparking further discussions about brain regions that are involved. In a study done with the combination of behavioral and fMRI research methodology, the authors concluded that activation in the neural populations of early visual cortex encode information related to value in connection to the monetary value of objects, and

have a role (further also sensory systems) in processing such information (Persichetti, Aguirre, & Thompson-Schill, 2015). Meaux & Vuilleumier (2016) combined in their study methods for the data acquisition from behavioral data methodology, eye-tracking methodology and fMRI methodology. With combination of such methods, they were able to, to some extent, distinguish between areas involved for the analytic and holistic face processing, while concluding that activated area are still in the domain of the brain network, as being assumed to be involved in face processing network. Following this notion, also for the field of behavioral finance, we could think about conclusions made by other fMRI studies, as about the involvement of amygdala response in the study by Rule et al. (2011). Is building on the accepted assumed notion that amygdala activation indeed plays a role in first impressions enough to claim that reported amygdala activation in their experiment confirms objective forecasts made in such way? Their conclusion, even thoroughly discussed, might be a bit too soon to make and an emphasis should be more on the part that further studies need to provide additional insights.

According to Bikas et al. (2013), behavioral finance assumes two sets of behavior, one set of individual behavior and one set of behavior on the level of the entire market. As such, it has in the assumptions themselves already present a challenge of integration of research methods framework. In what ways is best to research sets of individual behaviors and in what ways sets of the entire market? If taking into combination all the availability of the research methods for the individual behavior, from neuroscience to sociology and all the research methods for the entire market from traditional finance to sociology and complexity theory methods, integration is challenging, although very holistic and thorough.

There are numerous studies, based on the insights from brain sciences, research with combination to behavioral finance, which successfully managed to provide insights also for professional investors. Lo & Repin (2006) presented a study with measuring physiological characteristics on a sample of traders, during their real trading behavior, concluding emotional responses present an important factor on processing financial risks. Among others, Montier (2007) provided insights about the dopamine for investing, and Peterson (2005) provided additional fMRI insights for dopamine circuits and reward system for investor. In the research, combining fMRI study and simple task of the economic trust game, researchers extend understanding of the social component in fairness and intention to reciprocate observed behavior (King-Casas et al., 2005).

Mentioned research of trust and reputation, nicely extends also the debate by Love et al. (2017) about the reputation and leaders as intangible value of the company. Further, Sapra, Beavin, & Zak (2012) have taken a step further in their study and genotyped professional traders from Wall Street, observing that certain distinct alleles (of dopamine receptor and 4 promoter and catecholamine-O-methyltransferase) presented predominance in traders and were positively correlated with the years of trading and differences in personality and behavior of traders. Different studies, presented through the thesis show the variety of the phenomena, and research methods used to explain economic and investing behavior. One of

the further discussions from the scholars discusses the emergence of neurofinance and differences in biological fundamentals and neurophysiological responses (Ackert & Deaves, 2010), while some claim neurofinance as a new paradigm in finance, riding on the way of fast development of neurotechnology in order to observe and understand market behaviors (Tseng, 2006).

Having many studies and combining so many different disciplines and research methods can be challenging. Behavioral finance as a field should provide at least some sort of consensus and analysis of current trends and synthesize already researched phenomena (as proposed also by Ackert & Deaves (2010)). With the two classifications of information and two research methods for measuring the subjective information processing, we present the distinction and discrepancy between traditional finance and behavioral finance. With the distinction about the subjective measures of information processing and further generalization for the field of finance, the integration of different studies is not completely clear at this point, genotyping could be the future of behavioral finance. Until now, behavioral finance managed to successfully provide additional interpretations as a subfield to the established financial theories and research methods. However, in the future, if still wishing to coherently follow the advances in research in human cognition, some degree of research consensus and integration possibilities should be further discussed by the academic scholars or the field can also follow the current way, presented by emerging field of neuroeconomics (Fumagalli, 2010).

2.4.3 Personality Traits and Leadership Theory

One of the first studies relating to the business setting that was trying to bridge the gap between first impressions of the CEOs and firms' performance was, as already mentioned, conducted by Rule & Ambady (2008). In contrast to the Love et al. (2017) research approach (they have used the qualitative method of survey and hence assessed the data), they have conducted a behavioral experiment simply comparing the subjective predictor: first impressions of the CEOs with the objective predictor: companies' financial information reported through profits and revenues. Their conclusion was that not drawing a casual inference from their study: only partial correlations, that through naive judgment of the perceptions of the CEOs facial appearances, participants' judgments were successfully related to the profit that the corresponding firm made.

Since their research was building on the leadership literature and overlapping literature of personality traits that can be judged relatively reliably from the faces (Todorov et al., 2015; Gavrilescu & Vizireanu, 2017): competence, likeability, trustworthiness, dominance and facial maturity, respondents were answering to simple question to judge how good of a leader for a company a person would be. In such way the question could be misleading, as already implying that the presented person is a leader and respondents' responses solely reflect the judgment about the more successful and less successful companies. Secondly, traits were also analyzed with the principal component analysis as two groups of traits – power (competence, dominance and facial maturity) and warmth (likeability and trustworthiness), distinction used

also in the later studies. Following the same line of reasoning, authors replicated results with the female CEOs, concluding that on the basis of subjective and consensual perceptions objective performance can be predicted, as inferred from the judgment of personality of the female CEOs from their faces (Rule & Ambady, 2008).

In the organizational context of a non-profit organization, Re & Rule (2016) conclude that perceiving the leader is not the same across contexts and based on the organizational context, it can wary. Authors conducted an experiment on the sample of the United States of America law firms, with the assumption that managing partners in the law firms become so based on their experience as in comparison to the typical firms, where this is not an obligatory rule. In such setting they have come to conclusions that inferences from the personality traits, extracted from the photographs of the managing partners significantly relate to the related firms' profit.

As critique to the first study of Rule & Ambady (2008), Graham, Harvey, & Puri (2016) provide conclusions that solely relate it to the profits, does not necessarily mean that company is profitable. In their study, in contrast to Rule & Ambady's approach (2008), they use specific questions about the traits, relating traits judgment reference as specific question inferring from the faces. In such way the selection can be addressed too, and the framing effect, concept firstly presentedby Tversky & Kahneman (1981) minimized, since there is no suggestion whatsoever present that the person in picture is indeed already a leader.

Furthermore, Graham et al. (2016) indicate in their study that the facial traits do not relate to the performance of the company (when they controlled for the size of the company), but do relate to the compensation premium, especially in the case if CEO was hired externally. In their interpretation they argue for the behavioral finance interpretation that faces do indeed irrationally have effect on the perception of performance characteristics, and similarly as Love et al. (2017) that when there is insufficient information situation, decisions are more likely to be based on other information possible, namely also first impressions, where the influence of facial traits can have a role. In such manner, the decision about hiring the future CEO can be based on intuition (on heuristics and intuitive decision-making see Gilovich et al. (2002)). In case when there is a risky environment for the decision to be made, on the notion of proposed hypothesis of risk-as-feelings (Loewenstein et al., 2001), the divergence between the behavior and what is seen as the best course of action can occur. Graham et al. (2016) acknowledge that the selection bias done by the companies themselves when appointing CEOs can result in similar biases in later experiments, when asking about the traits or ability of CEOs, based solely on their photographs, since companies that are already performing well have also hired more competent looking CEOs.

In relation to the selection, Stoker, Garretsen, & Spreeuwers (2016), with the use of the biometric face comparison as an objective method evaluating faces, compared 150 photos of randomly selected CEOs (out of their bigger sample of Fortune 500 companies), 150 photos of citizens and 150 photos of university professors. Authors came to conclusions that facial
features of the United States of America's CEOs indeed significantly differed from the United States of America citizens and university professor. Hence, there are facial features that can distinguish appointed leaders and non-leaders. However, comparing the performance criteria (such as profit/assets ratio, profit/revenues and revenues) with the facial features of CEOs, in contrast to the previous studies and based on their results, they conclude that performance of the firm is not related to the facial features of the CEOs. Studies reflecting that human judgment is biased, and that there are other factors that might be having effects, e.g., emotions, building on the notion of the Damasio's somatic marker hypothesis, affect-as-information hypothesis and risk-as-feeling hypothesis (Loewenstein et al., 2001). However, as Eysenck & Keane (2010) emphasize in the computational cognitive science, with also the connectionist approach as a subfield, emotional factors tend to be neglected. Furthermore, as Bermúdez (2014) states, it is very difficult to from the third person perspective include properly feeling and emotion within the information-processing model of the mind.

2.4.4 Emotions and Assessment of Subjective Information

When assessing facial features as subjective information carriers it is inevitable to also briefly touch a complex field of emotions and their role, if any, in the information processing. Important theories and models brought by traditional finance (Nofsinger, 2011) do not take into account role of emotions and bring many important insights for the development of financial theory. However, in relation to financial markets, it is not rare that when reporting volatility of financial markets, press relies on emotions (Ackert & Deaves, 2010). Following the Keynes' and Minsky's principles, also for the relation between psychology and finance, Dow (2010) takes a step further for the emergence of new field of emotional finance. Similarly, Fairchild (2014) advocates for the formal modeling framework of emotional finance, following the notion of unconscious emotions and further Freudian psychoanalytical approach, which is his view of the paradigmatic shift in the finance.

Emotions play a role in financial decision-making, following the notion by De Martino, Kumaran, Seymour, & Dolan (2006), concluding on the amygdala activation in relation to the framing effect that emotional system in human brain have a role in mediating decision biases. Further empirical claims also present a notion that pride and regret have important consequences for the individual decision-making (Ackert & Deaves, 2010). A research done in the trading task in combination with the fMRI research method, also presents the notion that emotional regulation can play a role in decreasing loss aversion, excluding gains and hence reduces activation of amygdala (Sokol-Hessner, Camerer, & Phelps, 2013). Pixley (2004) connects in her book about emotions and finance inherently the emotions and trust in financial markets, notion that supports also the view presented by Dembinski (2009), seeing financial transactions as intangibles, as promises and commitments, where such contracts' meaning and value is dependent on the trust in the markets where transactions take place, while considering also what happened prior and after the transaction. Similarly, in the studies presenting certain degree of consensus about personality traits, extracted from facial features, trustworthiness in one of such traits (Todorov et al., 2015).

During the analysis of experiments conducted by the idea of Rule & Ambady (2008), one of the studies (Rule et al., 2011) was done with the method of fMRI scanning in combination to the behavioral response of judgment about the CEOs leadership ability. Authors have concluded in their study that amygdala responses confirm their conclusions for the subjective judgments and objective measures of leadership ability based on first impressions. Their main hypothesis was that activation of amygdala during the perceiving of the leaders' ability would respond to actual leadership ability and such responses would be related to the arousal theory. However, authors note that specific result in amygdala activation presented as arousal being accounted for only partially mediating the relationship between perceptions of leadership and company profits, where magnitude of activation of left amygdala increased in relation to the size of profits earned by the company. Company revenues were in their study unrelated to any neural activation in the brain. Authors lack a bit of conservative approach in claiming that based on such activation pattern (considering also the lack of bilateral amygdala activation), leadership ability can be extracted, even if perceivers were not aware that they were viewing CEOs and connected partially to the arousal theory. In a way it merely reflects previously proposing notion of certain features in faces that signal selection of the leaders (Graham et al., 2016; Stoker et al., 2016). Furthermore, only the left amygdala activation increased in relation to the size of profits earned by the company and not also the right amygdala. Activation of the right amygdala induces negative emotions (such as fear and sadness), while the left amygdala activation induces either pleasant (such as happiness) or unpleasant (such as sadness, anxiety) emotions (Lanteaume, 2007).

As provided in the discussed fMRI study by Rule et al. (2011), authors have only focused on the activation of the amygdala. It has an important role as occupying the center stage in neuroscience of emotions (Heatherton & LeDoux, 2009) also for the recognition of emotions in facial expressions (Adolphs, Tranel, Damasio, & Damasio, 1994; Adolphs et al., 1999; Schirmer & Adolphs, 2017). However, in the case of the study about the leadership ability, the objective was not about the emotions, but about the leadership ability. In such case, the question is probably more related to the face perception domain. In such case, Kanwisher & Yovel present in their review (2006) about the so-called fusiform face area the notion that the region plays a crucial role in the face perception and also in the connection to the holistic processing of faces; similar conclusion was also made by Zhang et al. (2012).

In the studies conducted by notion of thought as first proposed by Rule & Ambady (2008), the factor of warmth as underlining traits of likeability and trustworthiness was not statistically significant in correlation to the company performance (similar result in the study done with the law managing partners (Rule & Ambady, 2011) and in results from the study of the female CEOs by Rule & Ambady (2008)). However, when presenting the faces of non-profit organizations, inferences of both factors – power and warmth – were significant in relation to the success to the certain leader; further when providing context, only warmth was related to the perception of the presented leaders' success (Re & Rule, 2016). Researching the facial emotion perception, Lee, Choi, & Cho (2012) found that facial emotion perception is

dependent on the facial configuration, while also modulated by the context in which such face is presented as well.

The presented leadership theory interpretation strand, presented mostly by also following Rule & Ambady (2008), provides an indication of certain inference from the facial features that can be communicated for the future forecast of the business, not satisfying only with the proposition by Graham et al. (2016) of present bias in selection done by the company, nor with proposition by Stoker et al. (2016) that such processing should be conducted using computation methods in the most objective manner, since human facial processing and consequent forecasting is flawed. Further research could shed a light on the participants' emotional response, when producing a judgment about the CEOs personality traits in connection to the objective information, provided by the companies themselves. One of such proposals would be to repeat simple experimental task done by Rule & Ambady (2008), while using the research tools for the facial expression recognition (possible tool is The Computer Expression Recognition Toolbox – CERT, see Littlewort et al. (2011)). Having in mind the notion that the face perception, facial recognition, analysis of facial expressions and classification based on facial features are all processes conducted automatically in human mind with little effort (Samal & Iyengar, 1992), it would be also possible to assess the real time emotional reaction of the participant, while they provide a judgment about a certain trait of the CEO or about their leadership ability.

2.4.5 Hybrid Approach Combining Analytic and Holistic Views

In the hybrid approach, the assumption of strict distinction between solely processing from the analytic approach or solely from the holistic approach is altered. It proposes the dual-code view, where emotion recognition process is conducted in respect to local features and global configuration of local features, since the recognition of different emotions is dependent on certain types of information extracted from certain facial feature (Bombari et al., 2013). Meaux & Vuilleumier (2016) in their study with the analysis of behavioral data, eye-tracking methodology and fMRI methodology stimuli of happy and angry faces, further propose to some extent distinct neural pathways underlying feature-based analysis, combination with the whole-face configuration and holistic representations of meaningful expressions, while presenting notion that processes do engage separately, but within the face processing networks.

Following such notion, the research about the facial features from the faces of CEOs could be extended with a further combination of the eye-tracking methodology to assess local features in a sense if participants assess differently and which features they do assess: firstly, in faces of CEOs of more or less successful companies, and secondly, in faces of CEOs in comparison to other people. Results from the first condition would indicate an answer to which facial features indicate a distinction between a CEO of more or less successful company (or following the Graham et al. (2016) interpretation of the selection biases). Results from the second condition would indicate an answer to which facial features indicate a distinction

between a CEO in comparison to other people. It would then be possible to compare such features analysis in relation to the participants' responses of judgments about either leadership ability (following experimental design by Rule & Ambady (2008)) or personality trait inference (following experimental design by Graham et al. (2016)).

3 COMBINATION AND INTERPRETATION OF OBJECTIVE AND SUBJECTIVE INFORMATION

Following the presentation of information-processing model of human mind, and explanation of the concept of information as presented by Capurro & Hjorland (2005), we classify information as objective and subjective through the lens of the field of finance. Financial reports are recognized as carriers of objective information (taking into account rigorous standards that have to comply with, such as IFRS), while faces of business leaders' relation to the face perception are recognized as subjective information carriers, following Rule & Ambady strand of research (first study from 2008). Throughout the thesis, the underlying idea of the discussion between traditional and behavioral finance, with assumption of objective and subjective information carriers, is presented. At this point, we address two further aspects: firstly, the situation where entrepreneurs act as subjective information carriers and there is insufficient objective information present, and secondly, the notion of financial literacy and its implication on the assessment of objective and subjective information.

3.1 Entrepreneurs as Subjective Information Carriers in Case of Insufficient Objective Information

When we think about the entrepreneurship, start-ups or new ventures, we cannot neglect the importance of the entrepreneur (the term entrepreneur is used as general term, covering also an innovator and a founder of the start-up). An entrepreneur is a person with specific personality characteristics, vision, ideas and a way of thinking, and cognitive processes (the construct of entrepreneurial personality (Zhao et al., 2010; Miller, 2015). Cardon, Gregoire, Stevens, & Patel (2013) further provide a view that an entrepreneurial identity is a core element of entrepreneurial passion (perceived as the "heart of entrepreneurship"), and to some extent it is generally assumed that the action of founding a new venture is closely connected with the identity of the entrepreneur (Shepherd & Haynie, 2009).

Valuing a new venture is not an easy task, making a future forecast in an uncertain environment, while having non-credible financial information as objective information inputs, e.g., when venture capitalists are conducting the startup valuation in case of missing accounting data in a start-up. Where there is present an information asymmetry between objective and subjective information, investors have to rely on other type of data. In the field of entrepreneurship, the concept of human capital perspective is widely used, while also used as appealing and intuitive for predicting the various entrepreneurship outcomes, such as venture emergence, performance, engagement in venturing, and other outcomes (Dimov, 2017). The empirical study (Miloud, Aspelund, & Cabrol, 2012) provided insights that among other factors, the quality of the founder and top management is important criteria, however, they present such notion in relation to the experience the founder has. Similarly, Brusche (2016) emphasizes human factors, namely the human aspect, when venture capitals are considering possible investment decision. However, Dimov (2017) advocates that human capital analogy to financial capital is misleading and calls for a more qualitative orientated reasoning of human capital, since the underlying sources of human capital (namely specific set of knowledge and skills) are innately shaped also by individual entrepreneur and through the life-cycle of corresponding venture.

In case of business angels, where the rejection rate of numerous deals presented to them is high. The conducted research study (Mason, Botelho, & Zygmunt, 2017), combining research method of survey with the personal interviews method, presented the conclusion that the dominant criteria for rejection are people factors. On the basis of their analysis of the personal interviews, authors divide people factors by four themes. First and the most frequently occurring were characteristics that business angels look for in an entrepreneur such as openness, being straightforward, believable, trustworthy, and honest. Secondly, the entrepreneur appearing knowledgeable and competent, while thirdly, keeping certain amount of realism in relation to valuation and equity shares proportions. Lastly, business angels are aiming for a presence of feeling of some kind of personal rapport with the entrepreneur. Some of the traits pointed out in this study, trustworthiness and competence, were acknowledged and classified as subjective information. These personality traits (with few others) are also believed to be able to be inferred from the face features with a certain degree of reliability (Todorov et al., 2015), hence are also connected to the assumption we make about the objective and subjective information processing in finance.

In relation to trustworthiness, Maxwell & Lévesque (2014) based their study on the method of observational interaction, found indications that entrepreneurs which are constantly presenting numerous trust-building behaviors, while presenting less trust-damaging behaviors are more likely to receive an investment offer from the business angel. Traditional research and theories presented the notion that bootstrapping is an approach driven by the environmental necessities, rather than entrepreneurial agency (Grichnik, Brinckmann, Singh, & Manigart, 2014). Authors in their study, analyzing the relevance of individual's human capital, social capital and environmental characteristics for bootstrapping behavior, came to conclusion supporting the notion that bootstrapping activity. Hence, behavioral finance with understanding of the individual behavior and combining also ideas from traditional finance with advancement of ideas from the complexity theory can also present further development in the field of entrepreneurship itself.

3.2 Influence of Financial Literacy on Assessment of Objective and Subjective Information

In the following part, we discuss influence of financial literacy on the objective and subjective information processings, beginning with a brief presentation of psychology and social construct of money. Money, as a basic economic institution in society, is to some extent acknowledged as needed for society to function (Camera, Casari, & Bigoni, 2013), and as being an object as a complex symbol, carrying the meaning and symbolism that can be used to mainly (or only) facilitate exchange (Furnham, 1984). Others have argued that when discussing the psychology of money, the domains such as self-concept and money attitudes such as beliefs and values should also be taken into consideration (Prince, 1993). In relation to the traditional finance, such considerations about the underlying psychology of money and money as a social construct in the society should be considered by behavioral finance.

Some researchers (Bourgeois-Gironde, 2013) have taken another approach through the prism of the field of neuroscience (although with remaining many open questions, that authors further acknowledge). In their attempt to explain typical neural processing of coins (understood as a material and symbolic artefact, as the central object of modern economic life), they have taken an approach in the light of likeliness of the cultural cortical recycling hypothesis, on the basis of proposed neuronal recycling hypothesis in relation to cortical maps as applied to cultural objects – that explains cultural inventions as invading evolutionary older brain circuits, while also inheriting many of their structural constraints (Dehaene & Cohen, 2007; Stout, Toth, Schick, & Chaminade, 2008). Considering the digital transformation in light of prevailing presence of digital money, managing such resources also shifts (Dodgson, Gann, Wladawsky-Berger, Sultan, & George, 2015), while changing the representations in the human mind and hence the underlying information-processing processes.

Tallon-Baudry, Meyniel, & Bourgeois-Gironde (2011) define money as a powerful incentive that, in order to influence brain activity and consequently the behavior of the individual, has to be also identified as money on the neural level. In their approach, they take into account the notion that validity of money relies on the notion of money as a symbol, based on social agreement. In their study, based on measuring neural responses, they claim that there is an indication of currency through the presence of a categorical process, presence of category money (in a sense that different instances of money elicit the same type of responses), while the visual brain regions that they have found out to be involved (known to be also involved in object categorization) are also very much shaped by experience, even though taken into consideration notion that money is not a visual property, but a symbol. On the basis of the results from their study, they claim that money is indeed categorized in the ventral visual pathway as fast as natural, non-symbolic objects, defined by their visual properties, while the neural fluency of dealing with coins they see as also one of the reasons that influenced the worldwide success of the money. Such attempts are important for the understanding of the money as a symbol; however, it cannot fall under the classical cognitive science approach as

objective information, extracted from the financial statements, because money as a symbol can have different meaning (and also values) to different individuals.

3.2.1 Question of Financial Literacy

Growing fields of research in behavioral finance and behavioral economics present notions and underlying importance of financial literacy and financial socialization for the behavior of financial agents. In such manner, financial literacy is understood as concept of understanding individual's decision-making process in the field of financial concepts and money decision-making process that would consequently result in more optimal financial decision-making process (Lusardi, 2015; Lührmann, Serra-Garcia, & Winter, 2015).

Financial literacy has been researched in attempt to search for the childhood roots of financial literacy, while taking into account two strands of the literature, one strand dealing mostly with financial socialization (childhood experiences in shaping financial knowledge and behavior, and financial socialization by parents and also through schooling channel) and another one dealing with financial literacy levels impact on financial behavior (Grohmann, Kouwenberg, & Menkhoff, 2015).

Through understanding of the development of the metacognition in children (Kuhn, 2000), some understanding of the money (through another approach, social learning in children about knowledge of the symbol money as a social agreement, or social construct) can possibly shed a new light on the understanding on the process of acquiring such knowledge that consequently substantially influence our everyday lives (while also taking into consideration the subjective domain for each individual). One of the possible research question as an objective, within this research could be, how do children actually learn about the money as a visual symbol, and can with the research of the neural correlates of the unit of the currency (e.g., as interpreted of the coin by Tallon-Baudry et al. (2011)) in comparison to the research of numerical symbolic acquisition understand the representation and brain regions involved in understanding also money as a social symbol.

In connection to the financial literacy, Han, Boyle, Arfanakis, Fleischman, & Bennett, (2013) present a study with older adults, believing that greater financial literacy is associated with the stronger functional connectivity between anterior and posterior regions, typically associated with the Default Mode Network or that it may also be associated with functional connectivity between the posterior cingulate and basal ganglia structures.

Following such conclusions, if the children brains at certain age are not yet fully consistent at a certain stage in their life of the development as a normal course of life, how we can then pose financial literacy without thinking of such neural development (in their review, Broyd et al. (2009) propose that the default mode network indeed undergoes certain developmental changes).

Importance of the financial literacy for the discussion in academia, can be seen in the upwards trend in the graph in Figure 5, where the data obtained are the same as in Figure 1, Figure 2, Figure 3 and Figure 4. Numbers of sources were gathered from the academic database of the Digital Library of University of Ljubljana (DiKUL), where the sources included are scientific articles, books and e-books, conference proceedings, theses and dissertations published during the observation period of 15 years from 2002 to 2016, the observational unit being each year (table with exact numbers for Figure 5 can be found in Appendix A, Table 1).





When the crisis of the economy and financial markets strikes, people look for new solutions and answers on how to prevent the possible next one, since the consequences are quite severe, not only for the economy but also for individuals. One of the answers after the latest crisis, especially by the finance and policy professionals is to educate more (Jappeli & Padula, 2013; Taylor & Wagland, 2013; Grohmann et al., 2015; Lusardi, 2015), in a sense that there is a prevalent need to educate more of the financial content to children, young adults, and adults.

Alsemgeest (2015), Tang & Baker (2016), and Lührman et al. (2015) present a mixed response about the efficiency of such programs. Tang & Baker (2016) conclude in their study that financial knowledge has less importance and role in comparison to the psychological traits. Lührman et al. (2015), in the German study with a short financial education program on teenagers in German high schools, present the results that such a program indeed raises the interest and knowledgeability in such matters, but behaviorally the results were mixed. Some argue that higher arithmetic and mathematic skills (Jappeli & Padula, 2013) could also improve the financial education, financial skills and financial decision-making.

Inspired by the review in the domain of the effects of development and enculturation on number representation in the brain (Ansari, 2008) and with the notion of numbers as symbols, one could argue as similar to every unit of the currency of money as a symbol (carrying certain value based on the social construct, similarly as Arabic numbers are social construct of the numerical scale in the Western society). As a comparison, in the domain of the neural correlates of the numerical development, children use more prefrontal regions during numerical processing then adults (Ansari, 2008). In the same review, the author proposes that the role of extrastriate areas that are involved in specialization for the asemantic representation of visual symbols and of left-lateralized temporoparietal regions that are involved in symbolic representation of numerical magnitude, should be systematically investigated with the focus on the children that are making the transition into the formal classroom as the most appropriate, since it is the stage of the child's development at which children are systematically introduced to symbolic representations of numerical magnitude through formal education. Therefore, the authors propose further research on how the changes in such regions would change also the understanding of a unit of the visual currency, coin as a visual symbol, and if the development of this regions impacts the simple experiments with the money as a social construct.

If children acquire the meaning of number words before they learn the visual symbols that represent numerical magnitudes (Carey, 2001; Le Corre & Carey, 2007), then perhaps they also learn the meaning of the value of money before they can understand the numeric value of 1 euro as a numerical money, visual symbol and word symbol. In that sense the possible proposed experiment is to design a simple experiment with the number representations and the money of certain value, perhaps a unit of the coin as a visual currency unit symbol of the money, firstly with the use of number words and simple money words meanings, and consequently fMRI scanning of the brain regions activations. As Ansari (2008) proposes, the same experiment is repeated when the children enter the formal education. If indeed learning of the visual symbols that represent numerical magnitudes through the formal education impacts simple repeated money operations, then the simple proposal that more efficient mathematics teaching is sufficient for increasing financial literacy is true. However, if such learning has no significant impact, then there is something more behind understanding money symbols and with that also coins as a currency unit.

A research can provide an understanding of the possible similarities and differences in the brain regions involved, when learning about the symbols of the unit currency of the money and the numerical symbols. In that sense it can provide an insight about how important the numerical symbolic representation acquired at certain stage is important for attributing value to the certain unit of the currency. With that understanding, it could further possibly present, in combination with the understanding of the notion of financial socialization (Grohmann et al., 2015), an insight about the development of certain financial behavior, attitudes and understanding of the money as a social construct. Further understanding of this concept as the

representation in our brain could also improve our objective information processing through learning.

3.2.2 Financial Literacy in Relation to the Objective and Subjective Information-Processing

Financial education might not be the only answer to the global financial crisis due to the individual differences and limitations of one-size-fits-all normative process (Alsemgeest, 2015). However, financial education can be beneficial alone as well and embedded when there is also present a decision support system helping with the identification of a tailored consideration set of safe options Effective information remedies, referring to our basic assumption of information-processing processes, e.g., financial education and disclosures are possible under cognitive and intentional control, but not for behaviors with weak intention-behavior links (Fernandes, Lynch Jr, & Netemeyer, 2014). Acknowledging financial literacy as having effect on ability to locate information and to identify fees, risk and cost, that placement of information can also lead to positive influences on decision-making process (Foster, Ng, & Wee, 2015). Following these thoughts, some propose that in investors' decision-making process, the identification and evaluation of information can be improved by improving the individuals' level of financial literacy and knowledge of the individual, in order for the individual to be able to understand which information is important and what the weight of the importance on such information is (Lusardi, 2014).

Even if it remains important to further develop financial education initiatives for young people that have the potential to improve their financial decision-making upon reaching adulthood, it should be combined with initiatives that facilitate the understanding of financial information, the effect can be greater, especially in the short run as in line with the findings and propositions by Fernandes et al. (2014), by which content knowledge may be better transferred through "just-in-time" financial education, in a sense that there must be also subsequent present opportunity to enact and use the knowledge in order to avoid knowledge decay over time. Instead of providing financial education aimed at enabling people to take investment decisions in a complex information environment, it is to some extent easier to augment financial information in financial statement standardization in such a way that it is easier to understand for the average investor. By reducing the search costs and the burden of information overload, simplified, standardized and easily accessible investment information could result in more optimal portfolio choices (Kozup & Hogarth, 2008; Hung, Heinberg, & Yoong, 2010).

In relation to the improvement of subjective information processing as understood throughout this thesis, with the financial literacy, considerations go in line with the already proposed further research notions and in agreement with Rule & Ambady (2008), Re & Rule (2016), Rule et al. (2011), Love et al. (2017), and others that further research needs to be conducted in order to be able to better understand the underlying processes in subjective information-

processing approach, underlying presented correlations and causalities with objective information and valuations conducted in such manner.

3.2.3 Role of Social norms for Information Processing

In many parts of present discussion, we were either relating to the notion of society in general, to the notion of social cognition or touching on the topics of social norms and the influences for the financial markets. As argued, underlying social forces also modulate financial markets (Bikas et al., 2013). In the financial field there are observed differences between the Western and the Islamic finance (Zaher & Kabir Hassan, 2001), while differences in cultures around the world are present also in the emotion processing, emotion perception, where the universality of emotion has been questioned by the recent research; concluding that assumption of universality of perception of emotion is bounded by method that cues about certain emotions differ around cultures (Gendron, 2017). The current debate for the field of finance extends beyond the debate of universality of emotion processing and emotion perception, since there are also differences in the way we behave that has an impact for the information processing in finance, objective or subjective information processing. In the following part, the role of social norms and the related notion of cost of social norms are looked more specifically through the lens of behavioral finance (Ariely, 2008).

Lapinski & Rimal (2005) adopted a view connecting the social psychology and communication theory and understand (social) norms as representation of acceptable group manners of behaviors on the collective level, connected also to individuals' perceptions of the certain group behavior (further detailed distinction between collective and perceived norms for the purpose of this paper will not be discussed). From the viewpoint of the same approach, Aarts & Dijksterhuis (2003) stated that the role of norms is important, since they can guide a behavior in certain situations and environments, as a mental representation of appropriate behavior. Fehr & Fischbacher (2004) believe that cooperation in human societies is to a large extent based on social norms and that the latter present "standards of behavior that are based on widely shared beliefs how individual group members ought to behave in a given situation".

In field of behavioral finance, Ariely (2008) presents a view that we live simultaneously in two different worlds. His notion of two simultaneous different worlds rests on the idea that there is a world where social norms prevail and there is simultaneously a world where market norms prevail. Former represents the world according to the social norms, where social exchanges take place, and where social norms are in author's opinion embedded in our social nature and our need for community. He describes social norms as usually being warm and fuzzy, where instant payments are not required (e.g., if a friendly neighbor helps us with moving out of the apartment, he or she probably would not expect to be paid for their help), and the world where actions/behavior conducted provide pleasure for both agents involved and immediate reciprocity is not required. Second world is, according to author, a very different world, which is modulated by market norms, where market exchanges take place and where these exchanges are sharp-edged (e.g., wages, prices, rents, interest and cost-benefits)

and the notion of belief is that an agent gets what he (monetary) pays for. These kind of exchanges or market relationships include self-reliance, inventiveness, individualism and imply comparable benefits and precise, most of the times also immediate, payment. In such sense, author believes troubles can arise if there is a situation where market and social norms collide, which can also lead to the situation of cognitive dissonance and discomfort.

Fehr & Fischbacher (2004) conclude that it is also important how an individual views and analyzes social norms, the view which is also presented by Elster (1989) with the idea that on some occassions people invoke social norm to rationalize their self-interest (on the conscious or unconscious level). If an individual believes he has a financial position that he does not wish to formally disclose to the bank or anyone else, he would not go to the bank if he needed a small investment. He would probably go to his friend, "invoke" social norms and depending on the strength of their relationship and established trust get the needed money with a mere promise that he will repay (at some unstated point) in the future, without any formal procedure. Fehr & Fischbacher (2004) mention it is also important to mention that established social norms do not by themselves already imply enforcement of them by an individual regardless of the cost of such adherence and enforcement. They continue with conclusion that combining also the anthropological evidence human groups can differ greatly in their social norms.

Callen & Fang (2015) conducted a study with aim to examine if religiosity at the country level can be associated with the future stock price crash. Authors view religion as a set of social norms and the social norm of religion can in their view influence and reduce bad news hoarding. They argue that if the firm is headquartered in areas with higher levels of religiosity, it will be related with the reduced future stock price crash risk. Since behavior of people is influenced by social norms, they argue that managers will be more inclined to behave in accordance to the local social norms to minimize their disutility (or any social sanctions) might occurring as not conforming according to such norms. Authors also argue that religious social norms will counter managers' incentives to hoard bad news from investors and that managers of firms headquartered in areas with high level of religiosity will be more likely to follow religious norms, which would lead to lower level of future stock price crash risk (one of the three hypothesis tested in their study). They come to the conclusion (based on robust evidence) that religiosity is negatively associated with future stock price crash risk (which they state is consistent with the view religion can alter managers' incentive to hide bad news and consequently reducing future stock price) and that in the American firms located in the counties with higher level of religiosity do present low levels of future stock price crash risk. Authors in this study focus mostly on the influence of religion as a set of social norms (they also researched the impact of such norms in connection to the governance monitoring mechanism and riskiness of the firms, which will not be further discussed for the purposes of this paper) with recognizing their shortcoming that also other numerous noneconomic cultural factor have effect on corporate behavior.

In the study made by Heyman & Ariely (2004), exploring the effects of social and market norms, they made three experiments with very simple computer task, for which they gave their participants different rewards; there were three groups of participants, two with monetary reward, but different amount and one with societal reward. They came to the conclusion that first two groups implied market norms (they worked more if there was higher amount of monetary reward), and the third one implied social norms (worked hard as a favor). What they did not expect was that people under the social reward worked the hardest and had the highest performance on the task. When they introduced the gift reward results were on average the same among groups, but when market and social conditions are intertwined, meaning when there was a mixed market condition, they argue the market norms prevailed so that mixed markets are more closely related to monetary than societal market. Ariely (2008) argues that for the emergence of market norms it is enough to mention money (even if there is no actual monetary exchange taking place), which is to some extent also supported by the research made by Vohs, Mead, & Goode (2006).

To understand and modulate such behaviors, behavioral finance has to open the debate about the meaning of money. One of the notions in attempt to explain some of the observed irrational behavior towards money is in connection to understanding the money also through ethnographic studies, where the explanation offered is the view of money as having sacred meanings and acknowledging that money has different ways of usage in contemporary society (Belk & Wallendorf, 1990).

In attempt to connect presented ideas to the financial systems and underlying regulations of such system, Nicholson, Kiel, & Kiel-Chisholm (2011) researched the relation between social norms and the recent global financial crisis. They argue that effective financial market (they refer to market in a global sense, across nations and also across markets) regulation should allow policy makers to target human behavior through lens of understanding also the context and nature of relevant participants' norms, which is in line with the presented World Bank's World Development Report (The World Bank Group, 2015). Furthermore, they argue that markets do not emerge isolated and in complete distinct matter from the society (and also the rule of law), so understanding the clear distinction in a way that Ariely (2008) proposes can be difficult in the case of financial markets, especially connecting it to the presented view of Nicholson, Kiel, & Kiel-Chisholm (2011) that also financial sector meets the necessary conditions that are required for the norms to matter, such as being a social system and social community (with underlying social interaction, common ties, etc.). With the understanding of the social network structure and the ideas presented from the complexity theory (Battiston et al., 2016), the way how social norms spread through such networks and consequent effects on behavior to some extent sheds light on the behavior in financial communities, which is also influenced by social norms.

Researchers in the field of neuroscience (Buckholtz & Marois, 2012; Sakaiya et al., 2013; Makwana, Grön, Fehr, & Hare, 2015) acknowledge that there are some foundations connected to social norms and their evolution, strategic social choice and cooperation, which can in the

future perhaps provide clearer answers to some questions relating the traditional financial theory and behavioral finance.

Importance of understanding social norms not only within the company, but also outside the company can be also to some extend supported by the research, covering the area of the United States of America, and carried out by Leventis, Hasan, & Dedoulis (2013) that studied the effect of social norms on audit pricing in regards to different companies. Their findings showed that there are significant effects of social norms on audit pricing (considerably higher pricing) when the client firms were recognized as being part of a controversial industry (such as alcohol, firearms, gambling, military, nuclear power, and tobacco industries often described as "sin" companies). Hong & Kacperczyk (2009), also for the American area, researched the effect of social norms on markets and investing in stocks of "sin companies". Their findings have shown that norms-constrained institutions (e.g., pension plans) in comparing to no norms-constrained institutions (e.g., hedge funds) hold less of such stocks, are also less covered by the analysts and that this kind of behavior also had an effect on their price. Authors pointed out important question for future research to answer if strategy of socially responsible investing and charging higher audit services prices have potentially the power to change the behavior of the firms and what is the rationale and underlying mechanisms underpinning such behavior. Such behaviors can be thoroughly enough understood through the prism of combination of traditional and behavioral finance.

4 DISCUSSION

In the field of finance, there are present two paradigmatic waves – traditional and behavioral. The basis of the traditional financial models lies in economics, with the dominant paradigm of neoclassical economics, where individuals and firms act as a self-interested agent with an objective to optimize as best as possible with the given resource and constraints on them. The complexity theory and methods from physics have under different assumptions followed the efficient market hypothesis in their modeling (Mantegna & Stanley, 2000). However, such theoretical foundations in repertoire are not exhausting enough to present full theoretical-research framework in financial field. In relation to the leadership theory, as one of the theories proposed an interpretation of the results of face processing and subjective information processing in finance, one could argue that with advancement of the ideas of the complexity theory for finance, behavioral finance will see decrease in its interpretation power.

As application, in their study (although not specifically in domain of finance), Schneider & Somers (2006) similarly propose perspective in framework of the non-linear research methodology, namely Complex Adaptive System and neural networks, for the leadership theory. Their results examining the leadership process reflect its influence on the emergence of self-organization through the variables of the organizational identity and social movements. As authors also point out, the lack of such approach lies in the fact that even if such models are successful in explanation of the physical and biological sciences, their relevance for the

social sciences is limited to some extent, since they fail to incorporate processes from the psychological domain for the emergent processes. Hence, this domain will remain in the realm of behavioral finance and brain studies, also in the presented view in thesis.

Such discussions remain open and inherently modulated by advances also in the cognitive sciences. There is also a future prospect in understanding of the brain in relation to the emergence, embodied mind and human experience (Varela et al., 2017), assumptions that postulate cognition understood through the body and environment that defines such processes. In such regards, information-processing understanding will be also presented in light of new understanding. In such sense and notions of also computational models (e.g., neural networks) for the economic science Axtell (2007) presents a shift in economic sciences towards multi-agent systems and agent based models, which inherently incorporates emergent behavior than cannot be explained by the constituent parts of the system.

One of the applications of the research methodology of agent-based modeling has been already presented for presenting threats to financial stability (Bookstaber, 2012), and as methodology for bank stress testing (Arnold, Borio, Ellis, & Moshirian, 2012). Important consideration is that when presenting such modeling, important assumption is that since it underlies heterogeneous agents, behavior of the agent has to be yet computed. In this sense in many domains behavioral finance will have to provide its inputs, excluding the trading that would be exclusively in the domain of algorithmic trading (Kirilenko & Lo, 2013).

In such way, the orthogonal relationship between traditional and behavioral finance would not be appropriate anymore and the paradigmatic shift would call for interdisciplinary nature of finance as also Battiston et al. (2016) argue for financial regulation and economic policy with interdisciplinary approach when observing and modeling financial behavior (not just trading behavior, but of financial system as a whole). These ideas can present important insights also for the field of behavioral finance. In understanding insights from the network science and emergent phenomena from the agent-based modeling, insights into social cognition, as Ariely (2008) proposed also social norms and importance of the environment for exhibiting certain behaviors and decisions, for development of the financial literacy and for the understanding of the forces shaping current financial markets could be presented in the future.

Discussion, rising from the neural network models originating from the biological models of the imitation of the brains (Bermúdez, 2014), lead to the discussion of the application of the methodology of the neural network models for the financial field. As McNelis (2015) points out, underlying uncertainty of such models needs to be accepted, as it would come with such advancements in the field. One approach is in the neural network use in applications of financial field, where we are not completely certain which variables are taken for the forecasts (due to hidden layer's characteristics). Inputs mostly used in such applications are still numerical data from the financial markets and financial statements. Such classification of the data input is in our discussion closer to the objective information-processing class (e.g., study conducted by Gerardi et al. (2013) presented conclusions that numerical ability (as a measure

not modulated by other dimensions of cognitive abilities) can predict mortgage default). On the other hand, neural networks as a method are used in phenomena of cognition, where models are not established within the symbolic paradigm, but the phenomena related to two terms – neural networks in methodology approach for modeling and to neural (or brain) networks that activate when certain task mind process and behavior is happening. In such way, we have one of similar methodological approaches with different data inputs.

In our case, the basic distinction is in relation to the inputs from the field of finance as objective measurement and subjective measurements. In the domain of objectivity in relation to the financial statements, in line with Musvoto (2011) there is already established lack of objectivity of accounting information and that subjective accounting information is already incorporated in finance theory. Crucial point here is that such claims and analysis rely on the representational theory, where crucial emphasis is on representational. Hence, even in the mental process that accountants undergo during their work, there are representations of knowledge they use or manipulate. In such sense we approach our classification from the field of cognitive science, while incorporating the lens of financial field and concepts of numerical cognition (Wiese, 2003). Objectivity and subjectivity is considered with underlying assumptions from the fields of cognitive science and finance, taking into consideration also (even though not thoroughly discussed) biases in such processes.

In the domain of subjective information carriers, we present domain of face perception, with faces as carriers. For the discussion of face perception as subjective information carriers, as related to financial statement information as objective information carriers, we were inspired by a study done by Rule & Ambady (2008), where in their research experiment they came to conclusions that first impressions, especially impressions of CEOs have relevance for the future forecasts about the performance of their company. Further research could shed a light about the participants' emotional response, when producing a judgment about the CEOs personality traits in connection to the objective information, provided by the companies themselves. One of such proposals would be to repeat simple experimental task done by Rule & Ambady (2008), while using the research tools for the facial expression recognition (e.g., The Computer Expression Recognition Toolbox, CERT, see Littlewort et al. (2011)). In such manner, bearing in mind the notion that face perception, facial recognition, analysis of facial expressions, and classification based on facial features are all processes conducted automatically in human mind with little effort (Samal & Iyengar, 1992). In such manner, we would be able to also assess the real time emotional reaction of the participant, while they provide a judgment about the certain trait of the CEO or about their leadership ability. With development of techniques for experiments, fMRI study with an attempt to replicate results from the mentioned study could provide another interpretation.

When discussing the information-processing topics, it is important to also mention popular notion of financial literacy, especially after the latest financial crisis. Effect of such approaches is not completely clear and in relation to the improvement of subjective information-processing as understood throughout this thesis, with the financial literacy, more conservative approach will be taken. Considerations go in line with the already proposed further research notions and an agreement with Rule & Ambady (2008), Re & Rule (2016), Rule et al. (2011), Love et al. (2017), and others that further research needs to be conducted in order to be able to better understand the underlying processes in such subjective information-processing approach, underlying presented correlations and causalities with objective information and valuations conducted in such manner.

Further, importance of role of social norms is to be considered when analyzing behavior in financial markets. Ariely's (2008) proposal of two different markets, following two different set of norms – market or social norms – clearly has advantages and proposes new ways for understanding also the information processing, depending (but not strictly limited) to which set of norms in specific market we conform. Understanding the influence of social norms is important for economics, finance, companies, different institutions and also every individual.

Some research has been already made in order to understand possible effects of social norms to the market, companies, managers and individual's behavior. Further research can shed a light in connecting effects of (social) norms on the innovation process (although some research was already made, e.g., Müller & Wangenheim (2014) researched the connection between product markets and evolution of social norms, where one of the aspects researched was also to analyze what are the conditions for the positive impact of the innovation on the level of norm adoption) and also connecting different effects and understandings to policy and regulation formulation in fast developing society. One such attempt was also made by Ho, Zhang, Vaughan, & van der Schaar (2012) that proposed a framework possibly used in social norm design for crowdsourcing markets and towards the more complete theory of incentive design for crowdsourcing systems. We can expect further research made in the future, since economics, finance, regulation, policy making and law have to make needed steps forward, hand in hand with fast developing and more and more widely used technology.

CONCLUSION

In this thesis, the assumptions and framework of traditional finance (Hens & Rieger, 2010; Ackert & Deaves, 2010), behavioral finance (Thaler & Sunstein, 2008; Ariely, 2008), and complexity theory (Battistion et al., 2016) are discussed, developing an idea through the lens of the information-processing process from the field of cognitive science (Bermúdez, 2014; Markič, 2011). One of the main conclusion is that there should be some degree of consensus among the fields in the future if we still wish to coherently follow and model the financial markets, financial behaviors, and incorporate also advances in research of human cognition (for neuroeconomics such claims are seen by Fumagalli (2010) who acknowledges a high degree of heterogeneity in definitions, concepts and research methods).

We present an assumption of financial reports as objective information carriers, while explaining also assumption for the use of financial statements as a result of a strand of accounting, namely financial accounting. Furthermore, we briefly present the standards (mostly IFRS), adopted for the financial accounting, interpretation of information in IFRS (Bakker et al., 2017), and studies reflecting on their adoption and influence on quality of information (concept of information as presented by Capurro & Hjørland (2003). Discussion is followed by assumptions that financial reporting process brings to the carrier of information, such as role of a manager and some biases, while presenting some studies for such discussion, and concludes with the presentation of the second claim for the assumption of the objective information processing in such manner, in relation to numerical cognition, and tje concept of numerical values (Wiese, 2003; Dehaene, 1992). Next, we discuss subjective information carriers, its processes and the research approach in this domain (mainly by strand of research following the study which was carried out by Rule & Ambady (2008), and the importance of financial literacy for the information-processing process.

Some degree of research consensus and integration possibilities should be further discussed by the academic scholars, or the field can also follow the current way, presented by emerging field of neuroeconomics, where one of the further discussions from the scholars discusses the emergence of neurofinance and differences in biological fundamentals and neurophysiological responses (Ackert & Deaves, 2010), while some claim neurofinance to be a new paradigm in finance, following fast development of neurotechnology in order to observe and understand market behaviors (Tseng, 2006). The best approach seems to be in the middle, between the discussed traditional finance which follows trends from the complexity theory, and the behavioral finance which follows trends of brain science research. Can we claim that there exists a complementary, orthogonal relationship or is this just a phase of transition in finance? The answer to this question yet remains to be resolved by further observation and research.

REFERENCE LIST

- 1. Aarts, H., & Dijksterhuis, A. (2003). The silence of the library: Environment, situational norm, and social behavior. *Journal of Personality and Social Psychology*, 84(1), 18–28.
- 2. Ackert, L., & Deaves, R. (2010). *Behavioral finance: Psychology, decision making, and markets*. Mason: South Western, Cengage Learning.
- 3. Adolphs, R., Tranel, D., Damasio, H., & Damasio, A. (1994). Impaired recognition of emotion in facial expressions following bilateral damage to the human amygdala. *Nature*, *372*(6507), 669–672.
- Adolphs, R., Tranel, D., Hamann, S., Young, A. W., Calder, A. J., Phelps, E. A., Anderson, A., Lee, G. P., & Damasio, A. R. (1999). Recognition of facial emotion in nine individuals with bilateral amygdala damage. *Neuropsychologia*, 37(10), 1111–1117.
- 5. Agarwal, S., Driscoll, J. C., Gabaix, X., & Laibson, D. (2009). The age of reason: Financial decisions over the life cycle and implications for regulation. *Brookings Papers* on *Economic Activity*, 2, 51–117.
- 6. Alsemgeest, L. (2015). Arguments for and against financial literacy education: where to go from here? *International Journal of Consumer Studies*, *39*(2), 155–161.
- 7. Ansari, D. (2008). Effects of development and enculturation on number representation in the brain. *Nature Reviews Neurosciences*, *9*(4), 278–291.
- 8. Ariely, D. (2008). *Predictably Irrational: The Hidden Forces That Shape Our Decisions*. New York: HarperCollins Publishers.
- Arnold, B., Borio, C., Ellis, L., & Moshirian, F. (2012). Systemic risk, macroprudential policy frameworks, monitoring financial systems and the evolution of capital adequacy. *Journal of Banking & Finance*, 36(12), 3125–3132.
- 10. Arnold, V., Collier, P. A., Leech, S. A., & Sutton, S. G. (2000). The effect of experience and complexity on order and recency bias in decision making by professional accountants. *Accounting & Finance*, 40(2), 109–134.
- 11. Ascher, D., Da Silva, W., Da Veiga, C. P., & Souza, A. (2016). Neurofinance: a systematic review about a new way to look the financial decision-making. *European Journal of Scientific Research*, 141, 1–20.
- 12. Ashcraft, M. H. (1992). Cognitive arithmetic: a review of data and theory. *Cognition*, 44(1), 75–106.
- Atrill, P., & McLaney, E. (2007). *Management Accounting for Decision Makers* (5th ed.). Essex: Pearson Education Limited.
- 14. Axtell, R. L. (2007). What economic agents do: How cognition and interaction lead to emergence and complexity. *The Review of Austrian Economics*, 20(2-3), 105–122.
- Bahrammirzaee, A. (2010). A comparative survey of artificial intelligence applications in finance: artificial neural networks, expert system and hybrid intelligent systems. *Neural Computing & Applications, 19*(8), 1165–1195.
- Bahrick, H. P., Bahrick, P. O., & Wittlinger, R. P. (1975). Fifty years of memory for names and faces: A cross-sectional approach. *Journal of experimental psychology*, 104(1), 54–7.

- 17. Bak, P., Chen, K., Scheinkman, J., & Woodford, M. (1993). Aggregate fluctuations from independent sectoral shocks: self-organized criticality in a model of production and inventory dynamics. *Ricerche Economiche*, 47(1), 3–30.
- Bakker, E., Balasubramanian, T. V., Chaudry, A., Coetsee, D., Johnstone, C., Rands, E., Unsworth, C., van der Merwe, M., Varughese, S., & Yeung, P (2017). *Wiley IFRS 2017: Interpretation and Application of IFRS Standards*. Hoboken, New Jersey: John Wiley & Sons, Ltd.
- Barberis, N., & Thaler, R. (2003). A survey of behavioral finance. In G. M. Constantinides, M. Harris & R. M. Stulz (eds.), *Handbook of the Economics of Finance, vol. 1B* (p. 1053–1128.). Amesterdan [etc.]: Elsevier.
- Battiston, S., Farmer, D. J., Flache, A., Garlaschelli, D., Haldane, A. G., Heesterbeek, H., Hommes, C., Jaeger, C., May, R., & Scheffer, M. (2016). Complexity Theory and financial regulation. *Science*, 351(6275), 818–819.
- 21. Bazerman, M. H., Loewenstein, G., & Moore, D. A. (2002). Why good accountants do bad audits. *Harvard business review*, 80(11), 96–103.
- 22. Bear, F. M., Connors, W. B., & Paradiso, A. M. (2007). *Neuroscience: Exploring the Brain* (3rd ed.). Baltimore, Philadelphia: Lippincott Williams & Wilkins.
- 23. Belk, R. W., & Wallendorf, M. (1990). The sacred meanings of money. *Journal of Economic Psychology*, 11(1), 35–67.
- Belliveau, J. W., Kennedy, D. N., McKinstry, R. C., Buchbinder, B. R., Weisskoss, R., M., Cohen, M. S., Vevea, J. M., Brady, T. J., & Rosen, B. R. (1991). Functional Mapping of the Human Visual Cortex by Magnetic Resonance Imaging. *Science*, 254(5032), 716– 719.
- 25. Bermúdez, J. L. (2014). *Cognitive science: an introduction to the science of the mind* (2nd ed.). Cambridge: Cambridge University Press.
- 26. Beyer, A., Cohen, D. A., Lys, T. Z., & Walther, B. R. (2010). The financial reporting environment: Review of the recent literature. *Journal of Accounting and Economics*, 50(2), 296–343.
- Bikas, E., Jurevičienė, D., Dubinskas, P., & Novickytė, L. (2013). Behavioural finance: the emergence and development trends. *Procedia – Social and Behavioral Sciences*, 82(3), 870–876.
- Bombari, D., Schmid, P. C., Schmid Mast, M., Birri, S., Mast, F. W., & Lobmaier, J. S. (2013). Emotion recognition: The role of featural and configural face information. *The Quarterly Journal of Experimental Psychology*, 66(12), 2426–2442.
- 29. Bookstaber, R. (2012, December 21st). Using Agent-Based Models for Analyzing Threats to Financial Stability. *Office of Financial Research, US Department of the Treasury* (*Working Paper, No. 12-03*). Retrieved September 15th, 2017, from https://www.financialresearch.gov/working-papers/files/OFR_Working_Paper_No3_ABM_Bookstaber_Final.pdf
- 30. Borio, C., & Drehmann, M. (2009). Assessing the risk of banking crises-revisited. *BIS Quarterly Review, March 29*, 29–46.

- Bouchaud, J. P., & Cont, R. (1998). A Langevin approach to stock market fluctuations and crashes. *The European Physical Journal B-Condensed Matter and Complex Systems*, 6(4), 543–550.
- 32. Bouchaud, J. P., & Potters, M. (2003). *Theory of financial risk and derivative pricing: from statistical physics to risk management*. Cambridge: Cambridge university press.
- 33. Bourgeois-Gironde, S. (2013). Is a cultural cortical recycling hypothesis likely in relation to economic artifacts? *Translational Neuroscience*, *4*(4), 504–512.
- Bourgine, P., Le Moigne, J.-L., & Walliser, B. (1992). Interdisciplinary research between economics and cognitive science. In P. Bourgine, J.-L. Le Moigne & B. Walliser (eds.), *Economics and Cognitive Science* (p. 1–4). Oxford [etc.]: Pergamon Press.
- 35. Brochet, F., Jagolinzer, A. D., & Riedl, E. J. (2013). Mandatory IFRS Adoption and Financial Statement Comparability. *Contemporary Accounting Research*, *30*(4), 1373–1400.
- Broyd, S. J., Demanuele, C., Debener, S., Helps, S. K., James, C. J., & Sonuga-Barke, E. J. (2009). Default-mode brain dysfunction in mental disorders: a systematic review. *Neuroscience & Biobehavioral Reviews*, 33(3), 279–296.
- 37. Brusche, L. A. (2016). Gaps in academic literature on venture capitalists' decisionmaking on funding for early-stage, high-tech ventures. *Technology Transfer and Entrepreneurship*, 3(2), 82–89.
- 38. Buckholtz, J. W., & Marois, R. (2012). The roots of modern justice: cognitive and neural foundations of social norms and their enforcement. *Nature neuroscience*, *15*(5), 655–661.
- 39. Callen, J. L., & Fang, X. (2015). Religion and Stock Price Crash Risk. *Journal of Financial and Quantitative Analysis*, 50(1/2), pp. 169–195.
- 40. Camera, G., Casari, M., & Bigoni, M. (2013). Money and trust among strangers. *Proceedings of the National Academy of Sciences of the United States of America*, 110(37), 14889–14893.
- 41. Campbell, J. I. D. (1994). Architectures for numerical cognition. *Cognition*, 53(1), 1–44.
- 42. Capurro, R., & Hjørland, B. (2003). The concept of information. Annual review of information science and technology, 37(1), 343–411.
- 43. Cardon, M. S., Gregoire, D. A., Stevens, C. E., & Patel, P. C. (2013). Measuring entrepreneurial passion: Conceptual foundations and scale validation. *Journal of Business Venturing*, 28(3), 373–396.
- 44. Carey, S. (2001). Cognitive foundations of arithmetic: Evolution and ontogenesis. *Mind & Language*, *16*(1), 37–55.
- Cascino, S., Clatworthy, M., García Osma, B., Gassen, J., Imam, S., & Jeanjean, T. (2014). Who uses financial reports and for what purpose? Evidence from capital providers. *Accounting in Europe*, 11(2), 185–209.
- 46. Chakrabarti, B. K., Chakraborti, A. & Chatterjee, A. (eds.). (2007). *Econophysics and Sociophysics: Trends and Perspectives*. Weinheim: John Wiley & Sons.
- 47. Chen, F., & Sutcliffe, C. (2012). Pricing and Hedging Short Sterling Options Using Artifical Neural Networks. *Intelligent Systems in Accounting, Finance and Management,* 19(2), 128–149.

- 48. Chen, H., Tang, Q., Jiang, Y., & Zhijun, L. (2010). The Role of International Financial Reporting Standards in Accounting Quality: Evidence from the European Union. *Journal of International Financial Management and Accounting*, 21(3), 220–278.
- Christensen, H. B., Lee, E., Walker, M., & Zeng, C. (2015). Incentives or Standards: What Determines Accounting Quality Changes around IFRS Adoption? *European Accounting Reviwew*, 24(1), 31–61.
- 50. Coval, J. D., & Moskowitz, T. J. (1999). Home bias at home: Local equity preference in domestic portfolios. *The Journal of Finance*, *54*(6), 2045–2073.
- 51. Damodaran, A. (2002). *Investment valuation: tools and techniques for determining the value of any asset.* New York: J. Wiley & Sons.
- 52. Daske, H., & Gebhardt, G. (2006). International Financial Reporting Standards and Experts' Perceptions of Disclosure Quality. *ABACUS*, *42*(3/4), 461–498.
- Dayhoff, J. E., & DeLeo, J. M. (2001). Artificial neural networks. *Cancer*, 91(S8), 1615– 1635.
- 54. De Martino, B., Kumaran, D., Seymour, B., & Dolan, R. J. (2006). Frames, biases, and rational decision making in the human brain. *Science*, *313*(5787), 684–687.
- 55. DeBondt, W. F., & Thaler, R. (1995). Financial decision-making in markets and firms: a behavioral perspective. In R. A. Jarrow, V. Maksimovic & W. T. Ziemba (eds.), *Handbooks in Operations Research and Management, vol. 9* (p. 385–410). Amesterdam [etc.]: Elsevier.
- Decision Technology Ltd. (2010). Consumer Decision Making in Retail Investment Services: A Behavioral Economics Perspective (Final Report, supporting study). Brussels: European Comission.
- 57. Dehaene, S., & Cohen, L. (2007). Cultural Recycling of Cortical Maps. *Neuron*, 56(2), 384–398.
- 58. Dehaene, S. (1992). Varieties of numerical abilities. *Cognition*, 44(1), 1–42.
- 59. Dembinski, P. H. (2009). *Finance: Servant or Deceiver? Financialization at the crossroads.* New Yok: Palgrave Macmillian Ltd.
- 60. *DiKUL Digital Library of the Univresity of Ljubljana*. Retrieved October 20th, 2017, from dikul.uni-lj.si
- 61. Dimov, D. (2017). Towards a qualitative understanding of human capital in entrepreneurship research. *International Journal of Entrepreneurial Behavior & Research*, 23(2), 210–227.
- 62. Dodgson, M., Gann, D., Wladawsky-Berger, I., Sultan, N., & George, G. (2015). Managing digital money. *Academy of Management Journal*, *58*(2), 325–333.
- Dow, S. (2010). The Psychology of Financial Markets: Keynes, Minsky and Emotional Finance. In D. B. Papadimitriou & L. R. Wray (eds.), *The Elgar Companion to Hyman Minsky, Elgar original reference* (p. 246–262). Cheltenham: Edward Elgar.
- 64. Dowd, K. (2009). Moral hazard and the financial crisis. Cato Journal, 29(1), 141–166.
- 65. Dreyfus, H. L. (1972). *What Computers Still Can't Do: A Critique of Artificial Reason*. Cambridge & London: The MIT Press.

- 66. Duchowski, A. T. (2007). *Eye Tracking Methodology: Theory and practice*. London: Springer Verlag.
- 67. Dunis, C. L., Laws, J., & Sermpinis, G. (2009). The robustness of neural networks for modelling and trading the EUR/USD exchange rate at the ECB fixing. *Journal of Derivatives & Hedge Funds*, 15(3), 186–205.
- 68. Dunis, C. L., Laws, J., & Sermpinis, G. (2011). Higher order and recurrent neural architectures for trading the EUR/USD exchange rate. *Quantitative Finance*, *11*(4), 615–629.
- 69. Elster, J. (1989). Social Norms and Economic Theory. *Journal of Economic Perspectives*, 3(4), 99–117.
- 70. Estelami, H. (2008). Consumer use of the price-quality cue in financial services. *Journal* of Product & Brand Management, 17(3), 197–208.
- 71. European Commission (2012, July 3rd). *Impact Assessment, Accompanying the document Proposal for a Regulation of the European parliament and of the Council on key information documents for investment products.* Strasbourg: European Commission.
- 72. Eysenck, M. W., & Keane, M. T. (2010). *Cognitive psychology* (6th ed.). Hove and New York: Psychology Press.
- Fairchild, R. (2014). Emotions in the financial markets. In H. K. Baker & V. Ricciardi (Eds.), *Investor behavior: The psychology of financial planning and investing* (p. 347–364). Hoboken, New Jersey: John Wiley & Sonc, Inc.
- 74. Fehr, E., & Fischbacher, U. (2004). Social norms and human cooperation. *Trends in Cognitive Sciences*, 8(4), 185–190.
- 75. Fernandes, D., Lynch Jr, J. G., & Netemeyer, R. G. (2014). Financial literacy, financial education, and downstream financial behaviors. *Management Science*, *60*(8), 1861–1886.
- 76. Fodor, J. A., & Pylyshyn, Z. W. (1988). Connectionism and cognitive architecture: a critical analysis. *Cognition*, 28(1), 3–71.
- 77. Foster, D. F., Ng, J., & Wee, M., 2015. Presentation Format and Financial Literacy: Accessibility and Assessability of Retirement Savings Statements. *The Journal of Consumer Affairs*, 49(3), 519–549.
- 78. Fry, J., & Cheah, E. T. (2016). Negative bubbles and shocks in cryptocurrency markets. *International Review of Financial Analysis*, 47, 343–352.
- 79. Fumagalli, R. (2010). The disunity of neuroeconomics: a methodological appraisal. *Journal of Economic Methodology*, 17(2), 119–131.
- 80. Furnham, A. (1984). Many Sides of the Coin: The Psychology of Money Usage. *Personality and Individual Differences*, 5(5), 501–509.
- 81. Gavrilescu M., & Vizireanu, N. (2017). Predicting the Sixteen Personality Factors (16PF) of an individual by analyzing facial features. *EURASIP Journal on Image and Video Processing*, 59, 1–19.
- Geiger, N. (2017). The Rise of Behavioral Economics: A Quantitative Assessment. Social Science History, 41(3), 555–583.
- 83. Gendron, M. (2017). Revisiting Diversity: Cultural Variation Reveals the Constructed Nature of Emotion Perception. *Current Opinion in Psychology*, *17*, 145–150.

- 84. Gerardi, K., Goette, L., & Meier, S. (2013). Numerical ability predicts mortgage default. *Proceedings of the National Academy of Sciences, 110*(28), 11267–11271.
- 85. Gilovich T., Griffin D. W. & Kahneman D. (eds). (2002). *Heuristics and Biases: The Psychology of Intuitive Judgment*. Cambridge: Cambridge University Press.
- Glimcher, W. P. (2009). Neuroeconomics and the Study in Valuation. In M. Gazzaniga (ed.), *The Cognitive Neurosciences* (4th ed.) (p. 1085–1092). Cambridge & London: The MIT Press.
- 87. Gordon, P. (2004). Numerical cognition without words: Evidence from Amazonia. *Science*, *306*(5695), 496–499.
- 88. Graham, J. R., Harvey, C. R., & Puri, M. (2016). A corporate beauty contest. *Management Science*, 63(9), 3044–3056.
- 89. Graham, J. R., Harvey, C. R., & Rajgopal, S. (2005). The economic implications of corporate financial reporting. *Journal of Accounting and Economics*, 40(1), 3–73.
- 90. Gray, J. (2016). Behavioural finance and the macroprudential dimension. *Journal of Banking Regulation*, 17(4), 296–310.
- 91. Grichnik, D., Brinckmann, J., Singh, L., & Manigart, S. (2014). Beyond environmental scarcity: Human and social capital as driving forces of bootstrapping activities. *Journal of Business Venturing*, 29(2), 310–326.
- 92. Grohmann, A., Kouwenberg, R., & Menkhoff, L. (2015). Childhood roots of financial literacy. *Journal of Economic Psychology*, *51*, 114–133.
- 93. Hamid, S. A., & Habib, A. (2014). Financial forecasting with neural networks. *Academy* of Accounting and Financial Studies Journal, 18(4), 37–55.
- 94. Han, S. D., Boyle, P., Arfanakis, K., Fleischman, D., & Bennett, D. (2013). Financial literacy is associated with functional connectivity between anterior and posterior brain regions. *Alzheimer's & Dementia: The Journal of the Alzheimer's Association*, 9(4), 110–111.
- 95. Handa, M. L. (1986). Peace paradigm: transcending liberal and Marxian paradigms. Paper presented at the International Symposium on Science, Technology and Development, New Delhi, India (p. 20–25).
- 96. Harteis, C., & Gruber, H. (2008). Intuition and professional competence: Intuitive versus rational forecasting of the stock market. *Vocations and Learning*, *1*(1), 71–85.
- Heatherton, T. F., & LeDoux, J. E. (2014). The Emotional and Social Brain (Introduction). In M. S. Gazzaniga & G. R. Mangun (eds.). *The Cognitive Neurosciences* (p. 3–6). Cambridge & London: MIT Press.
- Heidhues, E. & Patel, C. (eds.). (2012). Globalization and contextual factors in accounting: The case of Germany (Series: Studies in Managerial and Financial Accounting). Bingely: Emerald Group Publishing Limited.
- 99. Hens, T., & Rieger, M. O. (2010). *Financial economics: A Concise Introduction to Classical and Behavioral Finance*. Berlin/Heidelberg: Springer.
- 100. Heyman, J., & Ariely, D. (2004). Effort for Payment: A Tale of Two Markets. *Psychological Science*, *15*(11), 787–793.

101. Ho, C.-J., Zhang, Y., Vaughan, W. J., & van der Schaar, M. (July, 2012). Towards Social Norm Design for Crowdsourcing Markets. *Human Computation, Association for the Advancement of Artificial Intelligence Technical Report (WS-12-08).* Retrieved October 10th, 2017, from

https://www.aaai.org/ocs/index.php/WS/AAAIW12/paper/download/5295/5608

- 102. Hong, H., & Kacperczyk, M. (2009). The price of sin: The effects of social norms on markets. *Journal of Financial Economics*, 93, 15–36.
- 103. Huang, J. Y., Shieh, J. C., & Kao, Y. C. (2016). Starting points for a new researcher in behavioral finance. *International Journal of Managerial Finance*, *12*(1), 92–103.
- 104. Huang, W., Keung Lai, K., Nakamori, Y., Wang, S., & Yu, L. (2007). Neural networks in finance and economic forecasting. *International Journal of Information Technology & Decision Making*, 6(1), 113–140.
- 105. Hung, A., Heinberg, A., & Yoong, J. K., 2010. Do risk disclosures affect investment choice? *RAND Labour and Population Working Paper (N–788)*.
- 106. The World Bank Group. (2015). World development report 2015: Mind, society, and behavior. Washington, D.C.: World Bank.
- 107. Jappelli, T., & Padula, M. (2013). Investment in financial literacy and saving decisions. *Journal of Banking & Finance*, *37*(8), 2779–2792.
- 108. Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the econometric society*, 47(2), 263–292.
- 109. Kanwisher, N., & Yovel, G. (2006). The fusiform face area: a cortical region specialized for the perception of faces. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 361*(1476), 2109–2128.
- 110. Daniel K., Hirshleifer, D., & Subrahmanyam, A. (1998). Investor psychology and security market under and overreactions. *Journal of Finance*, *53*(6), 1839–1885.
- 111. Kim, S. G., Jin, T., & Fukuda, M. (2013). Spatial resolution of fMRI techniques. In S. Ulmer & O. Jansen (eds.), *fMRI* (p. 17–24). Berlin & Heidelberg: Springer.
- 112. King-Casas, B., Tomlin, D., Anen, C., Camerer, C. F., Quartz, S. R., & Montague, P. R. (2005). Getting to know you: reputation and trust in a two-person economic exchange. *Science*, 308(5718), 78–83.
- 113. Kirilenko, A. A., & Lo, A. W. (2013). Moore's law versus murphy's law: Algorithmic trading and its discontents. *The Journal of Economic Perspectives*, 27(2), 51–72.
- 114. Kostanjčar, Z., Begušić, S., Stanley, H. E., & Podobnik, B. (2016). Estimating tipping points in feedback-driven financial networks. *IEEE Journal of Selected Topics in Signal Processing*, *10*(6), 1040–1052.
- 115. Kozup, J., & Hogarth, J. M. (2008). Financial Literacy, Public Policy, and Consumers' Self-Protection More Questions, Fewer Answers. *The Journal of Consumer Affairs*, 42(2), 127–136.
- 116. Kuhlmann, M. (2014). Explaining financial markets in terms of complex systems. *Philosophy of Science*, *81*(5), 1117–1130.
- 117. Kuhn, D. (2000). Metacognitive Development. Current Directions in Psychological Science, 9(5), 178–181.

- 118. Kuhn, T. S. (1970). *The Structure of Scientific Revolutions* (2nd ed.). Chicago & London: University of Chicago Press.
- 119. Lanteaume, L., Khalfa, S., Régis, J., Marquis, P., Chauvel, P., & Bartolomei, F. (2007). Emotion induction after direct intracerebral stimulations of human amygdala. *Cerebral cortex*, 17(6), 1307–1313.
- 120. Lapinski, K. M., & Rimal, N. R. (2005). An Explication of Social Norms. *Communication Theory*, *15*(2), 127–147.
- 121. Le Corre, M., & Carey, S. (2007). One, two, three, four, nothing more: An investigation of the conceptual sources of the verbal counting principles. *Cognition*, *105*(2), 395–438.
- 122. Lee, T. H., Choi, J. S., & Cho, Y. S. (2012). Context modulation of facial emotion perception differed by individual difference. *PLoS One*, 7(3), 1–6.
- 123. Leventis, S., Hasan, I., & Dedoulis, E. (2013). The cost of sin: The effect of social norms on audit pricing. *International Review of Financial Analysis*, 29, 152–65.
- 124. Levy, M., Levy, H., & Solomon, S. (1995). Microscopic simulation of the stock market: the effect of microscopic diversity. *Journal de Physique I*, *5*(8), 1087–1107.
- 125. Lindsay, P. H., & Norman, D. A. (1972). *Human Information Processing: An Introduction to Psychology*. New York & London: Academic Press.
- 126. Littlewort, G., Whitehill, J., Wu, T., Fasel, I., Frank, M., Movellan, J., & Bartlett, M. (2011, March). The computer expression recognition toolbox (CERT). *Automatic Face & Gesture Recognition and Workshops (FG 2011), 2011 IEEE International Conference Proceedings, 298–305.*
- 127. Lo, A. W., & Repin, D. V. (2006). The psychophysiology of real-time financial risk processing. *Psychophysiology*, 14(3), 323–339.
- 128. Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. Psychological bulletin, 127(2), 267–286.
- 129. Love, E. G., Lim, J., & Bednar, M. K. (2017). The face of the firm: The influence of CEOs on corporate reputation. *Academy of Management Journal*, 60(4), 1462–1481.
- 130. Lührmann, M., Serra-Garcia, M., & Winter, J. (2015). Teaching teenagers in finance: does it work? *Journal of Banking & Finance*, *54*, 160–174.
- 131. Lusardi, A., & Mitchell, O. S. (2014). The economic importance of financial literacy: Theory and evidence. *Journal of Economic Literature*, *52*(1), 5–44.
- 132. Lusardi, A. (2015). Financial literacy skills for the 21st century: evidence from PISA. *Journal of Consumer Affairs*, 49(3), 639–659.
- 133. Makwana, A., Grön, G., Fehr, E., & Hare, T. A. (2015). A Neural Mechanism of Strategic Social Choice under Sanction-Induced Norm Compliance. *eNeuro*, *2*(3), 1–8.
- 134. Mantegna, R. N., & Stanley, H. E. (2004). *An Introduction to Econophysics: Correlations and Complexity in Finance*. Cambridge [etc.]: Cambridge University Press.
- 135. Markič, O. (2011). Kognitivna znanost: filozofska vprašanja. Maribor: Aristej.
- 136. Mason, C., Botelho, T., & Zygmunt, J. (2017). Why business angels reject investment opportunities: Is it personal? *International Small Business Journal*, *35*(5), 519–534.
- 137. Matthews, P., & Jezzard, P. (2004). Functional magnetic resonance imaging. *Journal of Neurology, Neurosurgery and Psychiatry*, 71(1), 6–12.

- 138. Maxwell, A. L., & Lévesque, M. (2014). Trustworthiness: A critical ingredient for entrepreneurs seeking investors. *Entrepreneurship Theory and Practice*, 38(5), 1057–1080.
- 139. McNelis, P. D. (2005). *Neural Networks in Finance: Gaining Predictive Edge in the Market*. Amsterdam [etc.]: Elsevier Academic Press.
- 140. Meaux, E., & Vuilleumier, P. (2016). Facing mixed emotions: Analytic and holistic perception of facial emotion expressions engages separate brain networks. *NeuroImage*, *141*(1), 154–173.
- 141. Miller, D. (2015). A downside to the entrepreneurial personality? *Entrepreneurship Theory and Practice*, 39(1), 1–8.
- 142. Miloud, T., Aspelund, A., & Cabrol, M. (2012). Startup valuation by venture capitalists: an empirical study. *Venture Capital*, *14*(2–3), 151–174.
- 143. Montier, J. (2007). *Behavioural Investing: a practitioner's guide to applying behavioural finance*. West Sussex: John Wiley & Sons.
- 144. Müller, S., & von Wangenheim, G. (2014). The impact of market innovations on the evolution of norms: the sustainability case. *Joint Discussion Paper Series in Economics* (*No. 32-2014*). Retrieved September 20th, 2017, from https://www.econstor.eu/bitstream/10419/102365/1/785649867.pdf
- 145. Musvoto, S. W. (2011). Implications of the crisis of objectivity in accounting measurement on the development of finance theory. *The International Business & Economics Research Journal*, 10(2), 113–122.
- 146. Nan, L., & Wen, X. (2014). Financing and investment efficiency, information quality, and accounting biases. *Management Science*, 60(9), 2308–2323.
- 147. Newell, A., & Simon, H. (1976). Computer Science as Empirical Inquiry: Symbols and Search. *Communications of the ACM*, *19*(3), 113–126.
- 148. Nicholson, G., Kiel, G., & Kiel-Chisholm, S. (2011). The contribution of social norms to the global financial crisis: A systemic actor focused model and proposal for regulatory change. *Corporate Governance: An International Review*, *19*(5), 471–488.
- 149. Nieder, A., & Dehaene, S. (2009). Representation of Number in the Brain. *Annual Review of Neuroscience*, *32*, 185–208.
- 150. Nobel Foundation. (9.10.2002). Press Release: The Prize in Economic Sciences 2002. Retrieved October 25th, 2017, from https://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2002/press.html
- 151. Nobel Media AB. (9.10.2017). Press Release: The Prize in Economic Sciences 2017. Retrieved October 25th, 2017, from https://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2017/press.html
- 152. Nofsinger, J. R. (2011). *The Psychology of Investing* (4th ed.). Boston [etc.]: Prentice Hall.
- 153. Patel, C., & Millanta, B. R. (2011). "Holier-than-thou" perception bias among professional accountants: A cross-cultural study. *Advances in Accounting*, 27(2), 373– 381.

- 154. Penman, S. H. (2010). *Financial statement analysis and security valuation* (4th ed.). New York [etc.]: McGraw-Hill/Irwin.
- 155. Persichetti, A. S., Aguirre, G. K., & Thompson-Schill, S. L. (2015). Value is in the eye of the beholder: early visual cortex codes monetary value of objects during a diverted attention task. *Journal of cognitive neuroscience*, 27(5), 893–901.
- 156. Peters, E. (2003). Simple and Complex Market Inefficiencies: Integrating Efficient Markets, Behavioral Finance, and Complexity. *The Journal of Behavioral Finance*, *4*(4), 225–233.
- 157. Peterson, R. L. (2005). The neuroscience of investing: fMRI of the reward system. *Brain research bulletin*, 67(5), 391–397.
- 158. Phelps, E. A., & Delgado, M. R. (2009). Emotion and Decision Making. In M. Gazzaniga (ed.), *The Cognitive Neurosciences* (4th ed.) (p. 1093–1103). Cambridge & London: The MIT Press.
- 159. Pixley, J. (2004). *Emotions in Finance: Distrust and Uncertainty in Global Markets*. Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore & Sao Paulo: Cambridge University Press.
- 160. Prince, M. (1993). Self-concept, money beliefs and values. *Journal of Economic Psychology*, *14*(1), 161–173.
- 161. Rajan, U., Seru, A., & Vig, V. (2015). The failure of models that predict failure: Distance, incentives, and defaults. *Journal of Financial Economics*, *115*(2), 237–260.
- 162. Re, D. E., & Rule, N. O. (2016). Predicting firm success from the facial appearance of Chief Executive Officers of non-profit organizations. *Perception*, 45(10), 1137–1150.
- 163. Ricciardi, V. (2008). Risk: Traditional finance versus behavioral finance. In F. J. Fabozzi (ed.), Handbook of Finance, Volume 3, Valuation, Financial Modeling, and Quantitative Tools (p. 11–38). Wiley.
- 164. Robinson, L., & Bawden, D. (2014). Mind the gap: Transitions between concepts of information in varied domains. In F. Ibekwe-SanJuan & T. M. Dousa (eds.), *Theories of Information, Communication and Knowledge: a Multidisciplinary Approach* (p. 121– 141). Dordrecht: Springer.
- 165. Rocha, A. F., Vieito, J. P., Massad, E., Rocha, F. T., & Lima, R. I. (2015). Electroencephalographic Activity Associated to Investment Decisions: Gender Differences. *Journal of Behavioral and Brain Science*, 5(06), 203–211.
- 166. Rule, N. O., & Ambady, N. (2008). The face of success: Inferences from chief executive officers' appearance predict company profits. *Psychological science*, *19*(2), 109–111.
- 167. Rule, N. O., & Ambady, N. (2011). Face and fortune: Inferences of personality from Managing Partners' faces predict their law firms' financial success. *The Leadership Quarterly*, 22(4), 690–696.
- 168. Rule, N. O. Ambady, N., Adams Jr, R. B., Ozono, H., Nakashima, S., Yoshikawa, S., & Watabe, M. (2010). Polling the face: prediction and consensus across cultures. *Journal of personality and social psychology*, 98(1), 1–15.

- 169. Rule, N. O., Moran, J. M., Freeman, J. B., Whitfield-Gabrieli, S., Gabrieli, J. D., & Ambady, N. (2011). Face value: Amygdala response reflects the validity of first impressions. *NeuroImage*, 54(1), 734–741.
- 170. Rushworth, M. F. S., Chau, B. K. H., Schüffelgen, U. Neubert, F.-X., & Kolling, N. (2014). Choice Values: The Frontal Cortex and Decision Making. In M. S. Gazzaniga & G. R. Mangun (eds.), *The Cognitive Neurosciences* (5th ed.) (p. 501–512). Cambridge & London: The MIT Press.
- 171. Sakaiya, S., Shiraito, Y., Kato, J., Ide, H., Okada, K., Takano, K., & Kansaku, K. (2013). Neural correlate of human reciprocity in social interactions. *Frontiers in Neuroscience*, 7(239), 1–12.
- 172. Samal, A., & Iyengar, P. A. (1992). Automatic recognition and analysis of human faces and facial expressions: a survey. *Pattern recognition*, 25(1), 65–77.
- 173. Sapra, S., Beavin, L. E., & Zak, P. J. (2012). A combination of dopamine genes predicts success by professional Wall Street traders. *PloS one*, 7(1), 1–7.
- 174. Saunders, A., & Allen, L. (2010). *Credit risk management in and out of the financial crisis: new approaches to value at risk and other paradigms* (3rd ed.). New Jersey: John Wiley & Sons.
- 175. Schäfer, A., Schnabel, I., & Weder di Mauro, B. (2016). Financial Sector Reform after the Subprime Crisis: Has Anything Happened? *Review of Finance*, 20(1), 77–125.
- 176. Schirmer, A., & Adolphs, R. (2017). Emotion perception from face, voice, and touch: comparisons and convergence. *Trends in Cognitive Sciences*, 21(3), 216–228.
- 177. Schneider, M., & Somers, M. (2006). Organizations as complex adaptive systems: Implications of complexity theory for leadership research. *The Leadership Quarterly*, 17(4), 351–365.
- 178. Sermpinis, G., Laws, J., & Dunis, C. L. (2013). Modelling and trading the realised volatility of the FTSE100 futures with higher order neural networks. *The European Journal of Finance*, 19(3), 165–179.
- 179. Shepherd, D., & Haynie, J. M. (2009). Birds of a feather don't always flock together: Identity management in entrepreneurship. *Journal of Business Venturing*, 24(4), 316–337.
- 180. Shiller, R. J. (2003). From efficient markets theory to behavioral finance. *The Journal of Economic Perspectives*, 17(1), 83–104.
- 181. Shiller, R. J. (2006). Tools for financial innovation: Neoclassical versus behavioral finance. *Financial Review*, 41(1), 1–8.
- 182. Shiller, R. J. (2012). *The subprime solution: how today's global financial crisis happened, and what to do about it.* Princeton: Princeton University Press.
- 183. Simon, H. A. (1955). A Behavioral Model of Rational Choice. *The Quarterly Journal of Economics*, 69(1), 99–118.
- 184. Sokol-Hessner, P., Camerer, C. F., & Phelps, E. A. (2012). Emotion regulation reduces loss aversion and decreases amygdala responses to losses. *Social cognitive and affective neuroscience*, 8(3), 341–350.
- 185. Stoker, J. I., Garretsen, H., & Spreeuwers, L. J. (2016). The facial appearance of CEOs: Faces signal selection but not performance. *PloS one*, *11*(7), 1–11.

- 186. Stout, D., Toth, N., Schick, K., & Chaminade, T. (2008). Neural correlates of Early Stone Age toolmaking: technology, language and cognition in human evolution. *Philosophical Transactions of the Royal Society*, 363, 1939–1949.
- 187. Subramanyam, K. R., & Wild, J. J. (2009). *Financial statement analysis* (10th ed.) New York [etc.]: McGraw-Hill.
- 188. Tallon-Baudry, C., Meyniel, F., & Bourgeois-Gironde, S. (2011). Fast and Automatic Activation of an Abstract Representation of Money in the Human Ventral Visual Pathway. *PLoS ONE*, *6*(11), 1–7.
- 189. Tang, N., & Baker, A. (2016). Self-esteem, financial knowledge and financial behavior. *Journal of Economic Psychology*, *54*, 164–176.
- 190. Taylor, J. B. (2013). *Getting off track: How government actions and interventions caused, prolonged, and worsened the financial crisis.* Stanford: Hoover Press.
- 191. Taylor, S. M., & Wagland S. (2013). The Solution to the Financial Literacy Problem: What is the Answer? *Australasian Accounting, Business and Finance Journal*, 7(3), 69–90.
- 192. Tedeschi, G., Mazloumian, A., Gallegati, M., & Helbing, D. (2012). Bankruptcy Cascades in Interbank Markets. *PLoS ONE*, 7(12), 1–10.
- 193. Thaler R. H., & Sunstein C. R. (2008). *Nudge: Improving decisions about health, wealth, and happiness.* New Haven: Yale University Press.
- 194. Todorov, A., Olivola, C. Y., Dotsch, R., & Mende-Siedlecki, P. (2015). Social attributions from faces: Determinants, consequences, accuracy, and functional significance. *Annual Review of Psychology*, 66(1), 519–545.
- 195. Trueman, B. (1994). Analyst forecasts and herding behavior. *The Review of Financial Studies*, 7(1), 97–124.
- 196. Tseng, K. C. (2006). Behavioral finance, bounded rationality, neuro-finance, and traditional finance. *Investment Management and Financial Innovations*, 3(4), 7–18.
- 197. Tversky, A., & Kahneman, D. (1981). The Framing of decisions and the psychology of choice. *Science*, *211*(4481), 453–458.
- 198. Ulmer, S. (2010). Basics: Introduction. In S. Ulmer & O. Jansen (eds.), *fMRI: Basic and Clinical Applications* (p. 1–4). Dordrecht, Heidelberg, London & New York: Springer.
- 199. Van Belle, G., De Graef, P., Verfaillie, K., Rossion, B., & Lefèvre, P. (2010). Face inversion impairs holistic perception: Evidence from gaze-contingent stimulation. *Journal of Vision*, *10*(5), 10–10.
- 200. Varela, J. F., Thompson, E., & Rosch, E. (2016). *The Embodied Mind: Cognitive Science and Human Experience*. Cambridge & London: The MIT Press.
- 201. Viñals, J., Pazarbasioglu, C., Surti, J., Narain, A., Erbenova, M. M., & Chow, M. J. T. (2013). Creating a safer financial system: will the Volcker, Vickers, and Liikanen Structural measures help? (No. 13–14). International Monetary Fund.
- 202. Vohs, K., Mead, N., & Goode, M. (2006). The Psychological Consequences of Money. *Science*, *314*(5802), 1154–1156.
- 203. Wiese, H. (2003). *Numbers, language, and the human mind*. Cambridge: Cambridge University Press.

- 204. Zaher, T. S., & Kabir Hassan, M. (2001). A comparative literature survey of Islamic finance and banking. Financial Markets, *Institutions & Instruments*, *10*(4), 155–199.
- 205. Zhang, G., Patuwo, B. E., & Hu, M. Y. (1998). Forecasting with artificial neural networks: The state of the art. *International journal of forecasting*, *14*(1), 35–62.
- 206. Zhang, J., & Norman, D. A. (1995). A representational analysis of numeration systems. *Cognition*, *57*(3), 271–295.
- 207. Zhao, H., Seibert, S. E., & Lumpkin, G. T. (2010). The relationship of personality to entrepreneurial intentions and performance: A meta-analytic review. *Journal of management*, *36*(2), 381–404,
- 208. Zhao, M., & Bülthoff, I. (2017). Holistic processing of static and moving faces. *Journal* of Experimental Psychology: Learning, Memory, and Cognition, 43(7), 1020–1035.
- 209. Zhao, W., Chellappa, R., Phillips, P. J., & Rosenfeld, A. (2003). Face recognition: A literature survey. *ACM computing surveys (CSUR)*, *35*(4), 399–458.
- 210. Zhou, G., Cheng, Z., Zhang, X., & Wong, A. C. N. (2012). Smaller holistic processing of faces associated with face drawing experience. *Psychonomic Bulletin & Review*, 19(2), 157–162.

APPENDIXES

TABLE OF APPENDIXES

Appendix A: Supporting data for the figures	. 1
Appendix B: List of Abbreviations	.2
Appendix A: Supporting data for the figures

Year	''Financial Literacy''	''Network Analysis'' and ''Finance''	"Agent Based Models" and	''Neural Networks'' and ''Finance''	"Neurofinance"	''Behavioral Finance''	"Neuroeconomics"	"Behavioral Economics"
			"Finance"		-			
2002	384	527	55	822	0	343	6	601
2003	402	610	103	926	0	581	77	932
2004	548	746	97	1372	0	737	143	1206
2005	765	912	169	1617	0	837	400	1245
2006	760	1091	199	1639	2	923	420	1702
2007	794	1259	219	1639	7	1035	691	2141
2008	934	1330	253	1974	8	1213	1163	2639
2009	1323	1773	320	2284	17	1588	1198	3109
2010	1496	1806	300	2225	20	1654	1314	3940
2011	1858	2179	320	2334	15	1821	1452	4368
2012	2332	2481	384	2909	32	2110	1478	5244
2013	2589	3653	888	3405	16	1797	1501	5647
2014	3015	3940	547	3808	28	2289	1781	6249
2015	3587	3587	566	3445	36	2250	1599	7265
2016	3509	3509	553	3772	23	1874	1469	6535

Table 1. Number of sources, including selected keywords in a certain time period

Appendix B: List of Abbreviations

BOLD contrast	Blood Oxygenation Level Dependent contrast
CEO(s)	Chief Executive Officer(s)
CERT	the Computer Expression Recognition Toolbox – CERT
DiKUL	the academic database of the Digital Library of University of Ljubljana
ECB	the European Central Bank
EEG	the Electroencephalography
EUR	the Euro
fMRI	functional Magnetic Resonance Imaging method
IFRS	International Financial Reporting Standards
KIID	Key Investor Information Document
UCITS	Undertakings for Collective Investment in Transferable Securities
USD	the United States dollar