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Contemporary Trends and Challenges in Finance

Proceedings from the 6th Wroclaw International Conference in Finance

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Editors
Krzysztof Jajuga
Department of Financial Investments and Risk Management
Wroclaw University of Economics & Business
Wroclaw, Poland

Hermann Locarek-Junge
Fakultät Wirtschaftswissenschaften
TU Dresden
Dresden, Sachsen, Germany

Lucjan T. Orlowski
Department of Economics and Finance
Sacred Heart University
Fairfield, CT, USA

Karsten Staehr
Department of Economics & Finance
Tallinn University of Technology
Tallinn, Estonia

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Preface

This volume presents papers from the 6th Wrocław International Conference in Finance held at Wrocław University of Economics and Business via video conferencing on September 22–23, 2020. We have assembled a set of studies addressing a broad spectrum of recent trends and issues in finance, particularly those concerning markets and institutions in Central and Eastern European countries. In the final selection, we had accepted 15 of the papers that were presented at the conference. Each of the submissions has been reviewed by at least two anonymous referees and the authors have subsequently revised their original manuscripts and incorporated the comments and suggestions of the referees. The selection criteria focused on the contribution of the papers to the modern finance literature and the use of advanced analytical techniques.

The chapters have been organized along the major fields and themes in finance: financial markets, corporate finance, banking, and personal finance.

The section on financial markets contains seven papers. The paper by Saqib Amin investigates the relationship between diversity and stock market development by using data of 187 countries. Anna Białek-Jaworska in her paper answers the question whether withholding tax reduces income shifting with the use of debt and equity FDI. The paper by Lesław Markowski examines the relationship between conditional volatility of individual stock returns and trading volume on the Warsaw Stock Exchange. Dorika Mwamtambulo in her paper determines the factors behind the low individual investor participation in Dar es Salaam Stock Exchange. The paper by Aleksandra Pasieczna analyzes the model risk of Expected Shortfall and Value at Risk using different variants of Monte Carlo approach. Pham Khang in his paper presents an analysis of the tick size adjustment in Vietnamese stock exchange. Gopinath Ramkumar studies the portfolio of nine most important cryptocurrencies constructed using several types of strategies.

The section on corporate finance contains two papers. The paper by Julia Koralun-Bereźnicka studies the relation between corporate material and financial decisions, based on 12 EU countries. Katarzyna Prędkiewicz, Paweł Prędkiewicz,

and Marek Pauka in their paper examine whether Warsaw Stock Exchange is an effective means of alleviating financial constraints for high technology companies.

The section on banking contains three papers. The paper by Monika Kołodziej is aimed at critically analyzing the impact of blockchain technology on banking industry. Małgorzata Olszak and Anna Kowalska in their paper analyze what is the role of competition in the effects of macroprudential policy. The paper by Witold Szczepaniak and Marta Karaś presents the results of the empirical measurement of systemic risk levels using several quantile-based measures.

The section on personal finance contains three papers. The paper by Agnieszka Huterska is aimed at assessing the disproportions in the use of loan products by young people in the countries—old and the new members of the European Union. Katarzyna Kochaniak and Paweł Ulman analyze the gap between subjective and objective financial risk tolerance. The paper by Ergun Kutlu is aimed at finding the relationship between financial behavior and socio-demographic variables for Italian and Turkish students.

We wish to thank the authors for making their studies available for our volume. Their scholarly efforts and research inquiries made this volume possible. We are also indebted to the anonymous referees for providing insightful reviews with many useful comments and suggestions. In spite of our intention to address a wide range of problems pertaining to theoretical concept and empirical trends in finance, there are issues that still need to be researched. We hope that the studies included in our volume will encourage further research and analyses in modern finance.

Wroclaw, Poland — Krzysztof Jajuga
Dresden, Germany — Hermann Locarek-Junge
Fairfield, CT, USA — Lucjan T. Orlowski
Tallinn, Estonia — Karsten Staehr
February 25, 2021

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About the Editors

Krzysztof Jajuga is a professor of finance at Wrocław University of Economics and Business, Poland. He holds master, doctoral, and habilitation degrees from Wrocław University of Economics, Poland, the title of professor given by President of Poland, an honorary doctorate from Cracow University of Economics, and an honorary professorship from Warsaw University of Technology. He carries out research within financial markets, risk management, household finance, and multivariate statistics.

Hermann Locarek-Junge is Professor of Finance and Financial Services at TU Dresden, Faculty of Management and Economics. He graduated in the field of business and economics and earned his Ph.D. at University of Augsburg (Germany); he also studied business informatics and has been appointed professor in that field at Essen University. Since then, he has been visiting professor and research fellow at several international institutions and universities. During his academic career, he undertook research work for several banks.

Lucjan T. Orlowski is a professor of economics and finance and a director for the Doctor of Business Administration (DBA) in Finance Program at Sacred Heart University in Fairfield, Connecticut. His research interests include monetary economics and stability of financial markets and institutions. He has authored numerous books, chapters in edited volumes, and over 80 articles in scholarly journals. He is a Doctor Honoris Causa recipient from Wrocław University of Economics.

Karsten Staehr is professor at Tallinn University of Technology, Estonia. He is also employed part-time as a research supervisor at Eesti Pank, the central bank of Estonia. He holds a master's degree from the Massachusetts Institute of Technology and a master's degree and a Ph.D. from the University of Copenhagen. He carries out research and policy analysis within macroeconomics, international finance, monetary economics, and public economics. He is an associate editor of the *Baltic Journal of Economics* and on the editorial board of several other journals.

Part I
Financial Market

The Relationship Between Ethnic Diversity and Stock Market Development: A Global Perspective

Saqib Amin

1 Introduction

No doubt, stock market is a key determinants for economic prosperity of any country (Pan and Mishra 2018; Rousseau and Wachtel 2000). In order to find the determinants of stock market development, diversity is found as one of the key indicators, which directly affect the behaviour of investor's mentor. Limited debates in literature show the linkages between diversity and stock market development and somehow complex and puzzle (Forti et al. 2011; Tang et al. 2016; Zulfiqar and Weller 2013). However, diversity plays a vital role in drastically changes the stock market development that has directly and indirectly effects the economic development (Bove and Elia 2017; Montalvo and Reynal-Querol 2005; Nettle et al. 2007). This type of financial shocks leads to a catastrophically changes in country's economic prosperity. Most of the researchers argued that number of financial shocks i.e. great depression of 1929, financial shocks of 2008 and 2010 caused by the wreck people's behaviours, markets and the economy which creates the burden for local as well as global economy (Jain and Jordan 2009; Sacasa 2008; Verick and Islam 2010). On the other hand, some argued that the reasons behind these episodes of widespread economic bubbles, financial havoc and great depression are remains unclear. In their opinions, these types of bubbles happen when people mindlessly trust the behaviour of others particularly surrounded by ethnic peers. In this context, diverse societies are largely creators of bubbles because it creates changes on how people think, feel and behave.

S. Amin (✉)
Department of Economics, National College of Business Administration and Economics, Lahore, Pakistan

Department of Financial Investments and Risk Management, Wroclaw University of Economics and Business, Wroclaw, Poland

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Every country is trying to create a good investment environment to building up a strong, healthy and prosperous stock market. Traditional economists believed that financial market behaviour is affected by the key macroeconomic variables such as GDP growth (Levine and Zervos 1998), trade volume (Chinn and Ito 2006) inflation, exchange rate, etc., They argued that diversity is importance only in the context of economic advancement (Collier 1998; Elbadawi and Sambanis 2000; Watkins and Ferrara 2005) and investment (Montalvo and Reynal-Querol 2005). But, modern economist argued that despite the importance of macroeconomic variables, micro-economic variables are also important for the financial market development under the behavioural finance theory. They converted the directions most of policy makers and researchers towards socioeconomic factors in order to explain the stock market behaviours in contrast to the traditional economists (Alesina and Giuliano 2015). Patrick (1966), Hall (2001) and Guiso et al. (2006) argued that social factors are important as well as economic factors into the stock market development. They also argued that diversity explain more of the difference in finance, development and optimal utilization of resources within the society and economy (Stulz and Williamson 2003). Most of the researcher revealed that socioeconomic factors such as diversity has reposted impact on financial market behaviours (Bond et al. 2012; D. J. Miller 2006) financial development (Kwok and Tadesse 2006) and the investors behaviours (Breuer et al. 2014).

In this contemporary world and modern society the nature of markets always remained ubiquitous (North 1991). The stock market development has become a main central financial institution for development and prosperity of any country because it escalating the information, expectation and better use of resources other than the government or individual (Hayek 1945). Whereas stock market also cause of catastrophically changes such as price bubbles and share values are drastically changes upon the behaviours of entrepreneurs in market. Market herd behaviours emerge from the homogenous to heterogeneity society collectively changes the failure of market and prices changes such as prices bubbles. These types of changes destroy and destabilize the economy not just to the home country but also to the entire world. In this context, most of the psychologist, sociologist and economists have shown unsurprising regarding the bubbles behind the behavioural biases of individuals.

Attempting to pinpoint the cause of bubbles, some researchers have shown that bubbles are related to financial conditions such as excess cash, but also to behaviour that exhibits of irrationality. Indeed, bubbles have been long ascribed to collective delusions, implied in terms as “herd behaviours”, but their exact causes remain nebulous. In modern markets, traders place greater confidence in the actions of others. They are more likely to accept their co-ethnics decisions as reasonable, and therefore more likely to act alike. In a homogenous market, individuals are less likely to scrutinize on others behaviour than the diverse market. People tend to be more trusting of the perspectives, actions, and intentions of ethnically similar society (Brown 2000; Hogg 2007; Pettigrew et al. 2011). Therefore, those markets are more vigilant and overreliance on others decisions which may be more risky. Diverse society may be more harmful towards the modern markets due to the

confidence on other decisions. This study suggests that price bubbles arise not only from individual errors or financial conditions but also from the social context of decision-making.

Recently, in the financial economics debate, many researchers investigate the various determinants of stock market development but limited literature shows the relationship between diversity and stock market development. This study explores a very interesting relationship between diversity and stock market development using data of 187-countries of the world (for more detail see in Appendix list of the countries).

2 Theoretical Framework

In the behavioural finance theory, investor's decisions directly impact the stock market performance, whereas investor's decision-making are depends upon behavioural changes and adaptive diversification of societies. Literature shows gap to find the relationship between diverse society and stock market development. It may be one reason of this neglecting aspect is too difficult and complex in measuring diversity in quantification. However, this problem has resolved by the construction of fractionalization index by Alesina et al. (2003). In the macro perspective, various discipline and theories such as sociology, psychology, economics and finance are merging under this context. The theory of social conflict, rational choice theory, anomie theory, rational choice theory, social exchange theory, agency theory, rational expectation theory are well discuss directly or indirectly the relationship between diversity and behaviours of financial markets.

Ethnic diversity has been studied in multiple spheres, including economic growth (Alesina and Ferrara 2005; Florida 2002), social capital (Putnam 2007), cities and neighbourhoods (Pettigrew et al. 2011), organizational performance (Herring 2009; Richard 2000), work teams (DiTomaso et al. 2007; Van Knippenberg and Schippers 2007; Williams and O'Reilly III 1998), and jury deliberations (Sommers 2006). As intergroup contact theory and social identity theory, ethnic identity is mainly establishing the trust among strangers. Moreover, empirical evidence shows specifically that people surrounded by ethnic peers tend to process information more superficially (Antonio et al. 2004; Sommers 2006; Sommers et al. 2008). In markets, where information is incomplete and decisions are uncertain (Kahneman 2003), traders may be particularly reliant on ethnicity as a group-level heuristic for establishing confidence in others decisions. Such superficial information processing can engender conformity, herding, and price bubbles. This is not an individual idiosyncrasy, but a collective phenomenon pricing errors of traders in homogenous markets are more likely correlated than those of traders in diverse markets. The culmination of these processes leads to bigger bubbles.

Breuer et al. (2014) investigated the impact of cultural diversity on time preference and founded that cultural diversity is the time preference indicator: culture and time preference are closely related, and different cultures will lead to different time

preferences. The intertemporal investment consumption theory indicated that the different time preference of investors shaped by cultural diversity will deduce different trading strategy choice, thus affect the financial market. Whereas, cognitive processes get influenced by culture, thus the cultural diversity could bring heterogeneous beliefs, which promote the prosperity of the stock market. Behavioural finance studies have indicated that the heterogeneity of the expectations and beliefs caused by cognitive differences has an important impact on financial market (Chui et al. 2010). Tang et al. (2016) revealed that diversity could promote stock market prosperity and the effect varies from country to country. In particular, it was found that cultural diversity has positive impact on stock market prosperity in high development-level and legal system quality countries, and vice versa. Weller and Zulfiqar (2013) argued that greater diversity is associated with faster growth, larger credit markets, a broader deposit base, and a smaller chance of asset bubbles, all of which could contribute to more stability.

Researcher wants to know, does increase in the level of diversity will promote prosperity of the stock market? Diversity plays different role in different countries. Compared to the common ethnic and cultural conflicts in African countries, different ethnic groups in the European and American multinational countries get along well, and there is frequent diversity communication between them. Taydas et al. (2010) found that countries with higher levels of legal system have less social internal conflict. The good legal system level can provide protection of basic rights and a fair trading environment for investors. Only under the common standards and rules, the diversity of will not lead to market confusion, and the stock market can develop in an orderly manner.

Frame and White (2004) showed that financial innovation (new products, new services, new processes and new forms of organization) could improve the function of financial sector. Diverse society promote technological innovation which ultimate promote economic growth, and onwards lead to the prosperity of stock market (Ashraf and Galor 2011). Limited literature was found about relationship between diversity and financial innovation, but the positive effect of diversity on innovation became the academic consensus by Herbig and Dunphy (1998).

Head and Ries (1998) define this knowledge as more ethnic groups from different countries, more the export market can be expanded which stimulates trading volume. Egger et al. (2012) specify that ethnic groups engage in the market creation and make be able to open up to other foreign markets. The turnover ratio and trading volume can manipulate the stock market degree of activeness. Gozzi et al. (2008) suggested accounting for excessive measurement and data availability, turnover ratio is more suitable. Therefore, turnover ratio was used as a proxy variable for the prosperity of stock market, noted as in addition, in order to test the robustness of the model, trading volume as another proxy variable for the stock market prosperity level was used.

Stock market prosperity is usually defined as activity of buying and selling behaviour in the market and liquidity characteristics. This paper initially looks at the linkages between diversity and stock market development using panel data regression of 187-countries of worldwide (see list in Appendix) for the period of

1990–2010 (with 05-years of interval). To analyse the direct relationship of ethnic and religious diversity with stock market development, we adopt the standard specification and followed the model proposed by Alesina et al. (2003) and Bove and Elia (2017).

$$MC_{it} = a_i + \beta_1 FRACED_{it} + \beta_2 FRACRD_{it} + \beta_3 IC_{it} + \beta_4 FDI_{it} + \beta_5 GDPPC_{it} + \beta_6 IST_{it} + \beta_7 CI_{it} + \beta_8 GE_{it} + a_i + \varepsilon_{it} \quad (1)$$

$$VSTG_{it} = a_i + \beta_1 FRACED_{it} + \beta_2 FRACRD_{it} + \beta_3 IC_{it} + \beta_4 FDI_{it} + \beta_5 GDPPC_{it} + \beta_6 IST_{it} + \beta_7 CI_{it} + \beta_8 GE_{it} + a_i + \varepsilon_{it} \quad (2)$$

$$VSTM_{it} = a_i + \beta_1 FRACED_{it} + \beta_2 FRACRD_{it} + \beta_3 IC_{it} + \beta_4 FDI_{it} + \beta_5 GDPPC_{it} + \beta_6 IST_{it} + \beta_7 CI_{it} + \beta_8 GE_{it} + a_i + \varepsilon_{it} \quad (3)$$

$$DC_{it} = a_i + \beta_1 FRACED_{it} + \beta_2 FRACRD_{it} + \beta_3 IC_{it} + \beta_4 FDI_{it} + \beta_5 GDPPC_{it} + \beta_6 IST_{it} + \beta_7 CI_{it} + \beta_8 GE_{it} + a_i + \varepsilon_{it} \quad (4)$$

$$GEI_{it} = a_i + \beta_1 FRACED_{it} + \beta_2 FRACRD_{it} + \beta_3 IC_{it} + \beta_4 FDI_{it} + \beta_5 GDPPC_{it} + \beta_6 IST_{it} + \beta_7 CI_{it} + \beta_8 GE_{it} + a_i + \varepsilon_{it} \quad (5)$$

Whereas:

MC = market capitalization (% of GDP), α_i is the unknown intercept, VSTG = value of share traded (% of GDP), VSTM = value of share trade (% of market capitalization), DC = No. of listed domestic companies, GEI = S&P/Global equity index, $FRAC_{ED}$ = Fractionalization of Ethnic Diversity, $FRAC_{RD}$= Fractionalization of Religious Diversity, IC= Intergroup Cohesion, FDI = Foreign direct investment, GDPPC= GDP per capita PPP, IST= Intergroup Safety and Trust, CI= corruption perception index and GE= Gender equality, a_t is the unobserved time-invariant individual effect, and ε_{it} is the error term.

3 Methodology

In the context of diversity and stock market development, this study used panel data methodology to explore this nexus and dynamics for empirical analysis. Basically, panel data methodology is the mixture of cross-sectional and time series data which not just increase the power and size of data but also restructuring this effect that is difficult to distinctive with only cross-sections or time series data (Hsiao 1986). Baltagi et al. (2003) describes the key advantages of using panel data, such as how heterogeneity in individual (firms, regions or countries) is absent when using aggregate time series data.

Whereas in linear unobserved effect model under fixed effect can be expressed as

$$Y_{it} = \alpha_i + X'_{it}\ \beta + a_t + v_{it}$$

Whereas $t = 1,\ldots,T$, $i = 1,\ldots,N$ (i = entity and t = time), α_i is the unknown intercept, also called the individual effect of the individual heterogeneity, it reflects the unobservable variable that explains the inherent differences between the different individuals, which are indexed by i. a_t is the unobserved time-invariant individual effect. For example, the innate ability for individuals or historical and institutional factors for countries and v_{it} is the error term. In a fixed effects model, the un-observed variables are permitted to have any relations whatever with the observed variables. Fixed effect models organize for or partial out the properties of time-invariant variables with time-invariant effects. This is correct, whether the variables are explicitly measured or not, and how do varies by the statistical technique applied. Unfortunately, the effects of time-invariant variables are cannot be estimated.

To use fixed effect models are only interested in analysing the impact of variables that differ over time. When using fixed effect model the individual may affect or bias the outcome variables and it is necessary to control for this. One of the important assumptions about fixed effect model is that time-invariant characteristics are unique and should not be correlated with other explanatory variables for the entity i over time. Each entity is different so to error term and the constant not to be correlated with the others variables. If this assumption is violated, we face omitted variables bias. The second assumption ensures that variables are i.i.d. across entities $i = 1,\ldots,n$. This does not require the observations to be uncorrelated within an entity. This is basically a common property of time series data and the same is allowed for errors v_{it}. In order to control the third factors that do not change with time and the time effect, a panel model containing individual random effects and time fixed effects was used.

Data all the variables used in this paper free to access (see Table 1 for data description). The data of diversity (ethnic and religious) was copied from the database of Cline Centre for Democracy, University of Illinois, USA. This study followed the same methodology of Alesina et al. (2003) for diversity calculation (on the basis of ethnic and religious) by using the following formula.

$$\boldsymbol{FRAC_j = 1 - \sum_{i=1}^{N} S_{ij}^2}$$

Whereas, $\mathbf{S_{ij}}$ is the share of group i, ($i = 1,\ldots,N$) in the country j. The range of the fractionalization index is between 0 and 1. Zero "0" means homogenous country and "1" shows total heterogeneous country.

Table 1 Description of variables and expected signs

Variables category	Symb.	Description	Expected sign	Data source
Dependent variables				
Market capitalization (% of GDP)	MC	Market capitalization (also known as market value) is the share price times the number of shares outstanding (including their several classes) for listed domestic companies. Investment funds, unit trusts, and companies whose only business goal is to hold shares of other listed companies are excluded.		WDI
Value of share traded (% of GDP)	VSTG	The value of shares traded is the total number of shares traded, both domestic and foreign, multiplied by their respective matching prices. Figures are single counted (only one side of the transaction is considered). Companies admitted to listing and admitted to trading are included in the data.		WDI
Value of share trade (% of market capitalization)	VSTM	Turnover ratio is the value of domestic shares traded divided by their market capitalization. The value is annualized by multiplying the monthly average by 12.		WDI
No. of listed domestic companies	DC	Listed domestic companies, including foreign companies which are exclusively listed, are those which have shares listed on an exchange at the end of the year. Investment funds, unit trusts, and companies whose only business goal is to hold shares of other listed companies, such as holding companies and investment companies, regardless of their legal status, are excluded. A company with several classes of shares is counted once. Only companies admitted to listing on the exchange are included.		WDI
S&P/Global equity index	GEI	S&P Global Equity Indices measure the U.S. dollar price change in the stock markets covered by the S&P/IFCI and S&P/Frontier BMI country indices.		WDI

(continued)

Table 1 (continued)

Variables category	Symb.	Description	Expected sign	Data source
Independent variables				
Fractionalization of ethnic groups	FRACED	% of population with ethnic groups (out of total population) and used formulation of Alesina et al. (2003) for its calculations.	±	Cline Centre of Democracy
Fractionalization of religious groups	FRACRD	% of population with religious groups (out of total population) and used formulation of Alesina et al. (2003) for its calculations.	±	Cline Centre of Democracy
Intergroup Cohesion	IC	Intergroup Cohesion measures ethnic and sectarian tensions, and discrimination	+	ISS
Intergroup Safety and Trust	IST	Interpersonal Safety and Trust, focusing on perceptions and incidences of crime and personal transgressions	+	ISS
Gender Equality	GE	Gender Equality reflecting gender discrimination in home, work and public life.	+	ISS
Foreign Director Investment	FDI	Foreign direct investment is the net inflows of investment to acquire a lasting management interest in an enterprise operating in an economy other than that of the investor.	±	WDI
GDP per capita	GDPPC	GDP per capita (current US$)	±	WDI
Corruption perception Index	CI	The CPI scores and ranks countries/territories based on how corrupt a country's public sector is perceived to be by experts and business executives.	±	Transparency International

Note: WDI means world development indictors, database archives. ISS stand for institute of social development. The indices CI, IST and GE are composed from 21 reputable data sources for 195 countries, over the period from 1990 to 2015, and are updated as new data become available. The indices are aggregated using the innovative method of 'matching percentiles'. The S&P/IFCI Composite is a liquid and investable subset of the S&P Emerging market indices; BMI

4 Empirical Results

The focus of this study is to reveal the impact of diversity, i.e. ethnic and religious, on dependent variable, i.e. stock market development (including market capitalization, market liquidity, turnover ratio, listed domestic companies, S&P/global equity index). The results of all Tables 2, 3, 4, 5 and 6 shows diversity (i.e. ethnic and religious) has a significantly positive impact on all the stock market development

Table 2 Diversity and stock market development (Market capitalization in % of GDP). Dependent variable: Market capitalization

	Market capitalization (% of GDP)											
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$FRAC_{EG}$	0.2299*** (0.2797)								0.1105** (0.2838)	0.3702*** (0.3533)	0.9229** (0.2920)	0.1787*** (0.5024)
$FRAC_{RG}$		1.0874*** (0.3146)							1.1674*** (0.3291)	0.9487** (0.3944)	0.1251* (0.3308)	0.0947** (0.5810)
IC			1.3149** (0.7884)							1.7236* (0.9378)		2.6054*** (0.7235)
FDI				0.0075** (0.0031)							−0.0014 (0.0083)	0.0056 (0.0084)
GDPPC					3.2300*** (3.4800)					3.0100*** (5.7900)		1.5600*** (5.5100)
IST						3.5696*** (0.8215)				1.0301 (1.0026)		−0.6470 (0.7965)
CI							0.0259*** (0.0027)				0.0281 (0.0034)	0.0226** (0.0060)
GE								2.2339* (0.6986)			−0.2371 (0.7328)	0.340495 (0.7539)
C	3.416*** (0.1331)	3.0914*** (0.1398)	2.7481*** (0.4853)	3.5087*** (0.0709)	2.9204*** (0.0928)	1.7860*** (0.4408)	2.2950*** (0.1586)	1.9574*** (0.5107)	3.0610*** (0.1644)	2.9783*** (0.7503)	1.8945 (0.5217)	3.6367*** (0.7692)
$\mathbf{R^2}$	0.8239	0.8389	0.9110	0.7182	0.9296	0.8660	0.8512	0.9312	0.7463	0.7271	0.8859	0.91062
Model	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
Cross-sections	81	84	78	89	89	86	85	89	79	69	75	68
Obs.	283	297	252	315	320	269	277	319	279	195	241	186

Notes: Regressions are estimated with white cross-section standard errors correction. Heteroscedasticity robust standard error estimates are reported in parentheses. The asterisks *, ** and*** denotes statistical significance at 10%, 5% and 1% level respectively

Table 3 Diversity and stock market development (Market Liquidity). Dependent variable: Value of share trade

	Value of share trade (% of GDP)											
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$FRAC_{EG}$	1.2548*** (0.5014)								1.2372** (0.5221)	0.2934*** (0.5870)	0.6149* (0.5011)	0.0792** (0.8207)
$FRAC_{RG}$		0.2837*** (0.5759)							0.5014* (0.6022)	1.1734** (0.6456)	1.2904** (0.5667)	1.0003* (0.9437)
IC			1.4323** (1.3805)							2.7573 (1.5816)		3.1503*** (1.0411)
FDI				0.0002 (0.0059)							−0.0227 (0.0147)	0.0075 (0.0116)
GDPPC					4.6300*** (6.5400)					4.0100** (9.0200)		1.1200** (8.2500)
IST						8.1851*** (1.4222)				4.1421 (1.6611)		1.2159* (1.0723)
CI							0.0422 (0.0047)				0.0570*** (0.0060)	0.0548*** (0.0091)
GE								3.8315 (1.3233)			−0.7164 (1.2685)	1.1704 (1.1157)
C	2.3711*** (0.2394)	1.7777*** (0.2524)	1.0816*** (0.8437)	1.8514*** (0.1302)	0.9503*** (0.1719)	2.1932*** (0.7664)	−0.0222*** (0.2767)	0.9034*** (0.9613)	2.1465*** (0.2992)	0.5023*** (1.2845)	0.0215*** (0.8977)	−0.3428 (1.1736)
$\mathbf{R^2}$	0.8203	0.9077	0.9395	0.8605	0.8278	0.9047	0.9145	0.9739	0.9689	0.9282	0.9083	0.9551
Model	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
Cross-sections	84	87	78	93	93	87	86	93	82	68	75	67
Obs.	304	316	273	340	345	285	289	344	298	205	250	194

Notes: Regressions are estimated with white cross-section standard errors correction. Heteroscedasticity robust standard error estimates are reported in parentheses. The asterisks *, ** and*** denotes statistical significance at 10%, 5% and 1% level respectively

Table 4 Diversity and stock market development (Turnover Ratio). Dependent variable: Value of Share traded

	Value of Share traded (% of market capitalization)											
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$FRAC_{EG}$	1.2048*** (0.3796)								1.0149*** (0.3898)	0.4524** (0.4379)	0.0083** (0.4110)	0.0876** (0.6419)
$FRAC_{RG}$		0.6431*** (0.4490)							0.4963** (0.4575)	0.4174 (0.4895)	1.4128*** (0.4714)	0.9102** (0.7545)
IC			0.0341*** (1.0660)							1.7601* (1.1768)		0.4521 (0.9568)
FDI				−0.0079* (0.0042)							−0.0224 (0.0115)	−0.0072 (0.0113)
GDPPC					1.6700*** (5.4300)					1.7900** (7.0200)		−2.9700 (7.0000)
IST						4.3477*** (1.0740)				2.4662** (1.2389)		1.5058 (1.0355)
CI							0.0188*** (0.0040)				0.0294*** (0.0049)	0.0296** (0.0077)
GE								2.2623*** (1.0159)			0.1373 (1.0398)	1.3860 (0.9995)
C	3.4518*** (0.1818)	3.2208*** (0.1994)	3.0178*** (0.6527)	2.9689*** (0.1002)	2.5622*** (0.1449)	0.8127*** (0.5774)	2.0621*** (0.2406)	1.2634*** (0.7412)	3.5409*** (0.2293)	2.5981*** (0.9348)	2.1047*** (0.7418)	0.4614 (1.0278)
$\mathbf{R^2}$	0.8364	0.7272	0.8504	0.8139	0.9303	0.9635	0.9250	0.8185	0.9362	0.9235	0.9345	0.965291
Model	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
Cross-sections	80	84	77	89	89	83	84	89	79	66	74	65
Obs.	268	284	241	299	304	257	263	303	265	186	228	177

Notes: Regressions are estimated with white cross-section standard errors correction. Heteroscedasticity robust standard error estimates are reported in parentheses. The asterisks *, ** and*** denotes statistical significance at 10%, 5% and 1% level respectively

Table 5 Diversity and stock market development (Listed domestic companies). Dependent variable: Listed domestic companies number

	No. of listed domestic companies											
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$FRAC_{EG}$	0.3504*** (0.3283)								0.1833*** (0.3400)	0.1010*** (0.4267)	0.6908** (0.3698)	1.5840*** (1.2345)
$FRAC_{RG}$		0.1876*** (0.3872)							0.1552** (0.3936)	0.7643** (0.4762)	0.8954* (0.4248)	1.8966** (0.8925)
IC			1.7535*** (0.9828)							2.9335** (1.1341)		0.3000** (0.4261)
FDI				−0.0077** (0.0040)							−0.0328 (0.0112)	0.0001 (0.0047)
GDPPC					1.4100*** (4.6500)					1.08 (6.6500)		8.9300* (4.8600)
IST						3.9580*** (0.9611)				4.0155*** (1.1598)		0.5862 (0.4792)
CI							0.0158 (0.0037)				0.0285 (0.0044)	0.0221*** (0.0058)
GE								1.1661 (0.8660)			0.0571 (0.9257)	−0.1149 (0.5014)
C	5.1215*** (0.1542)	5.1110*** (0.1689)	6.2417*** (0.6068)	5.0284*** (0.0862)	4.7109*** (0.1207)	3.1065*** (0.5148)	4.3494*** (0.2151)	4.1442*** (0.6322)	5.0875*** (0.1899)	4.5032*** (0.9298)	3.8009*** (0.6557)	3.9872*** (0.7214)
$\mathbf{R^2}$	0.8353	0.8060	0.7969	0.7063	0.8238	0.8510	0.9092	0.9150	0.9313	0.9359	0.9456	0.9746
Model	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
Cross-sections	85	88	80	95	95	88	88	95	83	69	76	68
Obs.	326	342	298	370	375	308	316	374	320	222	271	212

Notes: Regressions are estimated with white cross-section standard errors correction. Heteroscedasticity robust standard error estimates are reported in parentheses. The asterisks *, ** and*** denotes statistical significance at 10%, 5% and 1% level respectively

Table 6 Diversity and stock market development (S&P/Global Equity Indices). Dependent variable: S&P/global equity index

	S&P/global equity index (% change)											
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$FRAC_{EG}$	0.6757** (0.3824)								0.9607** (0.4014)	0.4621*** (0.5177)	0.5695** (0.4608)	0.4052** (0.5585)
$FRAC_{RG}$		0.7839** (0.4120)							1.0291** (0.4343)	1.0282* (0.5337)	0.9774** (0.4847)	1.5443*** (0.6276)
IC			4.6745*** (1.0326)							2.5950* (1.3838)		2.1041** (1.6904)
FDI				−0.0068 (0.0114)							0.0003 (0.0121)	0.0026 (0.0144)
GDPPC					−1.6700* (5.2500)					−3.2400 (7.7600)		−2.9200 (8.7700)
IST						−2.0293** (0.9146)				−1.3034 (1.2299)		−2.4164* (1.4272)
Corr							0.0102*** (0.0035)				0.0025 (0.0048)	0.0091* (0.0077)
GE								−3.9898*** (0.9198)			−2.9391** (1.2377)	−2.8214 (1.6870)
C	2.4456*** (0.1732)	2.9786*** (0.1900)	5.4040*** (0.6172)	2.6862*** (0.1055)	3.0099*** (0.1401)	3.6904*** (0.4884)	3.1993*** (0.2193)	5.5795*** (0.6816)	2.7479*** (0.2132)	5.1816*** (1.0609)	5.1168 (0.8572)	7.2127*** (1.5072)
$\mathbf{R^2}$	0.8019	0.8204	0.7255	0.8204	0.8533	0.9281	0.7417	0.79516	0.7799	0.9179	0.9277	0.9873
Model	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
Cross-sections	70	74	73	76	76	76	73	76	69	67	66	64
Obs.	163	177	149	180	182	172	170	181	161	126	148	119

Notes: Regressions are estimated with white cross-section standard errors correction. Heteroscedasticity robust standard error estimates are reported in parentheses. The asterisks *, ** and *** denotes statistical significance at 10%, 5% and 1% level respectively

indicators. The robustness is represented in all tables, column 1–11. As Table 2 shows at 1% level of significance, ethnic and religious diversity has positive impact on market capitalization. The coefficient shows 1 unit change in ethnic and religious diversity, market capitalization boost-up with 0.17% and 0.09% respectively. As Table 3 shows at 5% and 10% level of significance, ethnic and religious diversity enhance the market liquidity with 0.79% and 1% respectively. Similarly, as Table 4 shows at 5% level of significance, ethnic and religious diversity enhance the turnover ratio with 0.08% and 0.9% respectively. As Table 5 shows at 1% and 5% level of significance, ethnic and religious diversity increment the no. of domestic companies with 1.5 and 1.8 units respectively. As Table 6 shows at 5% and 1% level of significance, ethnic and religious diversity enhance the global equality index with 0.40 and 1.5 units respectively. Religious groups also present same behavior in this case.

All the Tables 2–6 confirmed that ethnic and religious diversity both are important indicators, which enhance the stock market development. It means that, if the diversity is well established, shareholder engagements focus on persuading companies to take advantage of the benefits associated with gender diversity, including improved decision-making, oversight and financial performance. These results are similar with the literature such as diversity enhances the financial market development (Baier and Bergstrand 2001; Collier et al. 2000; Watkins and Ferrara 2005; Yanikkaya 2003). However, in some extent literature also found the relationship between diversity and stock market development through their socio-economic cost. They argued that ethnic diversification could be sometimes an engine for productivity and innovation, because different ethnic groups have different productive skills, which are complement to each other. Ethnic mix also embodied abilities, experiences and cultures when turns productive then may lead to innovation and creativity. Diversity may be helpful to ensure sustainable development because diversity itself demands for the intergroup cohesion process. Groups coming with different interests but equal influence will compete with each other, thus forcing conciliation on the growth-oriented policies from which all could lead to earn profit.

Furthermore, rise in both types of diversity do not create conflict inside and outside the society because of cohesive measures and collective actions. Fractionalization has the aptitude to make societies safe and emphasized that ethnic diversity has a positive role on stock market because it creates a non-coercive, stable, development-oriented state through intensive public engagements, it minimizes the possibility of civil war due to conflict. It improves varied productivity and innovation and lays a foundation for better performance of private sector. Ultimately, the evidence suggests ethnic fractionalization enhances stock market development. The results, therefore, strengthen the emerging positive consequences of ethnic diversity on stock market.

Roberson and Park (2007) affirmed a positive relationship between diversity and book-to-market equity, and a curvilinear U-shaped relationship between diversity and revenues, net income and book-to-market equity. Dutta and Mukherjee (2012) shows that as culture evolve in the form of greater trust, control and other traits, individuals attitudes towards financial market change, and they engage in greater

financial transactions. Considering multiple dimensions of culture, trust is a key cultural trait, should positively influence stock market development; uncertainty avoidance, Hofstede's cultural dimension should negatively influence the development of the stock market; and individualism, an alternate cultural dimension of Hofstede's measures, should be positively correlated with stock market development (Dutta and Mukherjee 2015).

According to the World Bank report (2000) emphasized that diversity can reduce civil war since maintaining the unity of a rebel movement composed of diverse groups tends to become harder over time. World Bank report concluded that ethnic diversity is a prevention mechanism rather than a cause of civil war. Collier (1998), tries to differentiate between ethnic fractionalization and ethnic dominance and conclude that fractionalization in democratic nations is not a problem by itself because it creates a reasonable competition among the private sector even though societies will have worse public sector performance.

In addition to number of control variables such as intergroup cohesion, corruption perception index, intergroup safety and trust used in empirical analysis. In all the above-mentioned Tables 2–6, corruption index has found a strong indicator, which shows significantly positive relationship with stock market development. Our results also similar with Mouselli et al. (2016) and Shahbaz et al. (2013) by confirmed a positive impact of corruption on stock market development, such as corruption greases the wheels of economy by expediting transactions and allowing private firms to overcome governmental imposed inefficiencies. As well as the corruption increases, the circulation of money within and outside the countries increases. This surplus money enhances the financial markets activities, in another aspect increase the underground economy. These results are opposite to Bolgorian (2011), Yartey (2010) and Cherif and Gazdar (2010) about negative relationship between corruption and stock market development. However, GDP per capita and gender equality shows insignificant relationship with stock market development. The literature shows that GDP per capita and gender equality has indirectly relationship with financial activities, basically it's directly link toward the wellbeing of society (Kabeer and Natali 2013; Masoud 2013).

5 Conclusion and Policy Implication

This study shows the relationship between diversity and stock market behavior by using data of 187-countries of the world. Based on panel data methodology this study concluded that diversity has significant positive impact on stock market development. These results are similar with literature that diversity enhances the financial market development (Baier and Bergstrand 2001; Collier et al. 2000; Watkins and Ferrara 2005; Yanikkaya 2003). We live in a deeply connected and global world. It should come as no surprise that more diverse companies and institutions are achieving better performance. The unequal performance of companies in the same industry and the same country implies that diversity is a competitive

differentiator shifting market share toward more diverse companies. Companies in the top quartile for racial and ethnic diversity are 35 percent more likely to have financial returns above their respective national industry medians. That is particularly true for their talent pipelines: attracting, developing, mentoring, sponsoring, and retaining the next generations of global leaders at all levels of organizations.

At now, most of the researchers intuitively affirmed that diversity matters. They believed that diverse markets are better able to win top talent and improve their customer orientation, employee satisfaction, and decision-making, and all that leads to a virtuous cycle of increasing returns. Literature also found the relationship between diversity and stock market development through their socio-economic cost. Tang et al. (2016) revealed that diversity could promote stock market prosperity and the effect varies from country to country. In particular, it was found that cultural diversity has positive impact on stock market prosperity in high development-level and legal system quality countries, and vice versa. Weller and Zulfiqar (2013) argued that greater diversity is associated with faster growth, larger credit markets, a broader deposit base, and a smaller chance of asset bubbles, all of which could contribute to more stability. According to the UN report 2017, if the diversity is well established, shareholder engagements focus on persuading companies to take advantage of the benefits associated with gender diversity, including improved decision-making, oversight and financial performance. Whereas, intergroup cohesion, GDP per capita and corruption index shows positive relationship with stock market development. Such as the circulation of money increased, more investors take part in financial activities, which ultimately enhance the stock market development.

This study showed limitation in this regards that other kinds of diversity for example, in age, sexual orientation, and experience (such as a global mind-set and cultural fluency) are also likely to bring some level of competitive advantage for companies that can attract and retain such diverse talent. This study suggests that diversity cannot be reduced it is a natural phenomenon; however, positive effect can be obtained by providing equal opportunity, secure and peaceful society through cohesiveness.

Appendix 1: Construction of the Fractionalization Index

1. **Approach.** This paper used ethnic fractionalization index, developed by the Alesina et al. (2003) for diversity calculation (on the basis of ethnic and religious) using the following formula.

$$\mathrm{FRAC_j} = 1 - \sum_{i=1}^{N} S_{ij}^2$$

Whereas, S_{ij} is the share of group i, ($i = 1,\ldots,N$) in the country j. The range of the fractionalization index is between 0 and 1. Zero "0" means homogenous country and "1" shows total heterogeneous country.

2. **Data.** The data of diversity (ethnic and religious) has been taken from database of Cline Centre for Democracy, University of Illinois, USA. The dataset contain annual data from 1990 to 2010 for 187-countries. Data at the Cline Centre based on various projects that document the changing varieties of social identity around the world (composition of religious and ethnic groups, CREG). In addition, they also identified the causes of conflict between religious and ethnic groups. The Composition of Religious and Ethnic Groups Project (CREG) has started to create a set of time-varying measures that gauge the nature and depth of country-specific socio-cultural cleavages. It focused on the largest countries in the world (all countries with a population above 500,000 (in 2014) during the post-WWII era to create country-specific projections on the relative sizes of the different groups during the post-war era.

3. **Final index.** The data at CREG project shows various types of groups each and every country at annual basis on the ethnic and religious identity. We have found the number of ethnic and religious groups of each country out of total populations. Therefore, it easy to apply the Alesina's fractionalization index formula to calculate the diversity for ethnic and religious basis. We constructed the index values for the year 1990, 1995, 2000, 2005 and 2010 because diversity is not change over time. We have also compiled the index for 187-countries (out of 195 totals) due to limitation of data. The result of index can be used for relative ranking of countries on basis of ethnic and religious identity in current scenarios. (Please see results at Appendix 3).

Appendix 2: Summary Statistics

Descriptive statistics

	VSTG	VSTM	MC	DC	GEI	FRACED	FRACRD	IC	IST	GE	FDI	GDPPC	CI
Mean	34.02	48.77	65.49	498.3	5.159	0.457	0.400	0.599	0.499	0.698	5.151	1285	42.82
Median	8.713	26.22	36.39	158.0	3.789	0.455	0.423	0.606	0.521	0.706	2.687	6631	34.50
Maximum	668.5	1721	1185	7487	158.0	0.989	0.925	0.788	0.773	1.021	341.0	1277	98.14
Minimum	0.000	0.015	0.010	2.000	−61.04	0.013	0.003	−0.031	0.231	0.211	−16.58	257.7	8.400
Std. Dev.	71.31	113.0	104.5	1049	28.97	0.258	0.218	0.100	0.100	0.100	14.76	1632	22.17
Skewness	5.117	11.21	6.942	3.839	1.153	−0.037	−0.130	−0.921	−0.414	−0.171	15.41	2.547	0.934
Kurtosis	38.72	160.4	66.62	19.16	6.617	1.696	1.746	5.936	2.874	4.537	325.5	11.66	2.696
Jarque-Bera	1985	3204	5654	5004	252.2	51.53	51.83	291.9	15.44	87.89	3714	3678	93.79
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	1173	1482	2095	1868	1697	331.9	304.0	349.7	263.6	593.5	4373	1123	2689
Sum sq. dev.	1749	3871	3486	4.124	2753	48.35	36.24	5.839	5.320	8.592	1847	2.334	3081

The above Appendix 2 shows the descriptive statistics of dependent and independents variables. VSTG, VSTM, MC, Dc and GEI have a maximum values such as 668.5, 1721, 1185, 7487 and 158 and minimum values 0.00, 0.015, 0.010, 2.00 and −61.04 respectively. Maximum values of FRACED and FRACRD are 0.98 and 0.92 and minima are 0.01 and 0.03 respectively. In the line of empirical analysis, Table 1 shows that data is well organized respective to dependent and independent variables.

Appendix 3: List of Countries

Andorra	Ireland	Qatar	Samoa	Eritrea
Antigua and Barbuda	Israel	San Marino	Sao and Principe	Ethiopia
Australia	Italy	Saudi Arabia	Serbia and Monten.	Gambia, The
Austria	Japan	Seychelles	Solomon Islands	Guinea
Bahamas, The	Kuwait	Singapore	South Africa	Guinea-Bissau
Bahrain	Latvia	Slovak Rep.	Sri Lanka	Haiti
Barbados	Liechtenstein	Slovenia	St. Lucia	Zimbabwe
Belgium	Lithuania	Spain	Sudan	Senegal
Brunei Darussalam	Luxembourg	Sweden	Afghanistan	Sierra Leone
Canada	Malta	HK, China	Benin	Somalia
Chile	Monaco	Hungary	Burkina Faso	Tanzania
Cyprus	Netherlands	Iceland	Burundi	Togo
Czech Republic	New Caledonia	Switzerland	Central African Rep.	Uganda
Denmark	New Zealand	Trinidad & Tob.	Chad	Rwanda
Estonia	Norway	UAE	Comoros	Liberia
Finland	Oman	UK	Congo, Dem. Rep.	Madagascar
France	Palau	United States	Nepal	Malawi
Germany	Poland	Uruguay	Niger	Mali
Greece	Portugal	Fiji	Kiribati	Mozambique
Albania	Cameroon	Gabon	Kyrgyz Republic	Pakistan
Algeria	Cape Verde	Georgia	Lao PDR	Panama
Angola	China	Ghana	Lebanon	Pap. New Guinea
Argentina	Colombia	Grenada	Lesotho	
Armenia	Congo, Rep.	Guatemala	Libya	
Azerbaijan	Costa Rica	Guyana	Macedonia, FYR	
Bangladesh	Cote d'Ivoire	Honduras	Malaysia	
Belarus	Croatia	India	Maldives	
Belize	Cuba	Indonesia	Marshall Islands	

(continued)

Bhutan	Djibouti	Iran, Rep.	Mauritania	
Bolivia	Dominica	Iraq	Mauritius	
Bosnia and Herz	Dominican Rep.	Jamaica	Mexico	
Botswana	Ecuador	Jordan	Micronesia, Fed. Sts.	
Brazil	Egypt, Arab Rep.	Kazakhstan	Moldova	
Bulgaria	El Salvador	Kenya	Mongolia	
Cambodia	Equatorial Guinea	Timor-Leste	Turkey	
Suriname	Taiwan, China	Tonga	Turkmenistan	
Swaziland	Tajikistan	Tunisia	Ukraine	
Syrian Arab Republic	Thailand	Vanuatu	Uzbekistan	
Venezuela, RB	Yemen, Rep.	Morocco	Paraguay	
Vietnam	Zambia	Namibia	Peru	
Nicaragua	Philippines	Russia		

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Does Withholding Tax Reduce International Income-Shifting by FDI?

Anna Białek-Jaworska

1 Introduction

On the one hand, foreign direct investment (FDI) inflows solve problems of limited investment issues and firm growth related to financing constraints (Harrison et al. 2004). FDI inflows bring such scarce capital to recipient firms in emerging countries and relax constraints to firm growth caused by limited access to debt or equity financing. FDI inflows augment investment resources and facilitate development (Kose et al. 2006; Henry 2007). FDI also brings knowledge to the host countries, improving both efficiencies of capital allocation and productivity (Bonfiglioli 2008; Bekaert et al. 2011; Benigno and Fornaro 2014; Benigno et al. 2015).

On the other hand, MNEs use debt FDI and equity financing to shift the profits from affiliates or subsidiaries in host countries with higher taxes through dividends or, even better, interests which can be deducted from taxable income (and allow to benefit from interest tax shield). This issue gradually becomes more apparent in the literature (Kudła 2018; Schimanski 2018; Polish Economic Institute 2020), the EU is looking for instruments to limit such unfair practice. Several initiatives were made: Base Erosion and Profit Shifting by OECD (2015), Anti-Tax Avoidance Directive by European Commission, and an allowance for corporate equity (ACE) rule in European countries (European Committee 2018).

Among factors that influence the FDI inflow into the host country, an important role is played by comparative advantages described in trade theories (Gudowski and Piasecki 2020) and tax competition (Kudła et al. 2015). After 1989, a financial capital movement's liberalization led to implementing the withholding tax (WHT) rate for FDI related to income-shifting (royalties, dividends, and interests). The

A. Białek-Jaworska (✉)
Faculty of Economic Sciences, University of Warsaw, Warsaw, Poland
e-mail: abialek@wne.uw.edu.pl

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efficiency of this instrument raises a new research question on the role of WHT. Our study is even more essential because of the recent amendments to the Polish tax law that restrict thin capitalization and limit taxable debt costs since 2018 (Bialek-Jaworska 2018). Next, it introduces a new mechanism of collecting WHT tax for dividend payments (in Poland and abroad) over 2 million PLN annually per one taxpayer. For lower annual payouts, the WHT agent will have to meet additional requirements to apply for a reduced WHT.

Moreover, interests and discounts on corporate bonds can be free of the WHT when the specific conditions are met. The legitimacy of applying a reduced WHT is limited to confirming that the recipient is a business partner engaged in actual business activity in the country of its registered office. A WHT taxpayer may apply to the tax authority for an opinion on applying for a WHT collection exemption. The tax authority has 6 months to respond, but this opinion is valid for 36 consecutive months. However, the tax authority may also reject the application if tax avoidance provisions apply (PWC 30.12.2020). We shed light on this urgent issue by analyzing WHT's impact on debt and equity FDI and related interest and dividend payments. This research design allows us to contribute to the literature.

The chapter aims to check whether WHT on interests and dividends reduces income-shifting by FDI. Thus, we intend to assess this tax policy tool's efficiency by measuring the sign and significance of WHT's impact on debt FDI and equity FDI inflow to Poland in 2010–2018 and their withdrawal. We target identifying which type of MNEs (vertically or horizontally integrated) use debt FDI instruments rather than traditional equity FDI.

The remainder of the chapter is organized as follows. Section 2 briefly reviews the literature and formulates the research hypotheses. Section 3 describes the methodology and research design, and Sect. 4 presents the results of our analysis. We conclude in Sect. 5.

2 Literature Review

The causes and role of FDI in the development of emerging markets, including Poland, have been studied extensively in the literature (i.e., Cieślik 2019a, b; Gorynia et al. 2015; Igan et al. 2020). The previous empirical analyses show that multinational companies (MNEs) are motivated by different advantages (market access motive, efficiency-seeking by vertically or horizontally integrated MNEs) in investment decisions. However, FDI may also be used for income-shifting to avoid taxes. Kałdoński (2016) studied in depth tax avoidance of European companies using the micro-econometric approach.

In tax avoidance and tax planning literature, debt and equity FDI are known as income-shifting instruments from high-tax to low-tax countries. This issue is discussed in the literature reviewed by Fonseca and Juca (2020). Borrowing from members of business groups located in low-tax home countries and lending to affiliates in high-tax host countries allows borrowers to deduct interest payments

from taxable income and benefit from debt tax shield (Mintz and Smart 2004). The difference in tax rates between home and host countries stimulates vertical integration due to transfer pricing for MNEs (Egger and Seidel 2013). Damgaard et al. (2019) highlight that the possibility of tax payment saving guides FDI, and a share of such foreign investment is directed to tax havens. For German MNEs, Buttner and Wamser (2007) show that tax-rate differences within the multinational business group influence income-shifting with intercompany loans. The authors assessed the implied tax revenue effects as relatively small. This effect can be caused by substantial costs related to adjusting the capital structure for income-shifting purposes. However, their research uses micro-level panel data made available by the Bundesbank. Therefore, our study can contribute to the literature by analyzing macro-level FDI data retrieved from the Balance of Payments.

Buettner et al. (2018) support our assumptions by pointing out that MNEs may use foreign operations' financial structure to shift taxable income. Intercompany loans may be used to create interest payments, which are deducted in countries with high taxes (Fuest et al. 2011; Dischinger et al. 2014; Hansson and Olofsdotter 2014; Devereux et al. 2018). MNEs that operate in a developed capital market optimize their tax payments by intercompany loans provided inside their business groups, from parent companies to their subsidiaries and among subsidiaries or affiliates (Desai et al. 2004; Bénassy-Quéré et al. 2005; Azémar 2010; Barrios et al. 2012; Egger et al. 2014; Hebous and Ruf 2017).

The EU aims to prevent profit-shifting via extraordinary debt financing by intercompany loans. Therefore the EU limits such opportunities increasing the restrictiveness of thin-capitalization rules. On the one hand, this has positive effects via curbing tax planning, but on the other—it negatively impacts investment (Merlo et al. 2019). Thus, the EU tries to solve this inefficiency by introducing an allowance for corporate equity (ACE) to achieve tax neutrality between debt and equity financing. In some EU countries, the ACE decreased debt financing in total but generated a rise in intra-group lending within MNEs for tax planning purposes (Hebous and Ruf 2017). Moreover, Buettner et al. (2018) show that anti-profit shifting legislation intensifies the adverse tax effects on FDI if imposed by host countries with relatively high tax rates.

Polish Economic Institute (2020) shows that 17 billion PLN of corporate profit was transferred abroad, adding to Poland's corporate income tax (CIT) gap. Among the recipient countries, there are the following tax havens: Ireland, Netherlands, Luxemburg, Switzerland, Cyprus, Belgium, and Malta. Because the Polish Economic Institute (2020) omits possible tax policy tools preventing such an income-shifting and focuses only on the size of the CIT gap, there is a place to contribute. By analyzing WHT's impact on debt and equity FDI and related interest and dividend payments, we shed light on this urgent issue and contribute to the literature. So far, Arena and Roper (2010) have provided evidence that differences in international tax rates and tax regimes affect MNEs' debt location decisions. They analyze micro-level data of 8287 debt issues from 2437 firms headquartered in 23 different countries with debt-issuing subsidiaries in 59 countries, considering differences in personal and corporate (PIT and CIT) tax rates, tax credit and exemption systems,

and bilateral cross-country WHT on interest and dividend payments. These researchers show that MNEs issue debt through subsidiaries located in countries with higher WHT on dividend payments. Simultaneously, MNEs issue more considerable debt in foreign countries with low or non-existing WHT on interest payments. Our chapter adds to the literature by focusing on WHT's impact on the debt FDI and equity FDI instruments' income-shifting role.

We contribute to the state-of-the-art of FDI by a separate analysis of debt FDI and equity FDI instruments, and an extension of the knowledge-capital (KC) model analyzed by Cieślik (2019a) for total FDI inflow to Poland till 2015. Cieślik (2019a) shows that the horizontal dimension explains FDI inflow to Poland from 15 EU members. Besides identifying integration type of MNEs that provide debt FDI or equity FDI to Poland, we check whether bilateral cross-country WHT is a tool to reduce the income-shifting via debt or equity FDI. Thus, we state the following hypotheses:

H1: Withholding tax (WHT) on interest payments reduces income-shifting by debt FDI instruments.
H1A: Higher WHT on interests motivates MNEs to withdraw debt FDI instruments.
H2: WHT on dividend payments reduces income-shifting by equity FDI.
H2A: Higher WHT on dividends increases the withdrawal of equity FDI.
H3: Vertically integrated MNEs are likely to use debt FDI instruments rather than traditional equity FDI.

3 Research Design

This chapter studies the determinants of debt and equity FDI to Poland in 2010–2018, and their withdrawals. We use inflow FDI data retrieved from the Central Bank of Poland (*Narodowy Bank Polski*, NBP) website. They allow us to separate debt from equity FDI instruments. Earlier, separate debt FDI and equity FDI data (a component of the Balance of Payments) were analyzed by Igan et al. (2020) to study their impact on the growth of industries in the emerging markets (including Poland) in 1998–2010. Contrary to that study, our research focuses on the profit shifting with the use of interests or dividend transfers from Poland to other countries, including 11 tax heavens (Cyprus, Hong Kong, Ireland, Liechtenstein, Luxembourg, Malta, the Netherlands, Singapore, British Virgin Islands, Andorra, Gibraltar, United Arab Emirates, Jersey, Cayman Island, Panama, Saint Kitts and Nevis, and the Isle of Man).

Table 1 presents the definition of variables. Four positions retrieved from the Balance of Payments are used as a dependent variable: debt FDI inflow to Poland, equity FDI inflow to Poland, and both of their withdrawals. We focus on the WHT's impact on interests (dividends) on income shifting using FDI.

We apply the theoretical knowledge-capital (KC) model. Because we distinguish between debt and equity FDI inflows and withdrawals, we replace the dependent

Table 1 Definition of variables

Variables	Definition of variables
Explained variable(s) (*y_FDI*)	
debt fdi	ln(debt foreign direct investment (FDI) inflow from country *i* to Poland)
withdraw debt fdi	ln(withdrawal of debt FDI from country *i* to Poland)
equity fdi	ln(equity foreign direct investment (FDI) inflow from country *i* to Poland)
withdraw equity fdi	ln(withdrawal of equity FDI from country *i* to Poland)
Explanatory variables	
kdiff	Capital per worker difference between host and home countries calculated as ln (a ratio of the national capital stocks expressed in PPPs in constant 2011 USD to total employees)
hdiff	Differences in human capital endowments between host and home countries calculated as ln(a ratio of the human capital indexes that are based on the mean years of schooling and returns to education to total employees)
sum	ln(sum of country-lender's and Poland's GDPs)
loans borrowings	ln(intercompany loans as a part of debt instruments of FDI)
sdi	Helpman's size dispersion index that is calculated using data on output-side real GDP at chained purchasing power parity (PPP) rates and expressed in constant 2011 US dollars for Poland and a country which companies provide loans to Polish firms $sdi_{ij} = 1 - \left(\frac{gdp_i}{sum_{i,j}}\right)^2 - \left(\frac{gdp_j}{sum_{i,j}}\right)^2$
$gdp_i/sum_{i,\,j}$	Country *i*'s share in the *sum* of GDPs calculated using data on output-side real GDP at chained purchasing power parity (PPP) rates and expressed in constant 2011 US dollars
$gdp_j/sum_{i,\,j}$	Country *j*'s share in the *sum* of GDPs calculated using data on output-side real GDP at chained purchasing power parity (PPP) rates and expressed in constant 2011 US dollars
distance	A proxy for trade costs equals to ln(a geographical distance of each parent country's capital city from Warsaw that is measured "as the crow flies" distance between the capital cities of the host and home country, and it is expressed in kilometers)
wht_int	Bilateral cross-country withholding tax rate on interest payments (Deloitte 2019)
wht_div	Bilateral cross-country withholding tax rate on dividend payments (Deloitte 2019)
kaufman	A mean of six Kaufmann's Worldwide Governance Indicators' estimates (Kaufmann et al. 2010)

variable used in the well-known KC model with the separate components of FDI inflows. The main explanatory variables of FDI inflows in the KC model are the similarity in economic size (*sdi*), the summation of Poland's and the home country's GDPs (*sum*), relative factor endowments based on human and physical capital per worker (*kdiff*, *hdiff*), and a geographical distance of each pair home and host countries' capital cities. The relative factor endowments describe Poland's

differential and the countries investing in Polish firms by equity injections or giving them loans. The *sdi*, *kdiff,* and *hdiff* explanatory variables allow us to identify how MNEs investing in Polish firms are integrated: horizontally or vertically, depending on investment: debt or equity. The Penn World Table 9.1 is the primary data source used to measure the KC model components. The research limitations deal with the availability of the Penn World data only until 2017. Therefore we used 1-year lagged data for the *sdi*, *kdiff*, *hdiff*, *sum* explanatory variables used in the theoretical KC model. This solution was previously applied by Cieślik (2019a). We extend the classic KC model by adding additional explanatory variables like bilateral cross-country WHT rate on interest *wht_int* (dividend *wht_div*) payments and Kaufmann's Worldwide Governance Indicator of home countries' governance quality (*kaufman*). The aggregate Kaufmann's indicators are based on several hundred individual underlying variables, taken from a wide variety of existing data sources that are grouped in six dimensions: Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption.

By assessing the statistical significance and signs of the estimated coefficients on the *sdi*, *kdiff*, *hdiff* explanatory variables, we identify what cross-country pattern of MNEs integration explains the debt FDI or equity FDI investments better. A positive coefficient at the similarity in the economic size of a pair of countries confirms the privilege of horizontal integration and the importance of the market access motive, whereas its insignificance proves the vertical integration favor. We use the Helpman's size dispersion index (*sdi*) to measure the similarity in relative country size (see definition provided by Table 1). Negative coefficients at the differences in relative physical and human capital factor endowments support horizontally integrated MNEs, while a significant positive relationship proves the favor of the efficiency-seeking motive over the market access motive. We control institutional governance using a mean of six Kaufmann's indices (regulatory quality, voice & accountability, political stability & absence of violence, government effectiveness, the rule of law, and control for corruption). The geographical distance between capital cities of host and home countries controls for trade costs. We focus on the WHT on interests and dividends impact on the income-shifting as an international tax avoidance tool separately. Therefore, we consider a withdrawal of both types of FDI instruments too.

Table 1 provides detailed definitions of all explained and explanatory, both test and control variables.

Table 2 shows descriptive statistics, whereas Table 3 illustrates the correlation coefficients of explanatory variables. Missings are caused by lack of data in the Penn World Table 9.1 for the Isle of Man, Jersey, Gibraltar, Andorra, Liechtenstein, Guernsey in total, and a lack of human capital and employment data for Saint Kitts and Navis, Cayman Islands, British Virgin Islands. There is a lack of Kaufmann Governance Indicators in the case of Guernsey, Gibraltar, and the Isle of Man.

We study the effectiveness of bilateral cross-country WHT instruments in reducing income-shifting by interests on foreign loans or dividends paid to foreign

Table 2 Descriptive statistics of the variables

Variable	N	Mean	Std. err.	Min	Max
debt fdi	595	2.24	2.66	0.00	9.55
withdraw debt fdi	595	1.60	2.41	0.00	9.24
equity fdi	595	1.92	2.74	0.00	9.91
withdraw equity fdi	595	1.17	2.42	0.00	9.72
kdiff	503	11.76	1.03	6.18	13.21
hdiff	503	−0.72	1.56	−7.84	2.92
sum	567	14.20	0.68	13.51	16.78
loans borrowings	595	3.32	3.77	0.00	10.77
sdi	567	0.26	0.17	0.00	0.50
distance	586	7.71	1.06	5.85	9.78
wht_int	586	0.11	0.06	0.00	0.20
wht_div	586	0.14	0.04	0.05	0.20
kaufman	559	0.76	0.76	−0.97	1.87

shareholders using the KC model. We estimate the models for four different dependent variables using the one-step Arellano-Bond dynamic panel-data estimator, adjusting standard errors for clustering on the country. We focus on the impact of WHT on interests and dividends on income-shifting using debt or equity FDI. This approach bases on the following equation of the extended KC model:

$$y\_FDI_{ijt} = \sum_{k=1}^{p} \alpha_0 y\_FDI_{ij,t-k} + \beta_1 sum_{ijt} + \beta_2 sdi_{ijt} + \beta_3 kdiff_{ijt} + \beta_4 hdiff_{ijt} + \beta_5 distance_{ij} + \beta_6 wht\_int_{ijt} + \beta_7 wht\_div_{ijt} + \beta_8 controls + v_{ij} + \varepsilon_{ijt} \quad (1)$$

Next, we apply the generalized method of moments GMM Arellano-Bond dynamic panel-data estimator. We estimate separate models for four different dependent variables: debt FDI inflow, equity FDI inflow, and both of their withdrawals (*y_FDI*). The GMM approach uses instruments for the differenced equation. Next, it eliminates the disadvantages of reduced sample size (Arellano and Bond 1991). The dynamic panel-data system allows a better understanding of adjustment dynamics when current behavior depends on past behavior.

4 Results

Table 4 presents results obtained from the estimations of models using the GMM Arellano-Bond dynamic panel-data estimator. The WHT on interests (dividends) is the leading test variable, while Kaufman's governance indices is a control variable.

Table 3 Correlation matrix

	kdiff	hdiff	sum	loans	sdi	dist	whtint	whtdiv	kaufman
kdiff	1								
hdiff	0.083	1							
sum	0.083	−0.54	1						
loans	0.530	0.018	0.228	1					
sdi	0.219	−0.69	0.111	0.109	1				
distance	−0.21	−0.198	0.218	−0.329	−0.014	1			
wht_int	−0.46	−0.025	−0.204	−0.548	−0.202	0.459	1		
wht_div	−0.23	−0.07	−0.145	−0.168	0.003	0.169	0.434	1	
kaufman	0.64	0.282	−0.09	0.564	0.031	−0.156	−0.378	−0.008	1

Table 4 Results of one-step Arellano-Bond dynamic panel-data estimation (Std. Err. adjusted for clustering on country)

	debt fdi (1)		debt fdi (2)		withdraw debt fdi (3)		equity fdi (4)		withdraw equity fdi (5)	
debt fdi									0.024	
									0.066	
L1.	0.2386	***	0.2386	***					0.090	
	(0.086)		(0.086)						(0.070)	
L2.	0.2730	***	0.2730	***					0.157	**
	(0.104)		(0.104)						(0.066)	
L3.									0.055	
									(0.087)	
withdraw debt										
L1.					0.1164	*				
					(0.0692)					
L2.					0.1368					
					(0.1023)					
equity fdi										
L1.							−0.126	#		
							(0.0962)			
L2.							−0.110			
							(0.0963)			
withdrawequity										
L1.									−0.236	***
									(0.071)	
L2.									−0.234	***
									(0.065)	
sum	−9.835		−9.8352		7.9990		12.5463		−3.1120	

(continued)

Table 4 (continued)

	debt fdi (1)		debt fdi (2)		withdraw debt fdi (3)		equity fdi (4)		withdraw equity fdi (5)	
	(7.610)		(7.6101)		(8.7905)		(7.7909)		(6.017)	
L1.	1.5216	*	1.5216	*	−1.4044	*	−0.3545		2.9004	
	(0.872)		(0.8722)		(0.8141)		(0.7202)		(6.576)	
L2.	−1.187		−1.1872		1.8876	**	3.0190	**	−2.3974	***
	(0.930)		(0.9296)		(0.8082)		(1.3862)		(0.474)	
sdi	14.543		14.5426		2.7216		−25.480	**	−9.4824	
	(11.70)		(11.697)		(14.612)		(12.208)		(12.62)	
L1.	−17.93	***	−17.928	***	18.4831	***			1.7164	
	(5.631)		(5.6313)		(4.9585)				(11.90)	
L2.	9.6014	**	9.6014	**	−6.1432				6.8648	***
	(4.843)		(4.8426)		(4.0012)				(1.713)	
kdiff	−0.683	***	−0.6827	***	0.7969	##	0.0100		−0.748	***
	(0.246)		(0.2457)		(0.5032)		(0.1404)		(0.239)	
L1.	0.2404		0.2404		0.1101		0.3633		0.459	
	(0.432)		(0.4322)		(0.5718)		(0.2226)		(0.334)	
L2.							−0.640	*		
							(0.3504)			
hdiff	4.1875	**	4.1875	**	−5.034	***	1.3032		0.302	
	(1.681)		(1.6808)		(1.6891)		(1.2981)		(1.116)	
L1.	−2.391	***	−2.3908	***	2.3711	***	0.1604		−1.6053	
	(0.849)		(0.8486)		(0.8093)		(0.3387)		(2.040)	
L2.	0.9641	**	0.9641	**	−0.2924		0.2019			
	(0.448)		(0.4476)		(0.3790)		(0.4166)			
distance			−63.929	*			58.3601	#		
			(38.476)				(44.362)			

wht_int	−102.4	***	−102.4	***	113.4	***			91.62	***
	(36.59)		(36.590)		(27.786)				(31.67)	
wht_div	94.247	**	94.2468	**	−123.36	***	35.1598	##	−123.22	***
	(43.30)		(43.304)		(35.015)		(23.68)		(42.67)	
equity fdi	0.0387		0.0387		−0.0412					
	(0.070)		(0.0700)		(0.0639)					
L1.	0.1245	*	0.1245	*	−0.1010					
	(0.068)		(0.0685)		(0.0628)					
L2.	0.1440	*	0.1440	*	−0.1541	**				
	(0.080)		(0.0801)		(0.0712)					
loansborrowings							0.2816	*		
							(0.1606)			
L1.							0.1953			
							(0.2232)			
kaufman	6.1854	**	6.1854	**	−8.135	**			2.1244	
	(2.745)		(2.7453)		(3.6940)				(2.080)	
year	0.3084	*	0.3084	*	−0.115		−0.325	##	−0.046	
	(0.191)		(0.1913)		(0.2317)		(0.2168)		(0.165)	
Sargan test	32.278		32.278		27.424		53.46		52.423	
p-value	0.1501		0.1501		0.3351		0.001		0.0004	
Arellano-Bond test										
AR1	−9.074	***	−9.074	***	−8.739	***	−4.51	***	−7.729	***
p-value	0.0000		0.0000		0.0000		0.0000		0.0000	
AR2	0.8857		0.8857		1.7451		0.957		−0.283	
p-value	0.3758		0.3758		0.0810		0.339		0.7774	

(continued)

Table 4 (continued)

	debt fdi (1)		debt fdi (2)		withdraw debt fdi (3)		equity fdi (4)		withdraw equity fdi (5)	
N observations	332		332		332		332		277	
N groups	56		56		56		56		56	
N instruments	45		46		45		42		43	
Wald test	132.19	***	139.02	***	84.64	***	61.96	***	213.48	***

***p < 0.01, **p < 0.05, and *p < 0.1, #p < 0.15, ##p < 0.2

Models in the first and second columns explain debt FDI inflow to Poland. In the model in the third column, we analyze its withdrawal. Thus, we control equity FDI inflow in these models. In the model that describes equity FDI inflow to Poland, we handle intercompany loans and borrowings (debt FDI instruments) as a control variable.

Our findings show a negative correlation between WHT on interests and debt FDI inflow to Polish firms (models 1 and 2), which align with the **H1** hypothesis. Thus, we confirm that WHT on interest payments reduces international income-shifting by debt FDI instruments. The positive impact of the WHT on interests on the withdrawal of debt FDI (a dependent variable in model 3) and the departure of equity FDI from Polish firms (model 5) follow our expectations and confirm the supportive hypothesis **H1A**. Therefore, we provide evidence that higher WHT on interest payments motivates MNEs to withdraw debt FDI instruments from Polish firms. The positive coefficient at the equity FDI inflow to Polish firms (explained variable of the model 4) supports the **H2** hypothesis but at a low (15%) level of significance.

This **result** means that WHT on dividends reduces international income-shifting by equity FDI, but the impact is less significant than in the case of WHT on interests. Moreover, the results of model 5, shown in the last column, confirm that an increase in the WHT on interests forces MNEs to withdraw equity FDI from Poland. However, this finding is contrary to the impact of WHT on dividends because higher WHT on dividend payments reduces the withdrawal of equity FDI instruments (see models 5). Therefore, we reject the **H2A** hypothesis. We identify that higher WHT on dividends decreases withdrawal of equity FDI, discordant to our expectations. However, higher WHT on dividends stimulates debt FDI inflow to Poland according to the results of models in columns (1) and (2). This relationship is in line with the negative impact of WHT on dividends on withdrawal of debt FDI presented in column (3). Nonetheless, WHT on interests positively influences the withdrawal of equity FDI instruments. To summarize, these results indicate that higher WHT on dividends motivates MNEs to provide intercompany loans and other debt FDI instruments instead of equity FDI.

We provide evidence that debt FDI inflow to Poland increases (its withdrawal decreases) with the size of the combined market of both lending and borrowing countries (*sum*). The similarity of pair-countries' economic size positively affects the withdrawal of both debt and equity FDI instruments. This coefficient shows that market access matters only for investment exits. However, in work-intensive industries, the efficiency-seeking motive is more important than the market access in debt FDI. Positive coefficients at the differences in relative factor endowments (*hdiff*) in models 1 and 2 confirm this finding. Thus, the debt FDI determinants' results support the **H3** hypothesis on the privilege of vertical integration of MNEs that provide debt FDI to Polish firms in work-intensive industries. The negative coefficient at the *distance* variable in column (2) supports the H3 hypothesis that vertically integrated MNEs likely provide debt FDI to Poland rather than equity FDI. Higher trade costs (proxied by a larger geographical distance between capital cities of host and home countries) discourage MNEs from providing debt FDI to Polish firms. Thus, closer neighbor countries provide more debt FDI to Polish firms. The negative influence of

the human capital relative factor endowments differential (model 3) identifies that horizontally integrated MNEs likely withdraw debt FDI, while vertically integrated MNEs renew debt FDI provided to Polish firms.

Regarding control variables, higher debt FDI, including intercompany loans, comes from countries with good quality governance and better institutional environment measured by a mean of Kaufmann's Governance Indicators.

Interestingly, the governance quality (including voice and accountability, political stability and absence of violence, governance efficiency, regulatory quality, the rule of law, and control for corruption) of host countries matters neither for equity FDI nor their withdrawal.

5 Conclusions

The literature on business groups underlines the role of loans provided within the internal capital market in liquidity management and financing investment projects of enterprises with limited bank loan access. Loans guarantee a higher and more certain rate of return than the dividend yield (Białek-Jaworska et al. 2019). The internal capital market may shift lending from less effective projects to more effective ones (Buchuk et al. 2014). However, restrictive thin capitalization rules limit borrowers' internal borrowing benefits since 2018 in Poland, although it is still more attractive than equity infusion. Intragroup loans' reallocation is more common and plays a more critical role in countries with less developed capital markets (Stein 1997). Intra-group loans are used to manage cash excesses in one firm and cash shortages in another (Bialek-Jaworska et al. 2020). Non-financial companies step into banks' shoes by lending using money gained from their cash flow, especially when they have long-term investments (Bialek-Jaworska 2017), including shares in affiliates. Next, business groups use internal revenues to set up or acquire capital-intensive firms (Almeida et al. 2011), as corporate investments are partly financed by the dividends paid out by the group members (Gopalan et al. 2014).

On the supply side, lenders may benefit from inter-corporate loans by lending at a higher interest rate than in the case of alternative investment (e.g., bank deposits). Intercorporate loans result from the redistribution of cash holdings and money borrowed from banks (Bialek-Jaworska et al. 2020). The redistribution effect is better known for the trade credit (Bialek-Jaworska and Nehrebecka 2016) that is also a component of the debt FDI. While on the demand side, inter-corporate loans are emergency financing for small firms with limited access to bank loans, suffering from financial constraints, and lacking creditworthiness (Bialek-Jaworska et al. 2019).

This chapter contributes to the literature with new findings that WHT taxation of interest payments effectively limits income-shifting by debt FDI instruments, contrary to WHT on dividends. However, negative externalities are observed because higher WHT on dividends motivates MNEs to shift from equity to debt FDI financing.

Our results should raise the policymakers' attention as debt and equity FDI are used as a tool for income-shifting from firms located in countries with higher taxes to low (or null) tax countries (including tax heavens). We show that an effective solution is to increase WHT on interests to reduce profit-shifting activity and stop the tax base's erosion in Poland. Under regulation valid till 2018, WHT on dividends seems inefficient, contrary to WHT on interests. A rise in WHT on dividend payouts motivates MNEs to shift to debt FDI instruments and provide intercompany loans instead of equity FDI.

WHT aside, this chapter finds vertically integrated MNEs likely to provide debt FDI to Polish firms. We adopt and extend the knowledge-capital model to study separate debt and equity FDI focusing on WHT on interest and dividend payouts. Using the Arellano-Bond dynamic panel data approach and controlling home countries' governance policy, we add to Cieślik (2019a)'s study on total FDI inflow from 15 EU member countries to Poland. We learn that home countries with better institutional environments provide more debt FDI to Poland. We add to the actual discussion on the FDI instruments' income-shifting that causes Poland's income tax gap. This issue was raised by Polish Economic Institute (2020). Our study's practical implications suggest how income-shifting practices can be reduced via FDI by increasing WHT on interests transferred to the home countries.

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The Relationship Between Trading Volume and Returns Volatility on Warsaw Stock Exchange

Lesław Markowski

1 Introduction

Investors throughout the trading day receive a lot of information at different times. This information is reflected in intermediate equilibrium prices and when investors glean the new information the final informational equilibrium in prices is reached. The flow and adoption of information is defined as sequential information arrival hypothesis (SIAH) (Copeland 1976). It can be assumed that with the simultaneous arrival of information, the trading volume of any asset will increase. Therefore, the volume can be a variable predicting variability in price changes. The Volume can represent the stochastic information flows process and therefore it can be used for construction estimators of liquidity and volatility of financial instruments (Będowska-Sójka and Kliber 2019, 2021; Olbryś 2018). There should be a positive correlation between trading volume and absolute returns of price changes (Copeland and Friedman 1987). This statement, in turn, is the subject of the mixture of distribution hypothesis (MDH) and proposed by Clark (1973). Price changes and trading volume as an information arrival rate are independently distributed but they can also be considered as a joint distribution. This implies positive contemporaneous relation between price volatility and volume. Conditional variance of price change and trading volume are positive function of information arrival. The potential impact of trading volume on price volatility can be tested using GARCH model in which the variance of returns is heteroskedasticity due to the information that arrive to the market. Using the contemporaneous trading volume should decrease the volatility persistence in conditional variance equation compared to the equation without that

L. Markowski (✉)
Department of Finance, Faculty of Economic Sciences, University of Warmia and Mazury, Olsztyn, Poland
e-mail: leszekm@uwm.edu.pl

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volume. This statement has found support in many studies. Lamoureux and Lastrapes (1990a) discovered that phenomenon of variance clustering diminishes when the contemporaneous trading volume is included to the variance equation. They also confirmed that GARCH measures of persistence in variance are sensitive to type of model misspecification (Lamoureux and Lastrapes 1990b). Gallo and Pacini (2000) also observed reduction of the estimated persistence in the GARCH (1) and EGARCH(1) for US stocks. Bohl and Henke (2003) in Polish stock market showed a reduction of persistence in volatility after including trading volume in the model. Gorgul and Wójtowicz (2006) demonstrated that for the equities listed in the DJIA index volume and returns volatility exhibit long memory. Louhichi (2011) on Euronext proved that trading volume decreases the persistence of volatility when the volume is introduced in the conditional variance equation. Ezzat and Kirkulak-Uludag (2014) in the Saudi Exchange provided strong evidence for the validity of the mixture of distribution hypothesis. They demonstrated that volatility persistence decreases when the trading volume is included in the conditional variance equation. The same effect Tan et al. (2015) revealed using the sample in Australian stock market. MDH and SIAH are verified by Tseng et al. (2015) and Shen et al. (2018). They supported the sequential information arrival using lagged volume to predict volatility. Wang et al. (2019) in the Bitcoin market documented significant relationship between trading volume and return volatility and supported the SIAH incorporated different kinds of measurements of volume and sample periods.

In this paper, the main problem is to define the role of volume as such, and in the context of price changes in the perception of information, often private information, by traders. The existence of strong simultaneous relations between the volume and the volatility of rates of return denotes that investors' decisions depend on the level of volume. In addition to the impact of trading volume on volatility, a problem of the relationship was raised in connection with the sign of arrival rate. The question arises whether good or bad information strengthened the volume and whether there is an asymmetry in the impact of a given type of information. A broad study on this topic was carried out by Tan et al. (2015). They proposed price movement indicators and revealed that model with these variables reduce persistence in returns' volatility more than models with volume alone. Furthermore, they observed that upward price movement influence conditional variance more than a downward price movement.

The objective of this study is to verify the relationship between return volatility and mixing variable as volume using GARCH(1) specification in Polish capital market. Changes of persistence in volatility are investigate considering trading volume in positive and negative price movement.

2 Methodology

2.1 Conditional Variance–Volume Relation

The explanation that stock returns are generated according with a mixture distribution hypothesis can be verify in using of proper ARCH model. That model can describe of the rate of information arrivals as a generating process of mixing variables (Ahmed et al. 2005). One of that variables is trading volume and it is incorporating to explain of conditional variance stock returns. The volume plays an important role from investors' point of view because it reflects their expectations. It seems important to study the joint distribution of returns and volume to confirm the mixture of distribution hypothesis.

The returns in the research period for trading day are calculated as follows:

$$R_t = \ln\left(P_t^{close}\right) - \ln\left(P_t^{open}\right) \tag{1}$$

The adopted methodology for determining the rates of return and price-volume indicators was ordered by several reasons. We can consider trading as a trading period and overnight non-trading period. In this article only price changes during the trading period were calculated. Moreover, this approach enables investors to avoid the influence of noise traders on prices. The role of noise traders in the context of the arbitrage approach to financial markets can be found at work (Shleifer and Summers 1990).

The GARCH(1) model is the tool that use contemporaneous trading volume and allow to measure the level of persistence' reduction. Including trading volume generalised variance specification with the mean equation considering autocorrelation in returns is given by (Tan et al. 2015):

$$R_t = \varphi_0 + \varphi_1 R_{t-1} + \varepsilon_t \tag{2}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + \delta Vol_t, \tag{3}$$

$$\varepsilon_t = \sigma_t \vartheta_t; \vartheta_t \tilde{IID}(0,1) \tag{4}$$

where Vol_t is return and trading volume in trading period t. The volume reflects an appropriate proxy of information arrival rate, where news tends to increase the trading volume. Therefore, the estimation of δ is expected to be positive, which means increasing conditional variance of stock returns. The sum of parameters $\alpha_1$and β_1 measures the level of volatility persistence. Including the mixing variable in the form of volume should reduce of the persistence in volatility that is eliminate the ARCH effect in time periods of returns. Nevertheless, the volume should be treated as a weakly exogenous variable (Lamoureux and Lastrapes 1990a). Karpoff (1987) argued that, if volume is not exogenous the regression of return volatility on volume can be biased.

2.2 Trading Volume and Price Movement Direction in Conditional Variance

In this paragraph, the study is expanded to include the impact of the type of information (good and bad news) on volatility-volume relation. Investors may react in distinct way to different types of information. Taking into account growing and descending price movement the conditional variance equation with a trading volume is as follows:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \xi_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + \delta_1 Vol_t^+ + \delta_2 Vol_t^- \tag{5}$$

where

$$Vol_t^+ = \begin{cases} Vol_t & if\ P_t^{open} - P_t^{close} < 0 \\ 0 & if \quad otherwise \end{cases} \tag{6}$$

$$Vol_t^- = \begin{cases} Vol_t & if\ P_t^{open} - P_t^{close} \geq 0 \\ 0 & if \quad otherwise \end{cases} \tag{7}$$

and P_t^{open}, P_t^{close} denote open and close trading price of any asset. Obviously, the price-volume indicators as variables (6) and (7) aggregate to the trading volume. Equation (5) leads to the following two research questions. Firstly, whether volume in upward and downward price movement periods more reduce a persistence in conditional variance than contemporaneous trading volume in Eq. (3). Secondly, assuming that investors react much more strongly and immediately to good news than to bad information, good arrival rate persuade conditional variance more than bad arrival rate.

3 Data

A dataset includes a series of daily log returns of 10 stocks quoted on the Warsaw Stock Exchange and belonging to the index WIG20, of which seven stocks are characterized by full time series. The trading volume is the daily transaction volume (number of shares traded during the day).

The sample period is from January 4, 2010 to December 30, 2019 what spans 2497 observations. Descriptive statistics of returns of stocks are given in Table 1. The skewness of a half of stocks is positive indicating right tail in distributions. The excess kurtosis for all shares is leptokurtic. The statistics of the Jarque-Bera test reject the hypothesis that the distributions of returns for all companies are normal. The results of the Ljung-Box test (are not present in the table) indicate that the rates of return exhibit autocorrelation in volatility, which justifies the use of ARCH class

Table 1 Summary statistics of daily returns

Stock	Mean	SD	Skew.	Kurtosis	J-B	ADF
Alior Bank	−0.00087	0.019	−0.015	1.402	142.87	−31.2 [0.000]
Bank Pekao	−0.00067	0.016	0.609	7.666	6268.49	−37.1 [0.000]
CCC	−0.00044	0.020	−0.170	3.071	992.99	−35.6 [0.000]
CD Projekt	0.00065	0.027	0.308	7.911	6551.44	−38.5 [0.000]
Cyfrowy Polsat	−0.00028	0.018	0.058	1.338	187.70	−37.5 [0.000]
Dino Polska	0.00047	0.021	−0.357	3.140	289.45	−25.9 [0.000]
Grupa Lotos	−0.00019	0.019	−0.008	1.475	226.23	−48.1 [0.000]
JSW	−0.00099	0.029	0.682	6.678	4097.33	−43.6 [0.000]
KGHM	−0.00137	0.019	−0.349	3.150	1082.94	−46.8 [0.000]
LPP	−0.00008	0.020	0.127	2.787	814.89	−35.5 [0.000]

Notes: J-B-Jarque-Bera test of normality with critical value as $\chi^2(2) = 5.991$; ADF-Augmented Dickey-Fuller test of stationarity in the version of intercept and trend
Source: Own study

Table 2 Stationarity and autocorrelation of daily volume

Stock	ADF	LB-Q (4)	LB-Q (8)	LB-Q (12)
Alior Bank	−22.5 [0.000]	386.2 [0.000]	631.8 [0.000]	927.3 [0.000]
Bank Pekao	−26.3 [0.000]	492.0 [0.000]	636.3 [0.000]	722.8 [0.000]
CCC	−27.8 [0.000]	1211.1 [0.000]	2110.6 [0.000]	3004.7 [0.000]
CD Projekt	−17.9 [0.000]	3554.9 [0.000]	5623.6 [0.000]	7709.2 [0.000]
Cyfrowy Polsat	−29.0 [0.000]	311.9 [0.000]	423.4 [0.000]	534.7 [0.000]
Dino Polska	−14,3 [0.000]	146.9 [0.000]	185.7 [0.000]	243.6 [0.000]
Grupa Lotos	−22.9 [0.000]	933.9 [0.000]	1232.3 [0.000]	1432.3 [0.000]
JSW	−21.1 [0.000]	1356.7 [0.000]	2337.1 [0.000]	3209.0 [0.000]
KGHM	−24.3 [0.000]	984.1 [0.000]	1367.5 [0.000]	1657.3 [0.000]
LPP	−30.1 [0.000]	289.2 [0.000]	477.0 [0.000]	676.9 [0.000]

Notes: ADF-Augmented Dickey-Fuller test of stationarity in the version of intercept and trend; LB-Q(k)-Ljung-Box test for the join significance of autocorrelation
Source: Own study

models. Augmented Dickey-Fuller test indicates that daily returns are stationary time series. For modelling conditional variance of returns is used GARCH(1) model which provides a good fit. The GARCH model will be used despite the limitations caused by the weakness of this model in situation with rapid changes in the level of volatility (Fiszeder and Perczak 2016).

Some diagnostic tests were performed for trading volume and the results are displayed in Table 2.

The Ljung-Box test was applied to investigate serial autocorrelation in the volume series. The statistics of LB-Q test for different lags provide a conclusive rejection of the null hypothesis that the volume time series is not autocorrelated. This serial correlation appearance is necessary in implementing the mixture of distribution hypothesis (MDH) with autoregressive conditional heteroskedasticity model specification. The MDH implies positive contemporaneous relation between price

and volume and the volume create the conditional heteroscedasticity of returns (Pati and Rajib 2010). The ADF test confirms the stationarity of volume time series.

4 Results

The study of the impact of volume on conditional variance compares the estimates of GARCH(1) model and the same model with trading volume. Results in Table 3 indicate the high level of persistence in nine of ten stocks which varies from 0.6287 to 0.9999. On the other hand, estimates of models with contemporaneous trading volume in Table 4 reveal a substantial decreasing of volatility persistence in nine

Table 3 Estimates of GARCH(1) model

Model	$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$		
Stock	$\widehat{\alpha}_1$	$\widehat{\beta}_1$	$\widehat{\alpha}_1 + \widehat{\beta}_1$
Alior Bank	0.1517^{***}	0.6265^{***}	0.7782
Bank Pekao	0.0508^{***}	0.9271^{***}	0.9779
CCC	0.0418^{***}	0.9217^{***}	0.9635
CD Projekt	0.1088^{***}	0.8439^{***}	0.9527
Cyfrowy Polsat	0.0871^{***}	0.5496^{***}	0.6367
Dino Polska	0.1248^{***}	0.5039^{***}	0.6287
Grupa Lotos	0.0646^{***}	0.8913^{***}	0.9559
JSW	0.0761^{***}	0.9097^{***}	0.9858
KGHM	0.0518^{***}	0.9252^{***}	0.9770
LPP	0.2054^{***}	0.0000	0.2054

Notes: ***, **, * indicates significance at the 1%, 5% and 10% respectively
Source: Own study

Table 4 Estimates of GARCH(1) model with trading volume

Model	$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + \delta Vol_t$			
Stock	$\widehat{\alpha}_1$	$\widehat{\beta}_1$	$\widehat{\alpha}_1 + \widehat{\beta}_1$	$\widehat{\delta}$
Alior Bank	0.1361^{***}	-0.0687^{**}	0.0674	$8.59 \times 10^{-7***}$
Bank Pekao	0.0495^{***}	0.9288^{***}	0.9783	7.99×10^{-10}
CCC	0.1389^{***}	0.2000^{***}	0.3389	$1.71 \times 10^{-6***}$
CD Projekt	0.0031	-0.0609^{***}	−0.0578	$1.69 \times 10^{-6***}$
Cyfrowy Polsat	0.0762^{***}	-0.0631^{*}	0.0131	$3.46 \times 10^{-7***}$
Dino Polska	0.0092	-0.0533^{**}	−0.0441	$2.25 \times 10^{-6***}$
Grupa Lotos	0.0591^{***}	-0.0569^{*}	0.0022	$1.09 \times 10^{-6***}$
JSW	0.0490^{***}	-0.0472^{***}	0.0018	$2.35 \times 10^{-6***}$
KGHM	0.0404^{**}	-0.0795^{***}	−0.0391	$4.71 \times 10^{-7***}$
LPP	0.1542^{***}	−0.0332	0.1208	$8.27 \times 10^{-5***}$

Notes: ***, **, * indicates significance at the 1%, 5% and 10% respectively
Source: Own study

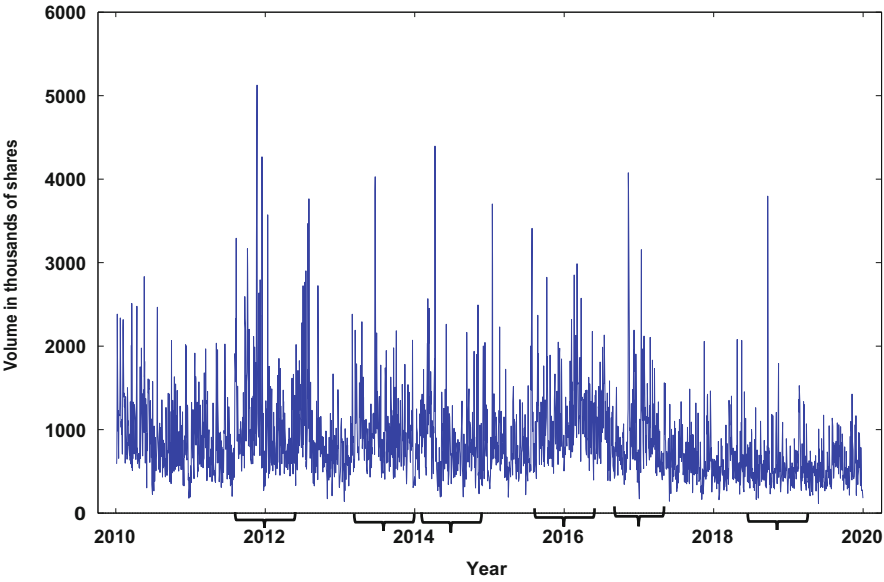

Fig. 1 The volume of KGHM in the period of 2010–2019. Source: Own study

stocks. The results of estimated models demonstrate that GARCH effects become much smaller when trading volume is included to the variance equation. These results are consistent with those obtained by Lamoureux and Lastrapes (1990a) and Koulakiotis et al. (2007). Furthermore, trading volume has statistically positive influence on conditional variance of these stocks.

Despite the general conclusions consistent with expectations, the negative estimates of parameter β_1 pay attention because they exceed the restrictions for this coefficient in the conditional variance equation. In the presence of volume with positive parameter δ, the parameters α_1 and β_1 are expected positive and insignificant if daily volume is serially correlated. Lifting restriction on these parameters should satisfy the requirement of a positive volatility process. Verification of the volatility process gave positive values of the conditional variance for all t. Nelson and Cao (1992) showed is not always the case that negative coefficients in GARCH models may result from misspecification or sampling error.

Similarities of contemporaneous changes in trading volume and conditional variance are given by plots in Figs. 1 and 2 for example for transactions of KGHM shares. Periods of increased investor activity are marked with graphic symbols in Fig. 1. They correspond in most cases to periods of relatively higher values of conditional variance in Fig. 2. It follows that if information arrival rate increases and thereby trading volume, then the volume becomes the explanatory variable for volatility clustering.

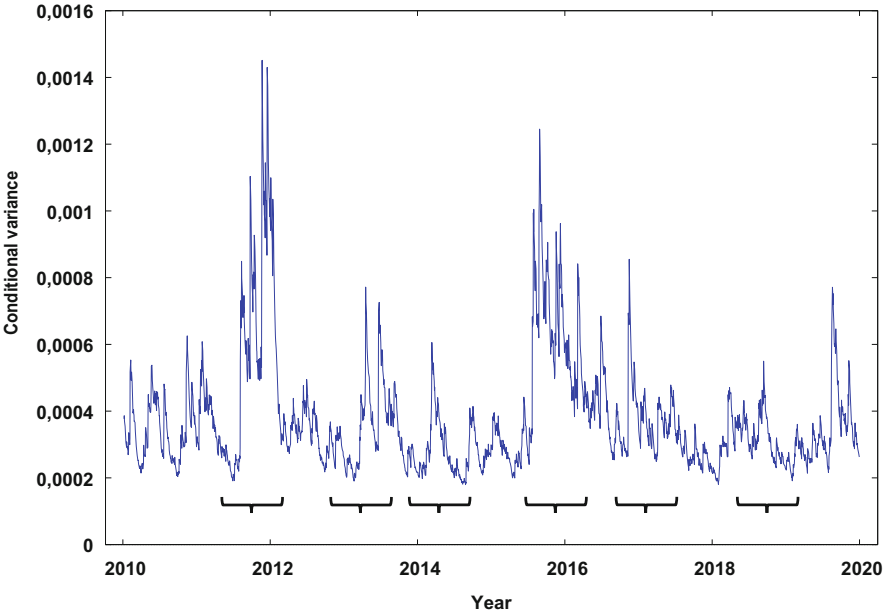

Fig. 2 The conditional variance from GARCH(1) model for KGHM in the period of 2010–2019. Source: Own study

The next stage of the study of volatility-volume relationships is the estimation of GARCH (1) models covering the impact of both volume and a price movement. The results are presented in Table 5.

The model outperforms the model only with trading volume in the variance equation in case of three out of ten stocks as far as persistence reduction. For all stocks, the sum of $\widehat{\alpha}_1 + \widehat{\beta}_1$ is lower than the sum of these parameters for variance equation without any exogenous variables. Variables considering price changes make an additional contribution to the explanation of conditional variance. As expected, the impact is mostly positive and statistically significant in the case of nine stocks both in positive and negative price movement. However, the above effect is asymmetric. Using the Wald test in seven stocks the combined variable (upward price movement and volume) has a greater impact on volatility than the variable connecting downward price movement with trading volume. This shows a stronger and less immediate response of investors to good news than bad news. These results are consistent with the results obtained by Tan et al. (2015). The explanation for such results can be volume levels in different price movement periods. On the example of KGHM, Fig. 3 gives the plots of trading volume of KGHM shares in upward and downward price movement, respectively.

For observations with positive price movement the volume was characterized by periods of increased investor activity throughout the sample period, while for

Table 5 Estimates of GARCH(1) model with trading period indicators

Model	$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + \delta_1 Vol_t^+ + \delta_2 Vol_t^-$					
Stock	$\widehat{\alpha}_1$	$\widehat{\beta}_1$	$\widehat{\alpha}_1 + \widehat{\beta}_1$	$\widehat{\delta}_1$	$\widehat{\delta}_2$	$\delta_1 > \delta_2$
Alior Bank	0.1204^{***}	-0.0305^{***}	0.0899	$2.95 \times 10^{-6\ ***}$	$3.87 \times 10^{-7\ ***}$	Y
Bank Pekao	0.0487^{***}	0.9289^{***}	0.9776	2.87×10^{-9}	-4.26×10^{-9}	N
CCC	0.1399^{***}	0.2209	0.3608	$1.37 \times 10^{-6\ **}$	$1.95 \times 10^{-6\ ***}$	N
CD Projekt	−0.0015	-0.0156^{**}	−0.0171	$3.08 \times 10^{-6\ ***}$	$9.27 \times 10^{-7\ ***}$	Y
Cyfrowy Polsat	0.0404^{***}	-0.0199^{**}	0.0205	$1.29 \times 10^{-6\ ***}$	$1.54 \times 10^{-7\ ***}$	Y
Dino Polska	0.0149	−0.0208	−0.0059	$4.30 \times 10^{-6\ ***}$	$1.22 \times 10^{-6\ ***}$	Y
Grupa Lotos	0.0177^{**}	-0.0272^{***}	−0.0095	$2.43 \times 10^{-6\ ***}$	$6.62 \times 10^{-7\ ***}$	Y
JSW	0.0340^{***}	-0.0284^{***}	0.0056	$4.45 \times 10^{-6\ ***}$	$1.36 \times 10^{-6\ ***}$	Y
KGHM	0.0524^{***}	-0.0829^{***}	−0.0305	$5.85 \times 10^{-7\ ***}$	$3.32 \times 10^{-7\ ***}$	Y
LPP	0.1539^{***}	−0.0335	0.1204	$8.21 \times 10^{-5\ ***}$	$8.34 \times 10^{-5\ ***}$	N

Notes: ***, **, * indicates significance at the 1%, 5% and 10% respectively
Source: Own study

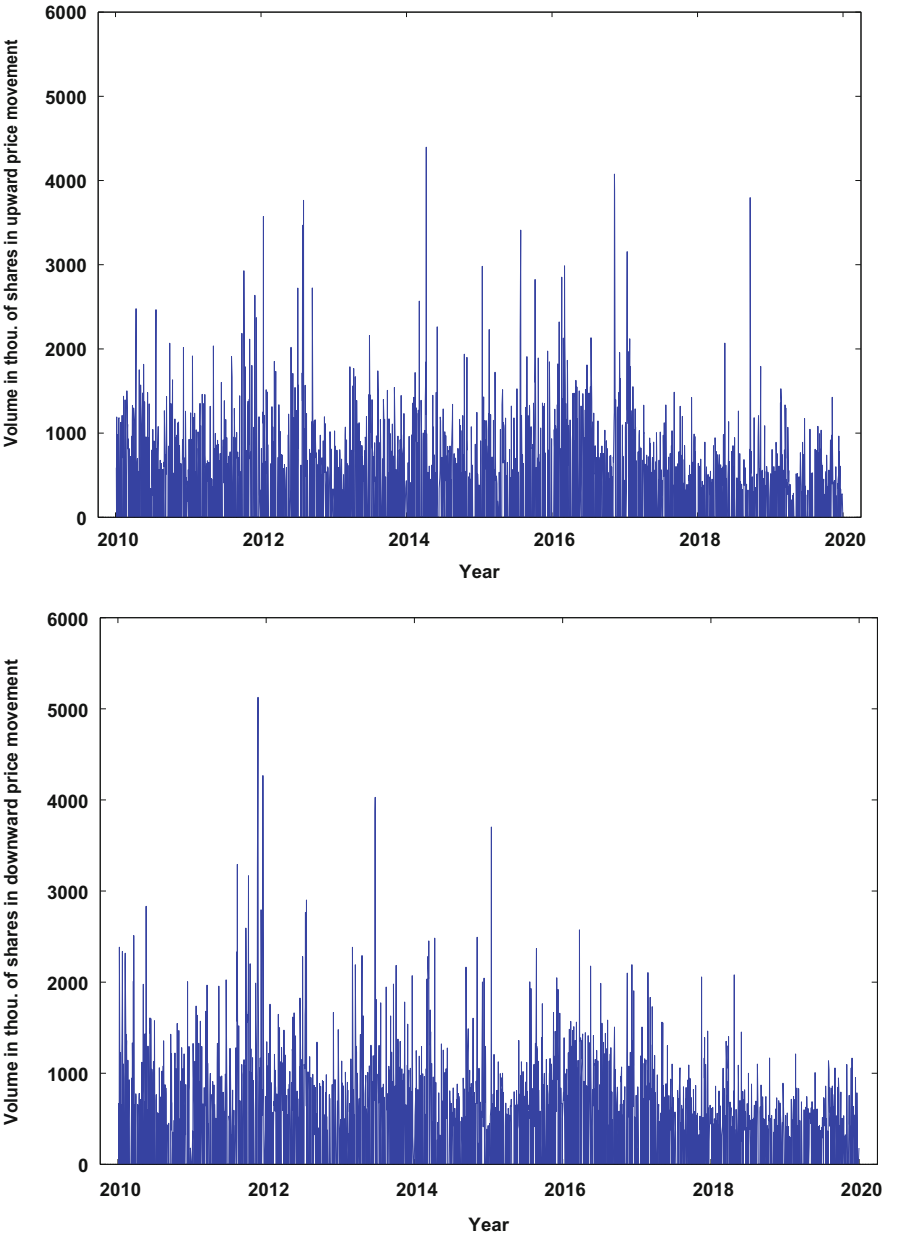

Fig. 3 The volume of KGHM in upward and downward price movements in the period of 2010–2019. Source: Own study

Table 6 The average trading volume of KGHM in thou. of shares

Direction of price movement	Subsample period		
	Subsample 2010–2014	Subsample 2015–2019	Whole sample 2010–2019
Positive price movement	922.2	855.0	889.7
Negative price movement	999.3	756.1	874.2

Source: Own study

periods with negative price movement, increased volume can only be seen in the first part of the sample period. This is confirmed by the values in the Table 6.

The average values of volume for upward price movement in the second subsample and whole sample are higher than in downward price movement.

5 Conclusions

The paper presents research the relationship between return volatility and trading volume using GARCH(1) model on the example of ten companies listed on the Warsaw Stock Exchange and belonging to the WIG20 index. Changes of persistence in volatility are investigate considering trading volume in upward and downward price movement.

The study provides some important findings. The higher trading volume the higher volatility of stock returns. Next, the results of variance equation reveal that contemporaneous trading volume causes a substantial decreasing of volatility persistence in nine out of stocks and it has a statistically positive influence on conditional variance of these stocks. This findings with the results of Doman (2008), which showed a significant influence of the volume on the volatility for the most liquid companies. Wójtowicz (2008) confirmed the significant linear relationships between the conditional variance of returns and the residuals of the ARFIMA-FIGARCH model for log-volume. The model with indicator variables considering both the volume and price movement demonstrate a reduction of the persistence in three stocks compared to the model with trading volume alone. Moreover, as expected, for more stocks the upward price movement has a greater impact on conditional variance than the downward price movement. The combined variables, volume and indicator of price movement direction have positive and statistically significant influence on returns' variation.

The work analysed the relationship between instrumental variables for the information process volume and price change versus volatility. The research verifies investors' behaviour in the trading period due to the type of information related to movement in price. Therefore, traders can consider the volume as an additional source of information. Observation of the trading volume by investors can increase

the advantage over other market players. Furthermore, it expands the capabilities of modelling and forecasting variation of traded stocks returns.

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Factors Influencing Individual Investor Participation in Stock Market

Dorika Jeremiah Mwamtambulo

1 Introduction

In 1969 an outstanding article related to an optimal selection of a lifetime portfolio was developed by Robert C. Merton. In the study, Merton (1969) examined how an individual investor should allocate his/her wealthy between risky and non-risky assets. In determining the optimal mix between risky and non-risky assets, he observed that both poor and rich individuals with a Constant Relative Risk Aversion (CRRA) would allocate equal weights on both risky and non-risky assets. In the case of a Decreasing Relative Risk Aversion (DRRA) utility; rich individuals assigned higher weights on risky assets in their portfolio as compared to poor individuals. From the findings, Merton (1969) argued that to maximise their utility through the optimal portfolio holding, both poor and rich individuals must hold some risky assets in their portfolio. Merton (1969) conclusion is on the need of individuals to participate in investing in some risky assets such as shares and bonds, which are significantly traded in capital markets.

In 1995 the findings of Merton (1969) were questioned on what is termed as the stock market participation puzzle. This is a puzzle observed by Haliassos and Bertaut (1995) in which despite the requirements of the Modern Portfolio Theories and the findings by Merton (1969), individual households are still reluctant in investing in risky assets. Very few individual households are observed to be willing to participate in investing in capital markets. The findings of Hunnicutt (2017) supported these observations, where only 17.5% of the global equity market is observed to be owned

D. J. Mwamtambulo (✉)
Wroclaw University of Economics and Business, Wroclaw, Poland
e-mail: Dorika.Mwamtambulo@ue.wroc.pl

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by index investors,[1] 25.6% by institutional investors[2] and the remaining 57% is owned by the government, pension funds, insurance and companies. According to Carlson (2018), only 19% of individual households in the United States of America (USA) are directly participating in the stock in the year 2018. In the UK, by 2018,[3] only 13.5% of individual investors owned equity type of investments (Statistics UK 2020). According to Hankur (2016), only 14% of Germans are participating in capital markets in 2016 despite savings tendencies in the country. Giannetti and Koskinen (2010) observed similar findings, where less than 50% of direct participation by individual households is observed in more than 20 countries around the world.

Many studies have been conducted on trying to find the reasons for low individuals' participation and hence solving the stock market participation puzzle. Factors of financial literacy, Intelligence Quotient (IQ), awareness and numeracy have been observed to be significant on influencing the participation decision (Grinblatt et al. 2011; van Rooij et al. 2011; Sivaramakrishnan et al. 2017). Factors of high transaction costs which included information, entry and recurrent costs are also observed to be associated in keeping away individual households from investing in stock markets (Bogan 2008; Leung 2013). Other factors include that of trust, social, community influence, income and financial wealth (Brown et al. 2004, 2008; Balloch et al. 2015). Demographic factors such as age, gender, marital status, education and behavioural factors of overconfidence, loss and regret aversion are also observed to be significant in some studies.

Tanzania like many other countries around the world is facing a problem of low participation of individual household in its capital market and in this case the Dar es Salaam Stock Exchange (DSE) market (Massele et al. 2013; Viswanadham et al. 2014; King and Milanzi 2015; Komba 2016). The low participation by individual households has been a persistent problem since its start of operations in April of 1998. The low participation in this market does not show any sign to change in the near future. Due to the persistent nature of the problem, there is a constant need for determining the factors behind the reasons for low individual households' participation in the stock market. Literature has provided an account of factors such as age, gender, marital status, education, financial literacy, income or wealth, transaction costs and behavioural factors such as overconfidence, loss and regret aversion to be significant in influencing the decision on whether to participate in the capital market. There is a significant need for testing these factors in Tanzania capital market to observe their applicability in accounting for low participation by individual households in Tanzania. The findings of the study are necessary for trying to answer the participation puzzle in Tanzania, where there is persistent low participation by individual households. Moreover, the findings are essential for setting up new

[1]This includes mutual funds, exchange-traded funds, institutional accounts and private investors tracking on the index.

[2]This includes the actively managed hedge funds, mutual funds and institutional accounts.

[3]This is an increase from 12.6 reported by Statistics UK (2017).

policies that are necessary to increase the level of individual households' participation in the stock market. The outcome of solving the problem of the participation puzzle is an increase in the number of individual households in the capital market. The increase in the number of individual households in the market are expected to bring into the economy a significant amount of savings which can be used for production and investment purpose.

2 Literature Review

A number of factors have been accounted for the low individual investors' participation in the capital market. In the study of Aroni et al. (2014b) using a sample of 311 individual investors out of 836,250 prevailing during 2013 in Nairobi stock market exchange observed that the amount of dividend pay-out by a company attract the individual investors to invest in shares. In the absence of dividend pay-out, fewer individuals are observed to participate in share investments. The findings of Nyamute and Maina (2011), Amisi (2012), Olima (2013) and Mwangi (2015) observed that financial literacy is a driving factor for individual investors to choose to invest in the capital market. In the study of Nyamute and Maina (2011), individual investors with financial training have better financial management on savings, expenditure, debt management, money, retirement and contingency practices. Olima (2013) observed a significant relationship between individuals with a high level of financial literacy with the decision to save and social security or retirement plans. In the study of Amisi (2012) pension fund managers with a high level of financial knowledge are observed to take a significant consideration on factors such as return, risk, portfolio composition, inflation, past performance. Other factors include the market index tracking, market, liquidity, operation, regulatory, strategy and counterparty risk when making the investment decision. Mwangi (2015) noted that although individuals with the high financial literacy are more likely to participate in the capital market but they are not limited only to invest in shares they also choose to invest in real assets. The choice on whether to invest in shares or real assets depends on individual investors dependency factors on expected dividends, capital appreciation and factors such as the price of the shares, the volatility of the market, gender, age and income.

Aroni et al. (2014a) observed the availability of financial information do influence the decision to invest in risky assets. Individual investors who can acquire all the necessary financial information are more willing to participate in the capital market as compared to those who are lacking access to financial information. Kimani (2011) on the other hand it is observed that behaviour factors of herding, loss aversion, regret aversion, mental accounting, overconfidence, gambler's fallacy, anchoring and availability bias influence the decision to participate in the capital market by individual investors. Market factors such as price changes, market information and past trends are also observed to influence the participation of the individual investors in risky assets. In the study of Ndiege (2012) economic factors of expected

dividends, capital appreciation and price of a share and behavioural factors of herding, advocacy and overconfidence are observed to be significant in influencing the decision as to whether individual investors in Kenya should participate in the capital market. Murungi (2011), on the other hand, observed that the factor of market awareness and trust in the stock market significantly influenced the individual Ugandan investors' decision to participate in the capital market. Sindambiwe (2015) observed factors of financial literacy and market awareness to be significant in influencing the decision to participate in Rwanda stock market. Increase in the individuals' saving behaviours in countries such as Botswana Kenya, Namibia, Swaziland, Zimbabwe, Ivory Coast, Malawi, Nigeria, Tanzania, Egypt, Morocco, Uganda, Tunisia, Ghana, Mauritius, South Africa and Zambia are observed by Andrianaivo and Yartey (2010) to increase the individuals participation in capital market. The increase in the participation by individual investors through saving are also attributed to the growth of the capital markets in these countries.

The USA holds the top two largest stock markets in the world. These are the New York Stock Exchange and the NASDAQ. Given this reputation, it can be expected that a large number of individual households are participating in the capital market. Nevertheless, the USA also accounted for a small proportion of individual households' participation in its capital markets. According to Carlson (2018), 30% of individual investors were directly participating in the USA capital market in 1999, and by 2018, the account was only 19%. The Federal Reserve Survey of Consumer Finance and Pisani (2017) accounted for a total of 62% of individual households who were, directly and indirectly, participating in the capital market before the financial crisis, and this fell to only 54% by 2017. A number of studies have accounted for low individual participation in the US stock market. This includes the studies of Brown et al. (2004, 2008), Hong et al. (2004), Shum and Faig (2006), Bogan (2008, 2013), Yoong (2011), Vestman (2012), Leung (2013), Balloch et al. (2015) Giannetti and Wang (2016), Bilias et al. (2017), and Chien and Morris (2017).

According to Brown et al. (2004), the influence of the surrounding communities and the presence of listed firms both local and public traded influences the individual households' participation in the stock market. Suppose the individual household surrounding neighbourhood (within 50 miles radius) included a number of individuals participating in the capital market. In that case, this increases the likelihood of that individual household to participate in the capital market. An increase in participation of neighbour households by only 2% increases individual investors' participation by 10% when there is no control of income. In the case of control of income, this will lead to an increase of 2%. Individual households are more motivated to participate in the market provided that their neighbours or surrounding communities do participate in the capital market. They choose to do more so when these household participating in the capital have similar income or wealth.

Similarly, Brown et al. (2004) observed that whenever there is a presence of at least one local firm that is traded in the stock market in the vicinity of 50 miles range increases the household participation by 1%. They do more so when a large traded company is within their community. In the light of Brown et al. (2004) findings,

individual households that are less surrounded by individuals participating in the stock market will lead to low participation in the capital market. The results are supported by Brown et al. (2008), who observed an increase of 10% in the average ownership of the community increase the individual participation stock market by 4%. The influence of communal interactions is also observed by Hong et al. (2004) where individuals who have a good relationship with their friends and relative are observed to participate in investing in capital markets significantly.

A similar finding is observed by Chien and Morris (2017). They observed that the participation in the USA capital market to be affected by the geographical location, i.e. State an individual is located. In their study, they examined different households' participation in the stock market in different states. They observed that the difference in income between the states leads to a difference in participation in the stock market. Those states with higher income are more willing to participate in the stock market than those with lower income. States with higher average income such as New York, Connecticut, are observed to have a large number of individuals participating in the capital market compared to state such as Mississippi. When they controlled for income and examined the individuals in the two-state with lower and higher average income, still those state with higher income had more individuals participating in the capital market. Although Chien and Morris (2017) did not investigate the factors behind this, one speculation can relate to the community and local firm influence. In cities like New York and California, many individuals participate in capital markets because a number of largest traded companies are registered in these areas. Both the community and local firm effect can account for the higher individuals' participation if control for income. In the study Balloch et al. (2015) they argue that communal effects are related to the level of financial literacy individual investors. Those with high financial knowledge are more likely to be influenced by advice from other members of the community. However, Balloch et al. (2015) emphasised that the factor of financial literacy and trust rather than community effect do influence the decision to participate in capital markets.

Using the USA Consumer Finance Survey for the years' 1992, 1995, 1998 and 2001 Shum and Faig (2006) observed that the selection of investing in stock is related to the factors of wealth, age, retirement savings and financial advice. Individual investors with a significant amount of wealth are willing to participate in the capital market as compared to those without wealth. This notion is confirmed by the findings of Wolff (2017) where 83% of the stock ownership is owned by only 10% of the most affluent families while 93% of the stock ownership is owned by 20% of the most affluent USA households. Age is observed to have a concave relationship with the investment decision to invest in shares. The concave relationship between age and participation in the stock market is also observed by Gardini and Magi (2007) in Italy; Fujiki et al. (2012) in Japan; Thomas and Spataro (2015) in Europe; and Fagereng et al. (2017) in Norway. Individual managing the retirement savings are more likely to invest in stock compared to those without savings. Individual receiving professional investments advice from brokers, financial adviser shows significant willingness to invest in the stock market.

The study of Bogan (2008) showed that when the individual investors are relieved from the cost burden of the information and transaction costs through the availability of internet are more likely to choose to invest in the capital market. This is observed not to be same as those individual investors with little or no access to the internet. Bogan (2008) argued that the cost burden that individual incurred for acquiring information and entry cost for participating in the capital market discourage many individual investors from participating in investing in risky assets. Leung (2013) also observed that the probability of senior generation using the internet in the USA to participate in the capital market has increased by 21.8%. This increase to 38.7% when advised by professional investors regarding the investment process. The findings of both Bogan (2008) and Leung (2013) showed that the information cost involving the process of learning the investment activities and obtaining the market information is managed or kept at minimal. Individual investors show more willingness to participate in capital markets. Bogan (2013), on the other hand, examined the influence of gender of the dependants to the participation in the stock market. He observed that family with female children are more likely to participate in the stock market as compared to parents with more male children. It is only single female parents with male children who are more willing to invest in the stock market as compared to any other single-parent family.

Yoong (2011), on the other hand, examined how financial literacy influenced participation in the capital market. Yoong (2011) observed that financial illiteracy individual investors are less willing to participate in investing in risky assets for fear of their lack of knowledge regarding the management of the assets. Vestman (2012) showed that house ownership is related to an increase in participation in the stock markets. His findings showed that house owners are twice (61%) more likely to invest in the stock market as compared to renters (26%). Vestman (2012) argued that the increase in participation in the stock market is a result of an increase in wealth rather than house ownership. The wealth is accumulated from the rental savings that individual households are no longer needed to pay. However, in the study of Bilias et al. (2017), individual investors participating in the capital market are observed not to accumulate a significant amount of wealth from their investment. In their study Bilias et al. (2017) observed that wealth inequalities between households did not change by participating in the capital markets. Giannetti and Wang (2016) examine the influence of corporate scandals on individual participation in stock markets. In the presence of corporate scandals such as Enron and WorldCom, individual investors are observed to decrease their level of participation in the capital market. The effect did not have only a negative impact on those companies caught up in the scandals; instead, it had a ripple effect on other companies that are not directly involved with scandals. This can be seen in the case of Arthur Andersen auditing firm that was related to the scandals of Enron and WorldCom, many traded companies audited by the firm experienced a drop in the participation of the individuals owning their shares.

The findings of Xia et al. (2014) in China showed that the individuals participating in the Chinese market are more overconfident regarding the level of skills and knowledge regarding investment. Their overconfident behaviour resulted in making

poor investment decisions. According to the findings, the factor of financial literacy had a significant role in increasing participation in stock markets. Individual investors who are financially informed are more likely to invest in a risky asset than individuals with little or no skills regarding the capital markets.

Fujiki et al. (2012) examined the influence of factors of age, income, financial assets and education on the participation Japanese in the capital market. Using survey data for the period between 2007 and 2010, they observed factor age to weakly influence the participation in the capital market after controlling for factors of income, education and financial assets. In Japan, the older generation is observed to participate more in the capital market than the young generation. However, when controlling for the factor of income and financial assets, young Japanese are observed to participate more in the risky market as compared to the old generation. With an increase in income, the concavity relationship between age and participation in the capital market is observed in the Japanese market.

Sivaramakrishnan et al. (2017) and Vohra and Kaur (2016) examined the factors influencing individual participation in India's capital market. In the study of Sivaramakrishnan et al. (2017) they observed that the attitude of individual investors towards risk, financial well-being, regulatory perception, social influence and investment hassles significantly influence the individual investors' decision to participate in the capital market. The level of financial literacy is also observed to be the factor behind the decision where individual investors with a high level of financial literacy are more likely to invest in the risky asset. In the study of Vohra and Kaur (2016) observed that factor of capital market awareness affects the level of participation between the group of women investors and non-investors. Women with a high level of market awareness choose to participate in the capital market than those lacking the general awareness of the market.

Hunkar (2016) argues that the increase in participation in the Germany stock market is a result of the lowering of the interest rate by the European Central Bank to nearly zero rates. The opportunity cost of individual investors of keeping their investment in fixed deposit is higher than investing in share markets. Using data from fifteen (15)[4] European countries, Hagman (2015) examined the influence of the level of trust on individual investors' participation in the stock market. Two types of trust are analysed, the trust with other individuals and the trust with institutions. The findings showed that the trust towards other individuals increases individual participation in the capital market. Only the trust of the government institutions led to an increase in individual investors' participation in capital markets. The influence of individual investors trust is also examined by Guiso et al. (2008) and they observed that less trusting individuals in both countries Italy and Netherlands are less likely to choose to participate in the capital market as compared to trusting individuals. The lack of trust in the stock market increased when the individual investors are observed

[4]The data was collected from a Survey of Health, Ageing and Retirement in Europe (SHARE) and it included the following countries Austria, Belgium, Czech, Denmark, Estonia, France, Germany, Italy, Israel, Luxembourg, Netherlands, Slovenia, Spain, Sweden and Switzerland.

to have little knowledge or lack of familiarity regarding the operations of the capital markets. In the study of Georgarakos and Pasini (2011), the factors of trust and sociability are observed to influence the individual investors' participation in the capital market. Using data from countries with high individual participation such as Sweden, Denmark and Switzerland and low participation such as Austria, Spain and Italy they observed that both individuals' trust and sociability increase their participation in the capital market. Social effects are observed to restore the individual investors' trust in participating in capital markets.

When examining the influence of financial literacy in the participations of Dutch in stock market Rooij, Lusardi and Alessie (van Rooij et al. 2011) observed that though many Dutch households showed to possessed basic financial knowledge, they lacked in terms of advanced financial knowledge. They are not able to show the difference between stocks and bonds. The analysis of results showed that the level of capital market participation is related to the level of financial literacy. Individual possessing high levels of financial knowledge are more likely to choose to invest in the capital market. Similar results are obtained by Guiso and Jappeli (2005) in Italy, Almenberg and Widmark (2012) in Sweden, Georgarakos and Inderst (2012) in 15 European countries, Brown and Graf (2013) in Switzerland, Almenberg and Dreber (2015) in Sweden. Guiso and Jappeli (2005), on the other hand, observed that lack of awareness regarding investment such as shares, bonds, mutual funds lead to less participation in capital markets. They also observed awareness regarding the capital market's investments increases with factors of education, house resources, social interactions and long-term relationship with the bank. Almenberg and Widmark (2012) examined both the influence of numeracy and financial literacy on the participation of Swedish households' in the capital market or house ownership. They observed that high numeracy ability is associated with both a high level of participation in the capital markets and house ownership. Financial literacy is only associated with house ownership. Brown and Graf (2013) observed that out of 1500 individual respondents half of them could answer the question regarding basic financial knowledge while individuals having a young family, low income and immigrant had trouble answering the questions. The failure regarding their financial knowledge is related to the lack of their participation in the capital market. In the study, Almenberg and Dreber (2015) observed that when controlling for basic financial knowledge, both male and female are more willing to participate in investing in the capital market. Georgarakos and Inderst (2012) on the other hand examined the influence of financial advice to participants in the stock market in Finland, Sweden, UK, Ireland, Denmark, Germany, Netherlands, Belgium, Luxemburg, France, Austria, Italy, Spain, Portugal, and Greece. Individuals who have received financial advice are more likely to participate in the capital market since the advice is related to investment that led to the maximisation of their expected utility.

Kaustia and Torstila (2011) examined the influence of political affiliation on participation in capital markets. Looking at whether individual investors are either a right- or left-wing voter or politician, they examined their likelihood to invest in share markets. They observed that when controlling for income, wealth and educated

left wings, voters and politicians show less interest in participating in the share markets. The decline is between 5–6% by an increase in 1 scale left and 17–20% when a scale is increased by 3. While Gardini and Magi (2007) examined the factors influencing participation in the stock market in Italy, they observed that difference in both financial and real wealth leads to a difference in participation. Those with higher financial and real wealth are more likely to participate in the stock market as compared to those will low wealth. Increase in wealth is also observed to play a significant role in influencing individual participation in the Swedish market. According to Briggs et al. (2015), increase in Swedish household wealth is associated with an increase in the level of participation in the capital market. Increase in wealth allowed the individual household to cover for both entry and periodic costs associated with investing in the capital market. The participation level is also observed by Gardini and Magi (2007) to be influenced by the concavity of the factor of age. The concavity relates to the likelihood of young people invest in shares as compared to older people. Meaning the participation in stock market increase with the factor of age at a decreasing margin. In the findings of Vestman (2012) Swedish individuals owning a house are more likely to choose to invest in the capital market that those renting a house. A same observation is observed in the USA market.

In the findings of Thomas and Spataro (2015) in Austria, Belgium, Denmark, Germany, Italy, France, Switzerland, Sweden and Netherlands observed factors of age, financial literacy, education, number of children, marital status, income and house ownership to influence the participation in the capital market. Investment in the capital market is observed to increase positively with the factor of age. As individuals get older, they choose to participate in investing in capital markets. They mostly do so in the early younger age as compared to old age accounting for the concavity relationship between participation decision and age. Increase in both financial literacy and education are observed to influence the participation in capital market positively. Financial literacy relates to having either basic or advanced financial knowledge, education look on if the individual has a basic knowledge of investment and decision making. Individual investors having both a high level of financial literacy and education are more likely to choose to participate in the capital market. Married individuals are observed to choose to participate in the capital market, but they choose not to do so when they have a large size number of children or dependants. Increase in income allows individual investors to save leading for investment. House ownership increases the wealth of individual investors through rental savings. Both the increase in income and house ownership is observed to increase the level of participation in capital markets. Fagereng et al. (2017) examined the influence of factors of age and education in Norway for the years between 1995 and 2009. They observed that a high level of education leads to the participation of the capital market at the early stage of the life cycle as compared to the later stages. This confirms the concavity influence of the factor of age, which is also associated with the level of education. These findings are confirmed by Thomas and Spataro (2015) with 2010 data.

Grinblatt et al. (2011) were interested in the idea of the influence of the Intelligence Quotient (IQ) on the decision to participate in the capital market of the Finland

residents. Using trading data between 1995 and 2002, they observed individual with high IQ are more likely to participate in the capital market after controlling for factors of age, occupation, income and factor of wealth. The individual with IQ when they participate in capital markets or mutual funds are observed to be facing a significantly low amount of risks and having a very high Sharpe ratio. On the other hand, Andersen and Nielsen (2011) examined the influence of wealth that has been suddenly acquired after death into individuals' participation in capital markets. The study aimed to check if individual investors are discouraged from investing in risky assets due to fixed costs which can be afforded by the newfound of wealth. They observed that the level of participation in the capital market increases with an increase in a windfall type of wealth. However, not all Danish who suddenly inherited the wealth chooses to participate in the capital market. The majority did not choose this option, and many who had inherited any share investment actively sell the whole investment rather than holding it. In the findings of Hurd et al. (2011) in Netherlands factor of return was an influence toward investing in the capital market individual was observed to be more pessimistic regarding the idea of a return from capital markets.

The analysis of the literature has accounted for the factors of risk, expected return, demographic, behavioural, economical, social and organisation factor to positively influence the stock market participation by an individual investor. Demographics factors include factors of age, gender, marital status, family size, level of income and education while behavioural factors include factors of overconfidence, anchoring, gambler's fallacy, availability and representative bias, mental accounting, herding behaviour, regret and loss aversion. Economical factors including the amount of accounting information disclosed by a company and its past and future performance. This also includes the amount of dividend and bonused declared by the company. On the other hand, social and organisational factors included the firm image and the influence of friends, relative and brokers on individual decision. This study aims at examining the influence of these factors on the participation of individual investors in Tanzania. The interest is on examining if these factors have the same positive influence as observed by the cited literature in this study.

3 Research Methodology

The population of interest to this study includes both individual households participating and not participating in the DSE. The individual households participating in the stock market consist of the involved in investing directly into share and bonds.[5] Non-participants include the population of individual households participating in investment other than bonds and share and those not investing at all. The study intends to use two population groups, the participators and non-participators in the

[5]Bond investment include both investment in government and corporate bonds.

DSE. The population of interest is generally the entire population of individual households of Tanzania. As of 2019, the Tanzania population is estimated at around 58.1 million people. As it is difficult to collect data from the whole population, a sample is drawn to present the population. As the sample needs to be a representation of the population, there is a need for a sample to constituents all the characteristics of the population. This requires the sample size to be large. As the population of interest is above 100,000 individuals, using the Lincoln University (2006) formula for determining the required sample size for the level of precision of ±3% and confidence interval of 95% and a P-value of 0.5 the sample size can be calculated from the formula:

$$n > \left(\frac{z \times s}{e}\right)^2$$

Where n is the sample size, $z = 1.95$, $s = 0.5$ and $e = \pm 3\%$ the required representative sample is over one thousand one hundred individuals (1100). In this study, a total of 1600 individuals' household are used in the data collection. A stratified[6] random sampling method is used in selecting the individual households in the sample. The stratified random sampling method allowed each household in the population to have an equal chance of being selected into the sample. This helps in ensuring that the data collected is independent and identically distributed (i.i.d), a characteristic that is necessary for modelling the results.

3.1 Data

Primary data is used for the analysis of factors determining the individual household's decision participation in the DSE. Primary data, rather than secondary data, is used due to the nature of the study aimed to be conducted. In the case where secondary data is used, it will only be limited to the individual households already participating in DSE. This will lead to failure of capturing in the model the factors influencing those individual households' not participating in the DSE. Moreover, primary rather than secondary data is collected due to information nature needed to be collected from individual households. Information such as demographic factors can be obtained from secondary data such as the Household Budgetary Survey (HBS), which is conducted in the country. The problem is on other factors such as behavioural factors, risk and returns attitudes as they are related to the individual attributes. The personality traits are hidden characteristics. In many cases, this kind of information attributable to personality traits are not readily available; thus, the need to shift from secondary to primary data. There is also a need to generate a

[6]Two strata are formed for the population of individuals participating and not participating in the capital market.

measure that will allow individuals to reveal their personalities through their response to a number of questions.

An interview-based questionnaire method of data collection is used on the collection of the data. Questionnaire rather than observation or interview methods are used because of its ability to cover a large group of individuals in a limited amount of time. It gets rid of the Hawthorne effect, which significantly occurs when an observation type of data collection method is in use. Moreover, the nature of the question, which involves the use of a number of Likert items that identify a specific Likert scale encouraged the use of the questionnaire method. On the other hand, to ensure a uniformly understanding of the requirements in the questionnaire, an interview-type rather than the self-administering method is used. An interview-type method of data collection is also used to increase the response rate a problem commonly occurring when a self-filling type of questionnaire is used.

In ensuring that the questionnaire measure the required attributes intend for the study, a Cronbach's Alpha test measure of reliability is used. A Cronbach Alpha test of greater than 0.7 is acceptable. A pilot study was conducted before the general survey to initially test the reliability of the questionnaire as an instrument for data collection. A sample of four hundred (400) individuals was studied under the pilot study which is above the required number of three hundred (300) needed to run a Principal Component Analysis (Comrey 1973). After the Pilot study variables that were observed to be less significant were dropped and only those who were considered to be significant constituent the final questionnaire.

The principal component analysis is used to group the Likert items into their respective Likert scale as argued by Clason and Dormody (1984), Hodge and Gillespie (2003), and Sullivan and Artino (2013). The component extracted from the PCA analysis will form the Likert scale, which is treated as a continuous variable. In this study, only those components extracted from PCA with communalities of greater than 0.5 are accepted. Moreover, Kaiser-Meyer-Olkin (KMO) measure of sample adequacy of greater than 0.5 and Bartlett's test of sphericity of less than 5% are considered.

Logit regression is used in modelling the decision on whether or not to participate in DSE. Logit regression than the Ordinary Least Square (OLS) is being used as the study is dealing with the limited dependent variable. The dependent variable the study needs to model that is the decision on whether to participate in the stock market take only two forms, 1 if an individual decided to participate in the stock market and 0 if otherwise. The maximum likelihood method is used to estimate the parameters in the models. The diagnostic test, including the goodness of fit, hypotheses testing, also performed.

3.2 Findings and Discussion

Table 1 below present the findings for the logistic regression on the participation decision. Demographic factor such as age, gender, marital status education, income

Table 1 Logistic regression results on the participation decision

Participation decision			
	Coefficient		Coefficient
Gender	0.0604	Anchoring[a]	(0.1290)
Age	(0.0308)	Representative bias	0.1119
Age square	0.0006	Gambler's fallacy[b]	0.0305
Marital status	0.4502	Pattern gambler[c]	(0.0038)
Number of children	(0.0411)	Availability bias	(0.0637)
Number of children in school	0.1893**	Loss aversion	(0.0016)
Household size	(0.0252)	Regret aversion	(0.3631) **
Household income earners	(0.0292)	Mental accounting[d]	(0.4852) ***
House ownership	(0.2241)	Market factor	0.3439**
Occupation	(0.2658)	Herding behaviour	(0.1583)
Working experience	0.0028	Past performance	(0.2204)
Education	0.0278	Accounting information	(0.4280) ***
Income	0.8660***	Expected earning	0.1854
Return	0.1434	Dividend/bonus pay-out	0.4060**
Risk	(0.2651) **	Advocacy	0.2708**
Risk aversion	0.2095	Image	(0.2552) *
Overconfidence[e]	0.3100**	Constant	(14.6437) ***
Pseudo R_squared	0.2987		
Model prediction	90.68%		

Source: Logit regression results. Note ***, **, * are 1%, 5% and 10% significance levels respectively

[a]The behaviour of relying heavily on single rather than multiple attributes of the investment

[b]This is the anticipation by investors that price patterns are more predictable than they are really are

[c]The behaviour of depending on the price pattern in making investment decision

[d]The behaviour of human of holding into a particular information irrespective of changes taking place

[e]The tendence of overestimating one's ability, attributing gains to one's skills and failure to bad luck

and family size are included in the analysis. Factors measuring the level of dependency per household, including the number of children per household and those who are in school are also included. The remaining factor measures the attitude of investors toward risk, return, available information and the influence of behavioural factors. It should be noted that during the model specification stage, the interaction factors were added to observe their increase in the explanation power of the model. This was rejected by both the Likelihood ratio and Wald tests; thus, they were dropped from the model. The results below are obtained from the model, which significantly explained the data in the analysis.

The likelihood of an individual investor to participate in DSE is observed to increase with the demographic factor of a number of children in school and income. An increase in the number of children per household going to school increase the need for an extra source of income to cover for the education expenses. Individual are observed to more likely to choose to invest in the DSE to obtain the extra income to support the household. Increase in the household income increase the level of

participation in DSE. Individual earning high income are more likely to save and opting to invest. Increase in income allows the individual household to explore different types of investments available, leading to their participation in DSE.

Risk aversion behaviour decreases the likelihood of individuals to choose to participate in the DSE. This is with the implication that many individual investors choosing to participate in the capital market are more risk-takers than an average investor. Individual choosing to participate in DSE are more overconfident with their level of skills. They are more likely to attribute their success with their skills and failure as bad luck. On the other hand, these skills allow them to make better investment decisions. This includes selling non-performing assets irrespective of their past performance while continue holding performing assets. This is observed by a significant negative relationship between the likelihood of participating in the DSE and factors of regret aversion and mental account. Although individual investors participating in DSE show significant decision-making skills, they are observed to be significantly affected by the noises from the market. This is observed by a significant positive influence of the market factor on the decision to participate in DSE.

Individual investors choosing to participate in the DSE are less likely to be dependent on the accounting information of companies and institutions trading investments in the DSE. The results showed that individuals who are significantly influenced by the amount of information disclosed by the financial statements of the companies are less likely to participate in the DSE. On the other hand, the amount of dividend or bonus declared in the market significantly increase the level of participation by individual investors. Individual investors are observed to be attracted to invest in companies paying out a significant amount of dividend per share owned by the investors. Individual investors decision to participate in DSE is observed to be significantly influenced by peers, relatives, friends and brokers. Individual investors depend on the advice given to them by their office peers, relatives, friends and brokers on whether or not to participate in DSE. This is with the implication that their decision on whether to participate in DSE is significantly influenced by how they highly weigh advices given to them by third parties rather than a decision made solely by the individual investor's judgment.

4 Conclusion

Since its discovery by Haliassos and Bertaut (1995) participation puzzle has been of interest to many researchers, especially the during the current situation where a low number of individual investors' participation in the capital market are being observed. The interest of the researcher is on findings the factors behind the low individual investors' participation in capital markets and thus solving the puzzle. Over the years, a number of factors have been identified to influence the participation decision and tended to vary in different countries. This study aimed at examining the factors behind the low individual household participation in Tanzania's capital market.

Data collected from a total of 1600 individual is used in logistic regression. It is observed that the willingness of individual investors to participate in the capital market increases with the increase in the number of children in school and income. Individuals with low-risk appetite are less likely to participate in capital markets as compared to an individual with high risk-taking ability. The high-risk taking behaviours of the individual investors in Dar es Salaam stock market conform with typical features of a frontier equity market Overconfidence individuals are more likely to participate in the capital markets. Similarly, individuals participating in the capital market are more likely to sell non-performing assets and keep on holding a performing asset and are not caught up with past performances. They significantly influence the noised in the market, although they do not follow the actions of others; rather, they make their judgments. They are less dependant to the accounting the information of companies trading their financial product in the markets but are interested in the dividend or bonuses announcement news. They also consider the advice from friends, relative or brokers.

In order to increase individual investors' participation in the stock market income level should be increased. This is through the central government, raising the minimum income level in the country and growing entrepreneurship in the country. Education on optimal decision making should be made available to individual investors interested to participate in the capital market. This includes different training organised by the Dar es Salaam Stock Exchange. Education should also be on the different ways of processing information from friends, relatives and brokers to ensure utilisation of information which is on the line of maximising their utility. Companies trading their financial products in the capital markets should disclose all relevant information, including past and future performances. The companies should ensure they maintain a dividend growth strategy to attract more individual investors participation in share markets.

In this study, very few factors from the literature are accounting for the lack of individual investors' participation in Tanzania capital market. This study suggests a further examination of the factors in the Tanzania context influencing the participation decision. This includes examining the influence of investment infrastructures; government policies, economic condition, law and regulations pertaining to investment and their participations on investment activities. The study also suggests the possibility of examining the study over a long period of time in examining the altering factors that influence each investment decision during a specific period.

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Model Risk of VaR and ES Using Monte Carlo: Study on Financial Institutions from Paris and Frankfurt Stock Exchanges

Aleksandra Helena Pasieczna

1 Introduction

Mathematical modeling has proven to be an efficient tool for contemporary finance practitioners. It becomes vitally important to judge these mathematical constructs before they are used in practice. Two intuitive ways exist to judge their validity—accuracy and precision. The first refers to the performance of the model, which can be understood as the distance of the obtained model result (prediction) from the *ideal* result. By ideal we mean a benchmark, or the actual result obtained from observation, depending on the type of model. The second corresponds to the reproducibility or the sensitivity of the model across multiple measurements or observations. A *good* model is a model that is both, accurate (not far from a benchmark), and precise (gives similar results repetitively).

Precision provides an estimate of the consistency of a model to give a reliable output on multiple simulations with slightly noisy input parameters. Unlike accuracy, there is no reference model or benchmark against which this quality can be judged, and only the repeatability (although under slightly different inputs) can be checked. In essence, the precision reflects the risk of the model. If the model is the risk measure, the precision will be *the risk of the risk measure*, henceforth called *model risk*.

In an earlier study (Pasieczna 2019), we presented the accuracy analysis of Value at Risk (VaR) and Expected Shortfall (ES) models with an application on the Polish WIG20 and mWIG40 indices. Here, we focus on the precision aspects of the models on 116 financial institutions (out of 126 after data cleaning) from the Paris and Frankfurt stock exchanges, while restricting the study to Monte Carlo-based

A. H. Pasieczna (✉)
Koźmiński University, Warsaw, Poland
e-mail: 1264-phdf@kozminski.edu.pl

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approaches only. VaR, recommended by the Basel II agreement (Basel 2004), is frequently used to estimate potential losses with a certain confidence, while ES was recommended by the Basel III agreement (Basel 2010), as it captures tail risk more efficiently. Both, VaR and ES, are frequently used by practitioners to analyze market risk.

This paper focuses on measuring the model risk for VaR and ES for different configurations (confidence intervals). Four models for each configuration are considered, based on the Monte Carlo technique (Pasieczna 2019), and attempt to analyze the effect of including inter-institutions covariance structure and the effect of filtering past data using rolling and exponential-weighted windows. For studying their model risks, we focused on the changes to the input parameters, which were made by choosing different historical periods. The work was applied on over hundred financial institutions traded on the Paris and Frankfurt stock exchanges.

2 Data Collection and Processing

The dataset consisted of daily close prices between 2000 and 2020 year, for 126 financial institutions traded on the Paris and Frankfurt stock exchanges. The list of companies was obtained by using the stock screener from Investing.com. The price data was then obtained using the Python package *investpy* (Investpy 2020).

In the simulations relative returns were used to compute the market risk measures. By *relative returns* we mean percentage price change with respect to the previous day's price. These returns are unitless and do not depend on the currency in which the stock might be potentially traded and form the basis for the uncertainty in our Monte Carlo simulations. However, using relative returns resulted in certain banks (whose prices did not change for several days) having a small standard deviation, and consequently—a small market risk, leading to high model risk, when compared across different historical time periods. To understand this, consider a bank whose returns are zero for large part of 2019. If the historical period considers data for 1 year, the estimated standard deviation will be small, and consequently the VaR and ES. If the historical time considers data for 2 years (2018 and 2019) then the estimated standard deviation will be larger than in the first case. Comparing these two standard deviations would give a low precision score due to this effect, thus the model risk is high. Additionally, these infrequent price movements might lead to incorrect covariance estimations between banks.

It should be pointed out that this indeed is a source of model risk and requires special treatment, which is out of the scope of this work. To deal with this, instead of rejecting the bank completely, the prices were forward-filled to a limit of five business days and not more, leading to missing values in the price time series. If within the simulation period for a day, a bank had missing data after this procedure, the bank was not considered for that particular day. In our dataset after this process, 116 institutions remained out of 126.

3 Theory and Computational Methods

3.1 Value at Risk

VaR is defined as the maximum possible loss that can be incurred over a particular time horizon within a particular confidence level. In this work we treat any given combination of a time horizon and confidence level as a "VaR configuration". Since this definition of VaR does not provide a computational algorithm, but only a property that it must have, multiple ways exist to compute it (Holton 2014). For our purposes, the time horizon is fixed to 1 day and the confidence levels are chosen to be 95% and 99%. Furthermore, we use the Monte Carlo approaches to estimate VaR on a basket of 116 financial institutions from the Paris and Frankfurt stock exchanges.

3.2 Expected Shortfall

Expected Shortfall (ES) is a market risk measure linked to VaR, which is defined as the expected average tail loss within a certain confidence level, but unlike VaR, it accounts for worse scenarios for an institution. It is considered to be more useful than VaR in terms of capturing market risk in the tail, and hence recommended in the Basel III agreement. It is calculated for a given confidence level (also called *quantile level*) and is defined as the expected portfolio loss when the loss is occurring at or below this level. As an example, if the average loss on the worst 5% of possible outcomes is 100 EUR, the expected shortfall is 100 EUR at 5% tail (95% confidence level).

3.3 Monte Carlo Methods

We chose the MC method (Glasserman 2003) to simulate the relative returns for a single trading day across all institutions in our dataset. The main advantage of the MC method is that one can simulate the different sources of uncertainty that affect the stocks by drawing random numbers from predetermined probability distributions. As such, the model limitations are mainly due to the choice of the distributions and the computational costs associated with the generation of statistics. MC methods have been applied in various areas of finance, such as portfolio optimization and risk analysis.

Our approach uses MC to simulate the uncertain relative price changes and the uncertainty is described through the mean, standard deviation and inter-institute covariance structure, determined by real past historical data. The VaR is then simply the quantile of these simulated price changes across multiple MC runs corresponding

to the configuration (e.g. 95%). The ES is the average value of the returns that crossed the VaR threshold. Four MC models were studied, based on the estimation methods of the mean and standard deviation, and the choice of inclusion of the covariance between banks. Two variants to compute the mean and standard deviation were used:

- Rolling approach: In this approach, equal weight is assigned to all points in a given window, with the mean for a bank at time t as,

$$\mu_t = \frac{1}{N}\sum\nolimits_{t'=0}^{N} r_{t-t'}$$

where N is the historical time window.
- Exponentially weighted approach (EWM): In this approach, more weight is assigned to more recent events with an exponentially decaying weight curve. The mean at time t is given as,

$$\mu_t = \sum\nolimits_{t'=0}^{\infty} \alpha\,(1-\alpha)^{t'} r_{t-t'}$$

where α is expressed in terms of a center of mass (com), with the com indicating an equivalent historical window $\alpha = \frac{1}{com+1}$.

Similar expressions exist for estimating standard deviations for each bank and covariance between two banks. Two additional variants were then constructed, one which includes the covariance structure of the banks, and the second which assumes their independence. The algorithm is as follows:

1. For all the banks and for each day, estimate the distribution quantities (mean, standard deviation, and covariance structure), based on the past historical data on relative price changes. Two variants were studied: using rolling quantities and using exponentially weighted quantities. Three historical periods were used: 125, 250, 500 trading days (approximately 0.5, 1 and 2 years).
2. Draw random numbers from a Gaussian distribution with the precalculated quantities (mean, standard deviation, covariance). These random numbers represent the next day's relative returns. Two variants were built: classical approach that ignores the covariance structure (each bank is independent), and a multivariate approach that samples random numbers using the pre-calculated covariance structure. For each day and each institution 20,000 numbers (MC iterations) were drawn based on the predetermined distributions.
3. Rank the simulated absolute returns in a descending manner and choose the quantile corresponding to the confidence level as the VaR. The ES is the average of the simulated returns below the VaR. Two confidence levels were tested—95% and 99%.

Once the VaR and ES were computed for the banks at the given confidence levels with the three historical periods with different MC approaches, model risk was estimated using precision-based metrics, described in the next subsection.

Normal distribution has been assumed for the returns (multivariate, as well as classical) in our work. This assumption is usually good enough to work with for the following reasons:

- Simplicity—Normal distribution is well studied and can be applied in a large range of applications. For this reason, it is also the starting choice for stock returns.
- Comparability—It can act as a benchmark for models with more complex distributions. While using models with other distributions, it is difficult to know whether certain failures are due to the choice of distribution, parametrization, or simply for computational reasons. This, in fact, increases model risk.
- Interpretability—Deviation from the normal distribution for stock returns happens mainly in the tails and less so in the bulk. Using a normal distribution simplifies computational code and allows us easy interpretation of the bulk of the days, where tail events do not happen. Since our work focuses on trying to understand the precision of the risk estimates, the actual risk estimate is less important, and we can focus on the bulk of the days.

Nonetheless, there are some shortcomings in this choice:

- Tail events—Fat tails are not considered within a normal distribution approximation, and so might cause an underestimation of the market risk. However, since we look at the *spread* of multiple measurements and not the actual value of the market risk, we expect a small impact from this.
- Skew, kurtosis and higher moments—Stock returns might have a tendency to deviate from the normal distribution, when higher moments are considered. These can have a significant impact on risk estimation and hence the model risk. In our case we look at VaR and ES solely based on the mean and standard deviation (first two moments), and so our model risk estimates are accurate up to these moments.
- Multi-modal distributions—Non-unimodal distributions have been shown to be important in VaR and ES estimations (Guegan et al. 2017). However, these approaches involve many more parameters and are less frequently used than those with unimodal distributions.

3.4 Model Risk Measures

Model risk refers to the risk that practitioners are exposed to when using a particular model in their work. In a broad sense, it signifies the uncertainty due to human error in model application (e.g. parametrization, inapplicability), or intrinsic model shortcomings (such as instability, sensitivity). According to Derman (1996), model risk is a consequence of general model construction and uncertainty in the field of finance. This is a view shared by Crouhy et al. (1998). Thus, everything related to a model can be part of the corresponding model risk, including data contaminations, wrong

implementations, badly approximated solutions, software or hardware bugs, and even the practitioners themselves.

Clearly it is then not possible to isolate individual sources of risk for risk control. Furthermore, the optimal solution or benchmark might simply not exist. Thus, it is not possible to truly mitigate all these risks, especially in the complex domain of finance. Other authors look at model risk with more focused points of views. For example, some research works define model risk as inaccuracy arising from estimation errors and uses of incorrect models (Boucher et al. 2014; Glasserman and Xu 2014; Hendricks 1996). Yet other authors might consider model risk induced by the probability space used for statistical modeling, choice of tests for the data and estimation of the model parameters (Sibbertsen et al. 2008). In our work, we focus on the model risk that arises due to the choice of input parametrization of the model. Additionally, model risk is represented by the concept of precision, specifically we look at the similarity of the model estimates across various input parameters.

Two measures were developed based on precision, the spread across ES and VaR estimates, and the ratio of the highest to lowest ES and VaR estimates. Their mathematical expressions for VaR are shown below (similar expressions for ES):

$$\text{spread} = \frac{\max\left(\text{VaR}_{125}, \text{VaR}_{250}, \text{VaR}_{500}\right) - \min\left(\text{VaR}_{125}, \text{VaR}_{250}, \text{VaR}_{500}\right)}{\text{mean}(\text{VaR}_{125}, \text{VaR}_{250}, \text{VaR}_{500})}$$

$$\text{ratio} = \frac{\max\left(\text{VaR}_{125}, \text{VaR}_{250}, \text{VaR}_{500}\right)}{\min\left(\text{VaR}_{125}, \text{VaR}_{250}, \text{VaR}_{500}\right)}$$

Note that the estimates used in these measures always correspond to the same configuration (prediction time period equal to 1 day and confidence levels 95%, 99%), but different historical periods. In our case, the spread is the difference between the maximum and minimum VaR or ES estimates obtained from the three historical periods (125, 250, 500 trading days) in units of the average estimate, whereas the ratio is the ratio of the maximum to minimum estimates. Ratio as a model risk measure has already been used to analyze market risk and systemic risk measures in literature (Danielsson et al. 2016).

4 Results and Discussion

We present here our simulation results for the 116 financial institutions, where the 1-day VaR and ES were computed at 95% and 99% confidence intervals. Estimates from three historical periods (125, 250, 500 days) for given confidence intervals were used to judge both precision metrics. As a recap, four models were built, classical rolling (rolling window filter with independence of institutions assumed), multivariate rolling (rolling filter with covariance of institutions included), classical

Table 1 Precision metrics—spread and ratio for the VaR and ES under different Monte Carlo approaches with the different confidence levels

		Precision (avg ratio)		Precision (avg spread/mean)	
		Rolling	EWM	Rolling	EWM
VAR 95	Classical	1.439	1.364	0.306	0.279
	Multivariate	1.438	1.466	0.306	0.337
VAR 99	Classical	1.432	1.348	0.302	0.270
	Multivariate	1.431	1.450	0.301	0.328
ES 95	Classical	1.434	1.352	0.303	0.272
	Multivariate	1.433	1.454	0.302	0.331
ES 99	Classical	1.430	1.344	0.300	0.267
	Multivariate	1.430	1.445	0.300	0.326

EWM (exponential weighted moving window with independence of institutions assumed), and multivariate EWM (EWM filter with covariance included).

Our results are summarized in Table 1. To analyze the spread, we divided the difference between the maximum and minimum estimates by the mean to make it comparable across time (unitless metric). This unit allows us to look at the model risk (maximum variation in the estimates) in terms of the average estimate providing for a more intuitive feel of the quantity. For example, if the spread is 0.3, then the variation can be up to 30% of the average estimate. The ratio on the other hand provides a different view on the variation in the estimates. For example, if the ratio is 1.4, then the variation in the estimates lies between values that are 1.4 times larger and 1.4 times smaller than any single estimate measurement. We observe that though the four models have similar VaR and ES model risks, the classical EWM approach performed slightly better than the rest, whereas the multivariate EWM performed slightly worse than the remaining models.

To compare temporal evolution of the precision metrics, we plot the average VaR and ES estimates across all financial institutions along with the spread and ratio metrics in Figs. 1, 2, 3 and 4. These plots allow us to study how the various quantities evolve during periods of financial crises (e.g. 2008, 2020) and post crises which are characterized by changes in volatility of relative returns. Intuitively we expect model risk to increase when volatility regimes change. To understand this further, consider the case where the volatility increases (typically associated with a crisis period or negative returns). Here, a VaR or ES estimate based on 125 days will react faster than an estimate based on 500 days, causing a jump in the model risk metrics. Interestingly, if the volatility drops, the same effect occurs causing yet another jump in the model risk.

Figures 1 and 2 present the VaR at 99% and 95% plots with the corresponding risk measures, respectively. We observe that the VaR tends to increase in magnitude during periods of turmoil. The model is considered precise when the spread and ratio are as close as possible to 0 and 1 respectively, which would imply that the model is not highly dependent on the input parameters (here, historical time period). However, in our study we observe that the ratio is never 1, and the spread is always

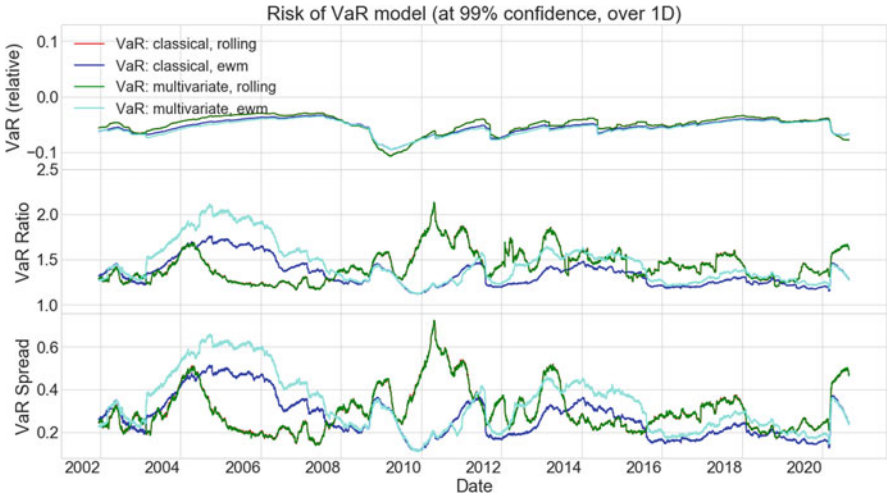

Fig. 1 Results for 1-Day VaR computed at 99% confidence level

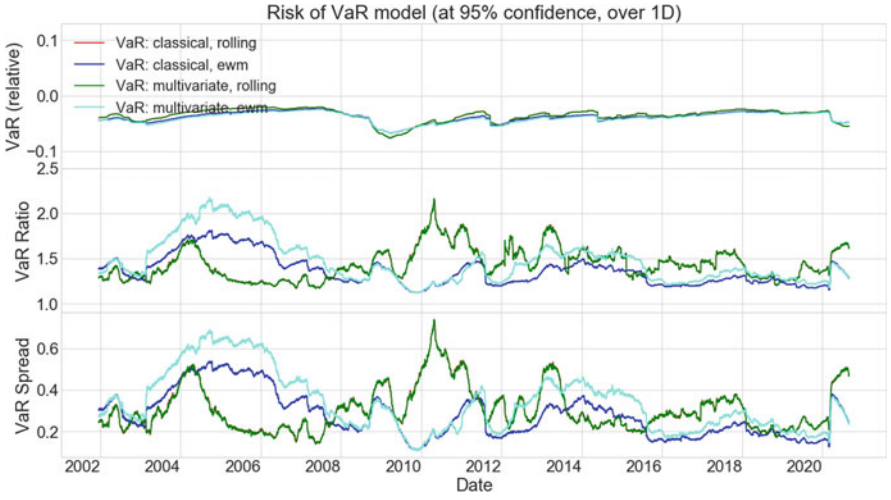

Fig. 2 Results for 1-Day VaR computed at 95% confidence level

greater than 0. This means that the model risk is never completely nullified. Interestingly we observe that though both model risk metrics provide different quantitative viewpoints on variability of the estimates, they are visually very similar across time.

Furthermore, we see an increase in these model risk measures during crisis and post crisis periods. However, we see a maximal peak in the ratio and spread for the rolling approaches that seem to be a lagged effect of the 2008 crisis. We interpret this as the consequence of one estimate having a memory of 500 days, compared to

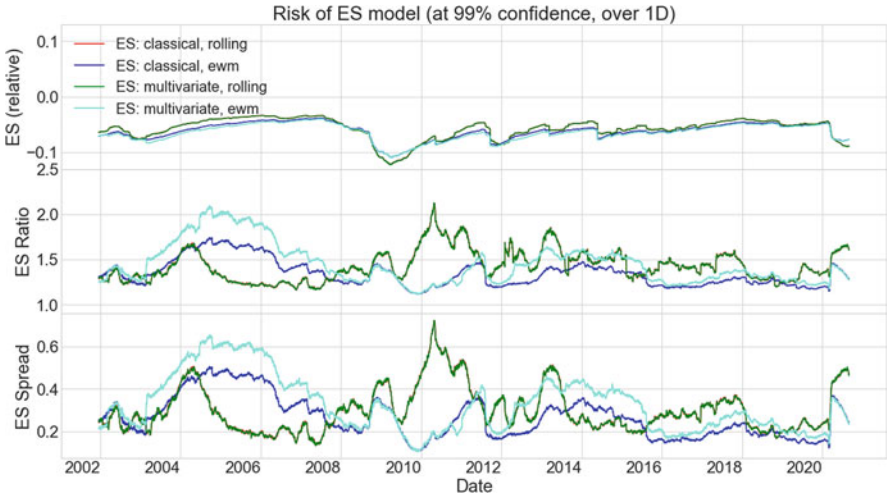

Fig. 3 Results for 1-Day ES computed at 99% confidence level

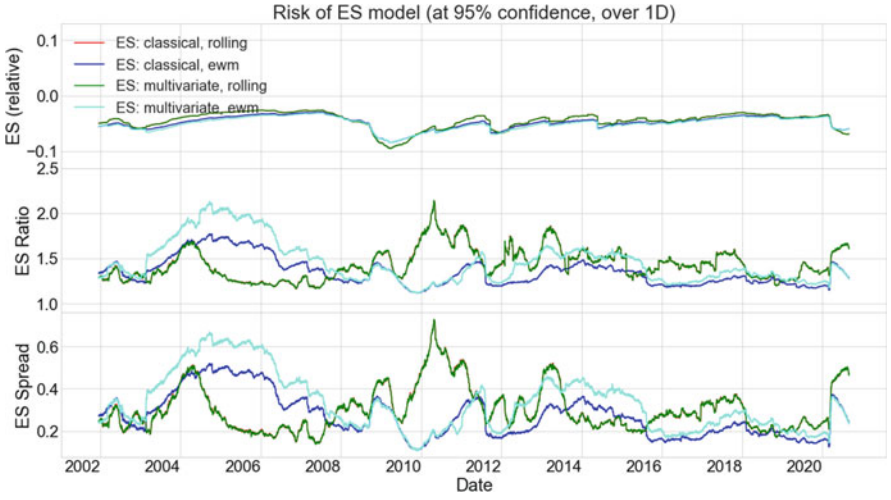

Fig. 4 Results for 1-Day ES computed at 95% confidence level

another estimate with a memory of 125 days. EWM approaches do not show that strong an effect, mainly because they are much more smooth filter functions on past data, which leads to a slightly lower model risk during these periods.

Figures 3 and 4 shows the results for the ES at 99% and 95% confidence levels, respectively. We see similar behavior as for the VaR, which we interpret to be a consequence of the fact that the ES is derived from the VaR. Indeed, the ES can be represented as an integral of the VaR at all quantiles above the threshold. Comparing the Figs. 1–4 with the Table 1 we conclude that though the model risk was not very

high overall, the main inconsistency is observed in times when the measures like VaR and ES are most needed.

5 Conclusions and Perspectives

We presented our analysis for the VaR and ES calculations of financial institutions traded on the Paris and Frankfurt stock exchanges. In particular, the precision-based model risk measures of ratio and spread were looked at based on different input parameters. Four Monte Carlo approaches were studied, based on how distribution characteristics were estimated. Our results indicate that the classical EWM approach performed best in terms of both precision metrics, whereas the multivariate EWM performed worst. The rolling-based approaches were similar for both, the classical and multivariate cases and had performance in between those of the EWM approaches. The temporal evolution of the precision metrics showed that model risk was high during and just after market crises, i.e. during periods when market risk measures matter most.

For future study we recommend considering different distributions, such as Weibull and Student distributions which might allow us to capture tail events. Additionally, it might be insightful to compare these models in a multidimensional setting, across different distributions and their parametrizations with the intention of understanding the importance of each component of model risk. Multivariate (copula) and multimodal distributions might also be studied with our approach to analyze the model risk.

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Tick Size Reduction and Liquidity Dimensions: Evidence from an Emerging Market

Quoc-Khang Pham

1 Introduction

Tick size on the stock market is the minimum price movement of a trading stock. Price movements vary significantly across stock exchanges. Tick size represents the minimum amount a stock price can move either up or down on an exchange. Recently, stock exchanges around the world have used a new tick size system. The purpose of the variation is to decrease transaction costs and improve market liquidity. For instance, the New York Stock Exchange and NASDAQ reduced the price increment from $US1/8 to $US1/16 in 1997; then, they reduced tick size to $US0.01 in 2001. The Stock Exchange of Thailand (SET) reduced tick size on 5 November 2001. The Warsaw Stock Exchange (GPW) employed a new tick size system on 4 March 2019. The tick size of shares on the GPW is determined by stock prices and the liquidity measure (turnover).

Several articles tell of empirical investigation that determined the impact of tick size changes on market structures. A smaller tick size decreases the transaction costs and spread. Harris (1991) authored the first study which examined the effects of a tick size reduction. Harris (1991) and Chordia et al. (2001) indicate that a decrease in a pricing grid leads to a reduction in the bid-ask spread. On the other hand, the U.S Securities and Exchange Commission (SEC) implemented a changing tick size pilot program. The pilot program would increase the minimum tick size from 1 cent to 5 cents for small market capitalization stocks. The tick size change took place over 2 years, from 3 October 2016 to 28 September 2018. The tick size pilot program inspired several studies (e.g., Rindi and Werner 2017; Griffith and Roseman 2019; Chung et al. 2020) to examine the impact of tick size on the financial market's

Q.-K. Pham (✉)
Wroclaw University of Economics and Business, Wroclaw, Poland
e-mail: pham.khang@ue.wroc.pl

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aspects. Rindi and Werner (2017) argue that liquidity demanders would have higher costs and earn higher profits. Griffith and Roseman (2019) analyze the three dimensions of liquidity following a tick size increase on the NASDAQ. The tick size increase results in a higher spread, less resiliency, and lower depth. Albuquerque et al. (2020) study the relationship between a widening in tick size and stock prices in the U.S after the pilot program. The results show a negative impact of tick size increase on stock prices. Albuquerque et al. (2020) find a growth in two proxies of transaction costs (quoted spreads and effective spreads) and price-impact proxy, but a decline in trading volume. Chung et al. (2020) explore the changes in liquidity in small and large orders followed by a widening of tick size on the U.S stock market. Chung et al. (2020) find that liquidity decreases for small orders but increases for large orders.

The stock exchanges adjust tick size to increase competitiveness among investors in an order-driven market. The previous empirical studies that examined the influence of tick size reduction on the order-driven markets show conflicting results. Aitken and Comerton-Forde (2005) found that tick size reduction improved liquidity on the Australian Securities Exchange. The average spread for the lowest price range group fell by 26%. However, it reduced liquidity in a group with a small tick size and a low trading volume group. Hsieh et al. (2008) indicate that a reduction in tick size increases market efficiency and decreases trading costs on the Taiwanese Stock Market. However, Pan et al. (2012) find a different result; aggregate liquidity for a liquid stock group declined in an order-driven market, the Hong Kong Stock Exchange. Anderson and Peng (2014) examine the impact of a tick size change experienced in 2011 by 17 eligible stocks in New Zealand. Anderson and Peng (2014) found that both spreads and depth decrease significantly during the post-period. This study has a limitation in that it could not determine significant statistical changes in liquidity. Bacidore (1997) analyzes the tick size reduction on the Toronto Stock Exchange, stating that spreads and depth declined, but there was no change in trading volumes. Ahn et al. (2007) find a significant decrease in spreads, resulting in a tick size reduction on the Tokyo Stock Exchange. However, Ahn et al. (2007) do not see a significant change in trading volume. Kuo et al. (2010) explore the impact of minimum price changes on the market liquidity on the Taiwan Stock Exchange (TWSE), which occurred on 1 March 2005. The results indicate that a decrease in tick size on the TWSE led to a decline in three transaction cost proxies: quoted spread, liquidity premium, and execution costs. However, two market depth proxies presented a significant decrease, including the best-quoted depth and the cumulative depth, because the market participants spent less time or executed a larger quantity of shares. In light of these findings, the study hypothesizes that the reduction in tick size leads to decreased quoted spread and increased trading volume.

Liquidity is a multidimensional concept; it includes tightness, depth and resilience dimensions (Kyle 1985). The tightness dimensions refer to the transaction costs, which are measured by various proxies based on bid/ask spread. The depth dimensions determine a possible trade size with a minimum price impact, captured by the volume-based or turnover-based measures. The resilience dimensions refer to

a characteristic of markets in which new orders flow quickly to correct order imbalances and return the prices to fundamental values (Pham-Quoc 2020).

The Ho Chi Minh Stock Exchange (HOSE) in Vietnam implemented a tick size reduction on 12 September 2016. The purpose of policymakers was to enhance market liquidity following the decline of tick size on the HOSE. This study aims to explore the effects of tick size reduction on the various liquidity aspects on the HOSE. To the best of my knowledge, the article is the first one that to investigate the relationship between tick sizes and liquidity aspects in the context of the emerging Vietnamese market.

Changes in the minimum tick size lead to changes in market participants' trading activities. Market participants are more flexible to offer a bid or ask prices. Regarding the empirical evidence in the literature, the study expects that the market liquidity is higher in the tightness, depth and resilience dimensions after the tick size reduction.

The remainder of the paper is organized as follows. In Sect. 2, the paper presents a brief description of the stock exchange features in Vietnam. Section 3 indicates the selection of data in the sample and introduces the methodology used in this study. Section 4 presents and discusses the empirical findings in liquidity dimensions after tick size reduction. The paper includes some concluding remarks in Sect. 5.

2 Institutional Features of the Ho Chi Minh Stock Exchange

The Vietnamese stock market includes two stock exchanges: The Ho Chi Minh Stock Exchange (HOSE) and The Hanoi Stock Exchange (HNX). According to the State Securities Commission of Vietnam, the Vietnamese stock market's participants contained about 28.5 thousand accounts of foreign investors and approximately 1.7 million domestic investors account as of the end of 2019. The HOSE has officially operated since 2000, while the HNX was established later in 2005. The HOSE is the larger of the two stock exchanges in Vietnam, with a market capitalization of about $US200 billion, over ten times more than on the HNX. The HOSE operates the trading as an order-driven market; without market makers as is the case with the stock exchanges in London or New York, investors execute their transactions through an automated order-matching system. The HOSE implements multiple tick size systems, with different tick sizes for different price ranges. Trading time on the HOSE takes place 5 days a week from Monday to Friday. It includes two kinds of the trading auction, i.e. continuous auction and periodic auction. The investors on the HOSE can make transactions in four different trading sessions during a trading day. The stock exchange determines the open and close-price each day using a single-price auction in the first and last session with types of order: At the opening order matching price (ATO), At the closing order matching price (ATC), limit order (L.O.). For the remainder of the day's sessions, the HOSE is

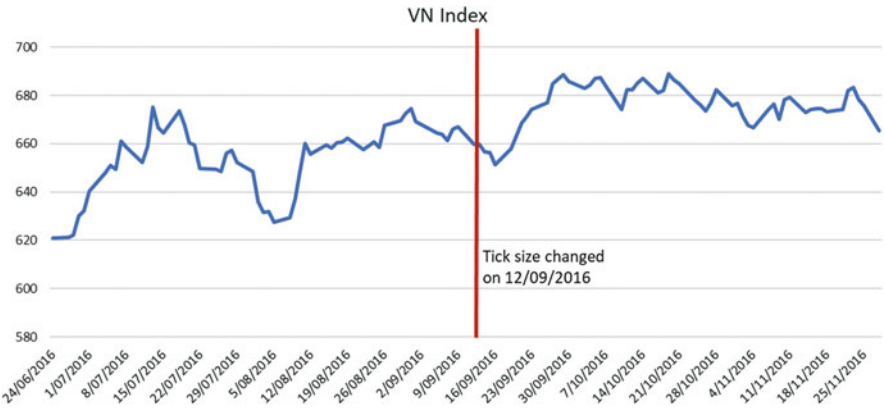

Fig. 1 Changes in the VNIndex. Notes: The figure shows the changes of the market indicator, VNIndex from 24/06/2016 to 28/11/2016. The vertical line, centered on 12 September, 2016, indicates the date that the HOSE implemented the tick-size reduction. Source: Ho Chi Minh Stock Exchange

operated in a continuous auction with two types of order: limit order (L.O.), market order (M.P.). The matching principles are implemented according to the priority of price, then time.

Figure 1 presents the market performance changes, named VNIndex, from 24 June 2016 to 28 November 2016. The VNIndex on the HOSE showed an upward trend during this period. The market index was 620.7 at the beginning of the period and then peaked at 688.89 at the end of September 2016. The VNIndex decreased slightly in the following months.

3 Data and Methodology

The HOSE launched a new system of tick size on 12 September 2016. The empirical sample consists of listed companies on the HOSE, covering the 3-month periods before and after the event date. Following Aitken and Comerton-Forde (2005), Hsieh et al. (2008), the data exclude the five trading days before and after the event date. This method is to avoid any unusual trading behavior surrounding the event date. The study uses a set of daily trading data, which is obtained from Thomson Reuter Datastream.

The literature investigates the influence of the tick size reduction by separating the sample into two periods: the pre-tick-size-reduction and the post-tick-size-reduction period. For instance, Chen and Hsieh (2013) examine the changes in liquidity before and after implementing a new tick-size rule on 1 March 2005. They compare the market liquidity between 10-day trading in the pre-event periods and 10-day trading in the post-event periods on the Taiwan Stock Exchange. Kuo

Table 1 Tick size rule before and after the tick size reduction on the HOSE

Group	Number of companies	Price range (VND)	Tick size in pre-event (VND)	Tick size in post-event (VND)	Difference	(%) Difference
1	108	<10,000	100	10	−90	−90
2	173	10,000–49,950	100	50	−50	−50
3	28	50,000–99,500	500	100	−400	−80
4	3	>100,000	1000	100	−900	−90

Notes: The event date of tick size reduction was on 12 September 2016. The pre-event period was from 24 June 2016 to 1 September 2016, and the post-event period was from 20 September 2016 to 28 November 2016
Source: Ho Chi Minh Stock Exchange

et al. (2010) use a sample that includes 52 trading days and 59 trading days before and after the change of tick size rule on the Taiwan Stock Exchange. Aitken and Comerton-Forde (2005) use a sample covered 80-day trading, including before and after the tick size reduction periods, to study market liquidity changes on the Jakarta Stock Exchange. Ahn et al. (2007) conduct a study to compare market liquidity between 68 trading days in the pre-event period and 76 trading days in the post-event period. Porter and Weaver (1997) have a comparison 1 month before and 1 month after the tick size reduction on the Toronto Stock Exchange, which was implemented on 1 April 1996. So, the 50-day trading period in the pre- and post-event period is sufficient to observe the traders' trading behavior changes comprehensively. After tick size reduction, traders would change their trading behavior immediately to become acquainted with new changes. The paper will analyze the changes in liquidity before and after implementing a reduction in tick size. The time frame includes pre- and post-event periods. The sample covers 50 trading days in the pre-event period (from 24 June 2016 to 1 September 2016) and 50 trading days in the post-event period (from 20 September 2016 to 28 November 2016). The sample stocks need to meet the following criteria: (1) stocks are still listing on the HOSE until the end of 2016, (2) the spread was not negative or missing. The number of companies listed on the HOSE at the end of 2016 was 320. However, the sample includes 312 companies listed on the HOSE that are eligible.

The HOSE has a multiple tick size system, in which tick sizes vary in different price regimes. After implementing a new tick size system on 12 September 2016, the price grids on the HOSE are separated into four groups (Table 1). Group 1 contains stocks whose prices are below VND 10,000.[1] Tick size for this group is reduced by 90%, from VND 100 to VND 10. The second group includes stocks whose price range from VND 10,000 to VND 49,950. Tick size for this group drops by 50% to VND 50. The price range in the third group is from VND 50,000 to VND 99,500. The HOSE adjusted tick size from VND 500 to VND 100. The HOSE implemented

[1]Exchange rate of USD/VND in 2016 was 1 USD = 22,300 VND.

a tick size reduction for the last group, which decreased by 90% to VND100. The sample, including 312 companies, was split into four subsamples as four price regimes to analyze the tick size reduction effect. The number of companies in the groups is 108, 173, 28, and 3, respectively.

The effects of the tick size reduction in this study are examined in different dimensions, i.e., tightness, depth and resiliency. The study analyzes the stock liquidity dimensions in a numerous liquidity proxy for an emerging market. Thus, the study constructs a set of low-frequency measures for empirical research. Low-frequency proxies are advantages to measure liquidity efficiently on every stock market. The daily data is available for not only developed but also emerging markets. The recent studies provide enormous literature on low-frequency (daily and monthly) liquidity proxies (Le and Gregoriou 2020). This section presents the low-frequency proxies regarding the liquidity dimensions, such as depth, tightness, and resilience.

Tightness dimensions, or known as transaction costs, are often measured by the spread measures. The most common proxies in the tick size studies are quoted spread and effective spread. Quoted spread, $QSPR_{i,\,d}$, is the difference between the best ask price and the best bid price as

$$QSPR_{i,d} = P^{A}_{i,d} - P^{B}_{i,d}, \tag{1}$$

where $P^{A}_{i,d}, P^{B}_{i,d}$ are the best ask price and the best bid price for stock i on day d.

The second proxy of the tightness dimensions is effective spread, $EFSP_{i,\,d}$, calculated as two times the absolute difference between the transaction prices and the midpoint of the quoted spread, as

$$EFSP_{i,d} = 2 * \left| PRICE_{i,d} - \frac{P^{A}_{i,d} + P^{B}_{i,d}}{2} \right|, \tag{2}$$

where $PRICE_{i,\,d}$is the closing price for i on day d.

The depth dimensions are captured by four common measures: traded volume, traded value, turnover ratio and Amihud (2002) measure. Traded volume, $VOL_{i,\,d}$, is the number of traded shares for stock i on day d. Traded value, $VAL_{i,\,d}$, is the amount of traded value for stock i on day d. And the turnover ratio is a ratio of the traded volume over the number of shares outstanding as

$$TURN_{i,d} = \frac{VOL_{i,d}}{NOST_{i,m}}, \tag{3}$$

where $TURN_{i,\,d}$ is the turnover ratio for stock i on day d; $NOST_{i,m}$ is the number of shares outstanding for stock i in month m.

The last measure in the depth dimensions is Amihud (2002) measure, which is the best proxy in the price-based measures (Fong et al. 2017). This illiquid measure is calculated as

$$AMIHUD_{i,d} = \frac{|R_{i,d}|}{VAL_{i,d}}, \tag{4}$$

where $R_{i,\ d}$, $VAL_{i,\ d}$ are the return, and the trading value for stock i on day d, respectively.

Regarding the resilience dimensions, the study follows Hasbrouck and Schwartz (1988), using the market efficiency coefficient (MEC) to proxy resiliency. The MEC indicates the fact that price movements continuous in liquid markets. Hasbrouck and Schwartz (1988) propose that MEC is defined as the ratio of observed long-variances and short-variances.

$$MEC = \frac{1}{T} * \frac{Var(LR_t)}{Var\ (SR_{t)}}, \tag{5}$$

where $Var(LR_t)$ is the variance of the logarithm of long-period returns, $Var(SR_t)$ is the variance of the logarithm of short-period returns, T is the number of short periods in each long-period. The resilient markets are closer but slightly below one (Sarr and Lybek 2002).

In my research, the study calculates the MEC over a week of trading (five trading days period) as a long-period and a given trading day as a short-period. The long-period variance (weekly), $Var(LR_t)$ is calculated following Martens and Van Dijk (2007) as Eq. (6). The short-period variance, $Var(SR_t)$ calculated follows the study introduced by Parkinson (1980) as Eq. (7).

$$Var(LR_t) = \frac{1}{4\log(2)} \sum_{d=1}^{5} (h_{d,t} - l_{d,t})^2, \tag{6}$$

$$Var(SR_t) = \frac{1}{5} * \sum_{d=1}^{5} \frac{h_{d,t} - l_{d,t}}{4\log(2)}, \tag{7}$$

where $h_{d,\ t}$, $l_{d,\ t}$ are the logarithm of the high and low prices for day d within week t (five trading days period).

The study is inspired by Ahn et al. (2007), Anderson and Peng (2014) as the standard procedure in examining the changes in liquidity dimensions after tick size reduction on the HOSE in September 2016. For this purpose, the study constructs aggregate liquidity measures using firm-level liquidity. The study first calculated daily measures for all stocks in the sample except for the MEC, which is calculated weekly. Then the study applied the value-weighted average based on market capitalization to estimate the aggregate liquidity.

The statistical significance in the difference during the pre- and post-event periods is tested using the Wilcoxon Signed-Rank Test, known as the Wilcoxon matched-pairs test. The Wilcoxon test is one of the most common tests to evaluate the same subjects under two sets of conditions. The Wilcoxon Signed Rank Test, based on

Table 2 Summary statistics for stock trading in four tick size categories

	Mean	Minimum	Maximum
Group 1 (n = 108 companies)			
Market capitalization (VND billion)	1218.4	27.1	25,283.3
Daily trading volume (thousand shares)	578.6	0.0	47,752.8
Daily trading value (VND million)	3701.2	0.7	299,250.9
Group 2 (n = 173 companies)			
Market capitalization (VND billion)	5131.4	62.4	153,238.7
Daily trading volume (thousand shares)	483.1	0.0	49,007.9
Daily trading value (VND million)	8968.2	0.0	552,959.0
Group 3 (n = 28 companies)			
Market capitalization (VND billion)	17,227.6	312.8	226,426.6
Daily trading volume (thousand shares)	162.4	0.0	9539.5
Daily trading value (VND million)	13,329.9	1.0	919,009.0
Group 4 (n = 3 companies)			
Market capitalization (VND billion)	6112.6	914.2	13,533.7
Daily trading volume (thousand shares)	95.9	0.0	515.8
Daily trading value (VND million)	12,580.4	1.0	3500.0

Notes: Group 1, 2, 3 and 4 indicate the first group with a price range under VND 10,000, the second group with a price range from VND 10,000 to VND 49,950, the third group with a price range from VND 50,000 to VND 99,500, the fourth group with price range above VND 100,000, respectively

different scores, analyzes the signs of difference through the magnitude of observed differences. The Wilcoxon Signed-Rank Test reveals the null hypotheses' statistic results, where the median difference is zero. The Wilcoxon test is applied commonly in the literature, for instance, Ahn et al. (2007), Ascioglu et al. (2010), Pan et al. (2012), Chen and Hsieh (2013), Anderson and Peng (2014).

Table 2 reports the descriptive statistics on the market capitalization and trading activities of stocks in four groups on the HOSE from 24 June 2016 to 28 November 2016.

Table 2 presents the difference in market capitalization on the HOSE in the sample. The first and second groups include stocks with a price under VND 50,000, having the smallest average market capitalization with VND 1218.4 billion and VND 5131.4 billion. The highest average market value is in the third group at VND 17,227.6 billion. The market value in this group varies from VND 312.8 billion to VND 226,426.6 billion. The fourth group contains stocks with the highest stock price, above VND 100,000. However, the market capitalization is only VND 6112.6 billion. Investors on the HOSE traded the most on stocks in the third and fourth groups. Specifically, they spend VND 13,329.9 million and VND 12,580.4 million for trading stocks in these groups, respectively. The highest trading value per day is also in the third group at VND 919,009.0 million. The third and fourth groups'

daily average trading volume is smaller than the two first groups with 162.4 and 95.9 thousand shares, respectively. However, the first group has the highest average trading volume at 578.6 shares per day. Because the stock price in this group is minimal, the trading value is the smallest at VND 3701.2 million.

4 Empirical Results

This section presents the description of stock liquidity before and after the event date and analyzes the empirical results. The paper will discuss the changes in liquidity dimensions, i.e., the tightness, depth and resilience.

4.1 Tick Size Reduction and Tightness Dimensions

This section explores the impact of changes in minimum tick size on the tightness dimensions. The study calculates two proxies for the tightness dimensions as quoted spread and effective spread.

Table 3 provides a comparison in the quoted spread between the pre- and post-event periods. In general, the quoted spread decrease after the reduction in tick size in four subsamples. The stocks have a price under VND 10,000 in group 1, illustrate a reduction in the quoted spread. The average quoted spread for group 1 fell from VND 159.12 to VND 146.55. Groups 2 and 3 also have a quoted spread decline, which accounts for about 3.8%. However, the pre- and post-event differences do not present significant statistics in the Wilcoxon test. The most change in quoted spread occurs in group 4, where stock prices are above VND 100,000. The quoted spread falls by 8.87%, from VND 1536.19 to VND 1399.91. The results prove significant

Table 3 Comparison of pre- and post-event in the quoted spread

Group	Pre-event	Post-event	Difference	(%) Difference	Signed-rank p-value
1	159.12	146.55	−12.57	−7.90	0.00***
2	361.76	347.98	−13.78	−3.81	0.05**
3	986.03	949.17	−36.86	−3.74	0.26
4	1536.19	1399.91	−136.29	−8.87	0.04**

Notes: The quoted spread is the difference in the best bid and best ask prices. This proxy is calculated for the pre-event period from 24 June 2016 to 1 September 2016, and the post-event period from 20 September 2016 to 28 November 2016. The whole sample includes all stocks in the sample. Group 1, 2, 3 and 4 indicate the first group with a price range under VND 10,000, the second group with a price range from VND 10,000 to VND 49,950, the third group with a price range from VND 50,000 to VND 99,500, the fourth group with a price range above VND 100,000, respectively. The study tests the null hypothesis that a tick size reduction does not decrease the quoted spread. *, **, and *** denote the statistical significance p-value from the Wilcoxon one-tailed test between the pre- and post-periods at the 10%, 5%, and 1% levels, respectively

Table 4 Comparison of pre- and post-event in the effective spread

Group	Pre-event	Post-event	Difference	(%) Difference	Signed-rank p-value
1	75.76	65.88	−9.88	−13.04	0.00***
2	203.58	211.12	7.54	3.70	0.96
3	513.67	495.32	−18.35	−3.57	0.04**
4	1,175.00	978.50	−196.50	−16.72	0.04**

Notes: The effective spread is two times the absolute difference between the trade price and the bid-ask midpoint. This proxy is calculated for the pre-event period from 24 June 2016 to 1 September 2016, and the post-event period from 20 September 2016 to 28 November 2016. The whole sample includes all stocks in the sample. Group 1, 2, 3 and 4 indicate the first group with a price range under VND 10,000, the second group with a price range from VND 10,000 to VND 49,950, the third group with a price range from VND 50,000 to VND 99,500, the fourth group with a price range above VND 100,000, respectively. The study tests the null hypothesis that a tick size reduction does not decrease the effective spread. *, **, and *** denote the statistical significance p-value from the Wilcoxon one-tailed test between the pre- and post-periods at the 10%, 5%, and 1% levels, respectively

statistical evidence for decreasing the quoted spread in groups 1, 2 and 4 after the tick size reduction. However, the decrease of quoted spread in group 3 is not statistically significant.

Table 4 shows the Wilcoxon test's results to examine the difference in the effective spread. The liquidity proxy reduces during the post-event, except for group 2. The effective spread decreases the most in groups 3 and 4 with stock prices above VND 50,000. The Wilcoxon test results indicate that the study can reject the null hypothesis in groups 1, 3 and 4. Tick size reduction decreases the effective spread and significant at the 0.05 level. The liquidity improves in the post-periods in these groups. However, the Wilcoxon test indicates that the changes in the effective spread are not statistically significant. The results support that tick size reduction decreases the effective spread.

4.2 Tick Size Reduction and Depth Dimensions

A market is deep when there is a massive flow of trading orders on both the buy and sell-side frequently. The depth dimensions are captured through four proxies: trading volume, trading value, turnover ratio, and Amihud (2002) measure. This section examines the difference in the liquidity proxies after the tick size reduction on the HOSE.

Table 5 provides the detailed changes in the trading volume for four groups before and after the event. The post-periods exhibit a decline in trading volume in the three first groups. Specifically, the trading volume in group 3 decreases sharply, about 88% in the post-periods. The Wilcoxon tests present that cannot reject the null hypothesis in all groups. Trading volume does not increase during the post-events following the tick size reduction.

Table 5 Comparison of pre- and post-event in the trading volume

Group	Pre-event	Post-event	Difference	(%) Difference	Signed-rank p-value
1	518,180.8	441,512.0	−76,669.2	−14.80	0.99
2	385,686.7	317,993.0	−67,693.9	−17.55	0.99
3	465,487.9	57,141.7	−40,8346.0	−87.72	0.99
4	236,867.9	238,411.0	1543.2	0.65	0.58

Notes: Trading volume is the number of traded shares for stocks. This proxy is calculated for the pre-event period from 24 June 2016 to 1 September 2016, and the post-event period from 20 September 2016 to 28 November 2016. The whole sample includes all stocks in the sample. Group 1, 2, 3 and 4 indicate the first group with a price range under VND 10,000, the second group with a price range from VND 10,000 to VND 49,950, the third group with a price range from VND 50,000 to VND 99,500, the fourth group with a price range above VND 100,000, respectively. The study tests the null hypothesis that a tick size reduction does not increase the trading volume. *, **, and *** denote the statistical significance p-value from the Wilcoxon one-tailed test between the pre- and post-periods at the 10%, 5%, and 1% levels, respectively

Table 6 Comparison of pre- and post-event in the trading value

Group	Pre-event	Post-event	Difference	(%) Difference	Signed-rank p-value
1	3251.53	2232.02	−1019.51	−31.35%	0.99
2	10,868.47	8900.44	−1968.03	−18.11%	0.99
3	5896.67	3871.99	−2024.68	−34.34%	0.99
4	36,262.70	34,786.38	−1476.32	−4.07%	0.33

Notes: Trading value is the amount of traded value for stocks. This proxy is calculated for the pre-event period from 24 June 2016 to 1 September 2016 and the post-event period from 20 September 2016 to 28 November 2016. The whole sample includes all stocks in the sample. Group 1, 2, 3 and 4 indicate the first group with a price range under VND 10,000, the second group with a price range from VND 10,000 to VND 49,950, the third group with a price range from VND 50,000 to VND 99,500, the fourth group with a price range above VND 100,000, respectively. The study tests the null hypothesis that a tick size reduction does not increase the trading value. *, **, and *** denote the statistical significance p-value from the Wilcoxon one-tailed test between the pre- and post-periods at the 10%, 5%, and 1% levels, respectively

Table 6 details the changes in the trading value during the pre- and post-periods. Unfortunately, the trading value decreases in the post-event periods in four subsamples. Groups 1 and 3 have the most declines, above 30%. In contrast, the highest stock price group has the least changes in trading value, about 4%. The Wilcoxon tests prove that they cannot reject the null hypothesis. The tick size reduction does not increase the trading value in the post-periods.

Table 7 presents the changes in another proxy of the depth dimensions, turnover ratio during the pre- and post-periods. The results present declines in the turnover ratio on the HOSE after the tick size reduction. The first group has the highest turnover ratio in the pre-periods with 3.82×10^{-3}. The proxy declines the most by -1.6×10^{-3} following the tick size reduction. On the other hand, the last group has the least difference in the post-periods, which occurs similarly in remained proxies of the depth dimensions. The Wilcoxon tests do not show significant statistical evidence to reject the null hypothesis. They suggest that the tick size reduction does not

Table 7 Comparison of pre- and post-event in the turnover ratio

Group	Pre-event	Post-event	Difference	(%) Difference	Signed-rank p-value
1	3.82×10^{-3}	2.2×10^{-3}	-1.6×10^{-3}	−41.05	0.99
2	3.62×10^{-3}	2.6×10^{-3}	-1×10^{-3}	−26.65	0.99
3	2.2×10^{-3}	1.7×10^{-3}	-5×10^{-4}	−23.85	0.99
4	7×10^{-4}	6×10^{-4}	-3.4×10^{-5}	−5.07	0.16

Notes: Turnover ratio is a ratio of the traded volume over the number of shares outstanding. This proxy is calculated for the pre-event period from 24 June 2016 to 1 September 2016 and the post-event period from 20 September 2016 to 28 November 2016. The whole sample includes all stocks in the sample. Group 1, 2, 3 and 4 indicate the first group with a price range under VND 10,000, the second group with a price range from VND 10,000 to VND 49,950, the third group with a price range from VND 50,000 to VND 99,500, the fourth group with a price range above VND 100,000, respectively. The study tests the null hypothesis that a tick size reduction does not increase the turnover ratio. *, **, and *** denote the statistical significance p-value from the Wilcoxon one-tailed test between the pre- and post-periods at the 10%, 5%, and 1% levels, respectively

Table 8 Comparison of pre- and post-event in the Amihud (2002) measure

Group	Pre-event	Post-event	Difference	(%) Difference	Signed-rank p-value
1	4×10^{-4}	5×10^{-4}	1×10^{-4}	30.58	0.99
2	1×10^{-3}	1.04×10^{-3}	-4×10^{-5}	−4.36	0.22
3	7×10^{-4}	2×10^{-3}	1.3×10^{-3}	148.68	0.99
4	3×10^{-4}	2×10^{-4}	-8×10^{-5}	−31.23	0.37

Notes: Amihud (2002) measure is a ratio of the absolute stock returns over trading value. This proxy is calculated for the pre-event period from 24 June 2016 to 1 September 2016, and the post-event period from 20 September 2016 to 28 November 2016. The whole sample includes all stocks in the sample. Group 1, 2, 3 and 4 indicate the first group with a price range under VND 10,000, the second group with a price range from VND 10,000 to VND 49,950, the third group with a price range from VND 50,000 to VND 99,500, the fourth group with a price range above VND 100,000, respectively. The study tests the null hypothesis that a tick size reduction does not decrease Amihud (2002) measure. *, **, and *** denote the statistical significance p-value from the Wilcoxon one-tailed test between the pre- and post-periods at the 10%, 5%, and 1% levels, respectively

increase the turnover ratio, and market liquidity is not enhanced relating to the decline of tick size minimum.

Table 8 provides the changes in Amihud (2002) measure, an illiquid proxy of the depth dimensions in the post-event periods. The results indicate that the measure in groups 1 and 3 become higher than before the tick size reduction. It suggests that market liquidity decreases groups 1 and 3 during the post-periods. Stocks in group 3 have the most remarkable change in this measure that increases by 2×10^{-3}. In contrast, the proxy declines slightly by 1×10^{-3} and 2×10^{-4} in groups 2 and 4. The liquidity improves modestly in these groups after the changes of tick size minimum. However, the Wilcoxon tests prove that Amihud (2002) measure decreases in the post-periods. It suggests that market liquidity is not improved following the tick size reduction.

To sum up, the Wilcoxon tests do not illustrate statistical evidence that three liquid proxies (trading volume, trading value and turnover ratio) increase, and the

Table 9 Comparison of pre- and post-event in the MEC measure

Group	Pre-event	Post-event	Difference	(%) Difference	Signed-rank p-value
1	1.34×10^{-2}	1.28×10^{-2}	-6×10^{-4}	−4.37	0.99
2	1.06×10^{-2}	1.05×10^{-2}	-1×10^{-4}	−0.60	0.32
3	8.10×10^{-2}	7.20×10^{-3}	-9×10^{-4}	−11.04	0.99
4	8.40×10^{-2}	9×10^{-3}	6×10^{-4}	6.79	0.29

Notes: MEC measure is the ratio of observed long-variances and short-variances. This proxy is calculated for the pre-event period from 24 June 2016 to 1 September 2016, and the post-event period from 20 September 2016 to 28 November 2016. The whole sample includes all stocks in the sample. Group 1, 2, 3 and 4 indicate the first group with a price range under VND 10,000, the second group with a price range from VND 10,000 to VND 49,950, the third group with a price range from VND 50,000 to VND 99,500, the fourth group with a price range above VND 100,000, respectively. The study tests the null hypothesis that a tick size reduction does not decrease the MEC measure. *, **, and *** denote the statistical significance p-value from the Wilcoxon one-tailed test between the pre- and post-periods at the 10%, 5%, and 1% levels, respectively

illiquid proxy (Amihud (2002) measure) decrease in the post-periods. Thus, the depth proxies present that tick size reduction does not improve market liquidity.

4.3 Tick Size Reduction and Resilience Dimensions

Table 9 provides a comparison between the pre- and post-event periods in a proxy of the resilience dimensions, the market efficiency coefficient (MEC). Stocks in groups 1, 2 and 3 have declines in this liquidity measure after the event date. The MEC decreases by 4.37%, 0.60% and 11.04%, respectively. On the other hand, the MEC in group 4 increases by 6.79% after the tick size reduction. The results indicate that the Wilcoxon tests do not prove specific evidence to reject the null hypothesis. It suggests that the declines of the MEC are not statistically significant. The tick size reduction does not enhance the market liquidity through resilience dimensions in the post-event periods.

5 Conclusions

This study has explored the changes in liquidity dimensions on an emerging stock exchange, following a tick size reduction. The main findings are as follows.

The study finds that market liquidity significantly decreases in the post-event of the tick size reduction on 12 September 2016 on the HOSE. The Wilcoxon tests examine the statistical hypothesis and indicate that the market liquidity is not enhanced on the HOSE, except for the tightness proxies. The tick size reduction positively affected liquidity related to the tightness dimensions because the transaction costs are narrower. In contrast, the results suggested that the depth dimensions

are reduced following the smaller minimum tick size implementation. The study does not find an improvement in the market resiliency during the post-periods. These findings are consistent with Jones and Lipson (2001), Kuo et al. (2010), Pan et al. (2012), Anderson and Peng (2014). The article proves empirical evidence for the policymakers in Vietnam that tick size reduction has not enhanced the HOSE market liquidity.

The study illustrates several contributions relating to the first change of tick size on the HOSE. The article provides a comprehensive understanding of stock market liquidity, particularly on an emerging South East Asia market. The market efficiency coefficient, which has not been applied in the literature for the Vietnamese stock market, is analyzed first in this study. Finally, the results shed light on the stock market liquidity through the tick size reduction on the HOSE. Further research is needed to find more direct evidence of tick-size reduction effects on the HOSE market liquidity relating to the macroeconomy, stock returns and firm characteristics.

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Cryptocurrency Portfolio Construction Using Machine Learning Models

Gopinath Ramkumar

1 Introduction

Time series forecasting is challenging. Unlike the simpler problems of classification and regression, time series problems add the complexity of order or temporal dependence between observations. Traditional timeseries linear methods like Autoregressive integrated moving average (ARIMA), Autoregressive moving average (ARMA) and vector auto-regression (VAR) are popular and well understood. However, these methods do suffer from limitations like completeness of data, focus on linear relationship, fixed temporal dependence, univariate data and are one step forecasts. Meanwhile, deep learning neural networks of convolutional neural networks (CNNs) and recurrent neural networks (RNNs) have been widely applied in multi-step time series forecasting and are able to learn arbitrary complex mappings from inputs to outputs and support multiple inputs and outputs. These methods are attributed to the open source deep learning frameworks, such as keras[1] and Tensorflow,[2] including flexible and sophisticated mathematical libraries.

Cryptocurrencies are one of the recent innovations in a long list of financial market developments that were generally aimed at accumulating, concentrating, and redistributing financial resources and risk. The market of cryptocurrencies is undoubtedly dominated by Bitcoin, a decentralized digital currency. However, alternative currencies (altcoins) among which Ethereum, Ripple, Litecoin are popular, boldly gaining attention as well as market shares. As on 25th Sep 2020, the

[1] https://keras.io/.

[2] https://www.tensorflow.org/.

G. Ramkumar (✉)
Wroclaw University of Economics and Business, Wroclaw, Poland

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Fig. 1 Structure of the paper

global market cap for cryptocurrencies is $340.55 B.[3] Because of the high percentage of daily traded volume of cryptocurrencies and control the risk better, machine learning methods are considered as the most powerful tool to boost investment return.

In general, investment portfolios should adhere to following stages: setting investment goals, choice of investment portfolio, implementing a portfolio trading strategy and evaluating the effectiveness of strategy. In this paper, nine cryptocurrencies based on availability of data and market capitalization are identified. The cryptocurrency closing prices are forecasted using machine learning methods in the likes of CNN and LSTM using four factors that will be discussed Sect. 3.2. The forecasted methods with least RMSE (Root Mean Squared Error) are taken as final model for prediction. Different investment portfolios are created using various techniques and will be discussed in Sect. 3.3. The optimal investment portfolio is formulated using portfolio performance measures discussed in Sect. 3.4. An empirical analysis using pair trading strategy is performed to confirm the increase in profitability of the optimal investment portfolio.

The remainder of the paper is structured as follows. Section 2 summarizes related work. Section 3 proposes relevant methodology of the forecasted methods, portfolio construction methods and portfolio performance measures. Section 4 presents the data set used and results. Section 5 concludes with a brief discussion. Figure 1 shows the structure of the paper.

2 Related Work

Many research works have been published in terms of time series forecasting using machine learning methods and cryptocurrency as an investment option is becoming the hot topic in investment banks, hedge funds and brokerage houses. For example, Vanstone et al. (2012) used a neural network to decide about the buying and selling signal of the stock. The inputs are variables from the fundamental analysis: return on equity (ROE), price-earnings ratio (PER), dividend payout ratio (DPR) and price book-value ratio (PBR) and expected returns of the predicted stock served as the output. Abe and Nakagawa (2020) predicted the cross-sectional daily stock prices in Japanese stock market using deep learning for actual investment management. Wan

[3] https://coinmarketcap.com/.

et al. (2019) has used multivariate temporal convolutional network (M-TCN) model to improve prediction accuracy and data dependence on aperiodic data for Beijing PM2.5 and ISO-NE dataset. Bohte and Rossini (2019) has compared the forecasting of cryptocurrencies by Bayesian time-varying volatility models. It has been shown that the stochastic volatility is significantly outperforming the benchmark of VAR in point and density forecasting. Ta et al. (2020) has proposed long short-term memory to predict stock prices and constructed an efficient portfolio using multiple portfolio optimization techniques including equal-weighted modeling (EQ), simulation modeling monte carlo simulation (MCS) and mean variance optimization (MVO) thus improving portfolio performance. Chen and He (2018) has proposed deep learning method based on CNN to predict stock price movement of Chinese stock market and concluded CNN is reliable for stock price prediction. Yang et al. (2020) has proposed a deep learning framework to predict price movement direction based on historical information in financial time series. The paper has combined CNN and LSTM network for stock price prediction and concluded the CNN and LSTM model outperforms state of art models in predicting stock price movement direction. On the prior researches in cryptocurrency and portfolio management, Elendner et al. (2017) found that top 10 cryptocurrencies by market capitalisation have low linear dependency with traditional assets. Cheun et al. (2017) investigated performance of such portfolio when adding CRIX. Other notable literature like Elendner et al. (2017) introduced Liquidity bounded risk-return optimization (LIBRO) and considered including a large sample of cryptocurrencies into a portfolio consisting of S&P100, US Bonds and Commodities. Jiang and Liang (2017) has proposed model less convolutional neural network can be effectively used with set of cryptocurrency assets as its input, outputting portfolio weights of the set. Leung and Nguyen (2019) has analysed the process of constructing cointegrated portfolios of cryptocurrencies. Platanakis and Sutcliffe (2019) has compared the performance of seven heuristics in forming a portfolio of six popular cryptocurrencies.

However, some of the studies did not justify the input choices and some studies did not consider stressed period for the portfolio construction. The main idea behind this paper is to construct an efficient portfolio with simple techniques using forecasted data.

3 Problem Formulation and Methodology

In this section problem formulation is explained first and time series forecasting techniques is explained second, portfolio construction methods are formulated next and portfolio performance measures are explained last.

3.1 Problem Formulation

Let us consider closing price of cryptocurrency i at day t represented as U_t and the four technical factors in Table 2 referred in Sect. 4.1 by $x_{i,\ t} \epsilon R^4$ serving as input values. The variable dimension used in this project is 4. The output values are, $y_{i,\ t+1}, y_{i,\ t+2} \cdots y_{i,\ t+w} \in R$, where N is number of days to train the dataset, K being the size of training data and w being the length of forecasted output. The problem is to find the predictor f and θ_T is the parameter calculated by solving the below Eq. (1). In this project, root mean squared error (RMSE) is used as a loss function and we can define RMSE when training the model at T as,

$$RMSE_T = \sqrt{\frac{1}{K}\sum_{t=T-N}^{T}\sum_{i\in U_t}\left(\left(y_{i,t+w} - f(x_{i,t};\theta_T)\right)\right)^2} \tag{1}$$

RMSE is a quadratic scoring rule that also measures the average magnitude of the error. It's the square root of the average of squared differences between prediction and actual observation as seen in Eq. (1). Also, one of the salient features of RMSE is sensitivity to outliers. The need to measure forecast accuracy using scale-dependent measure like RMSE is to choose forecasted price from CNN or LSTM to create different portfolios.

3.2 Forecasting Methods

CNN and LSTM are used as prediction models of the function f and ARIMA (p, q, d) as a comparison model to measure if prediction model accuracy outperforms comparison model.

ARIMA Model

ARIMA methods are widely used approach to timeseries forecasting. It takes past values of time series plus previous error terms containing information for the purposes of forecasting. Though it is popular and one of the common approaches used as reference testing more complex problems, it also has its own limitations such as focus on missing data, linear relationships, fixed temporal dependence, univariate data and one step forecasts. Makridakis et al. (2018) has argued ARIMA models have better prediction accuracy compared to other machine learning methods. Figure 2 illustrates the general ARIMA modelling and forecasting strategy and it is self-explanatory.

An ARIMA model can be created using python library "statsmodels"[4] by calling ARIMA () function and passing p, q and d parameters. The training data is used to prepare the model by calling fit () function. Predictions can be made by calling the

[4] https://www.statsmodels.org/stable/index.html.

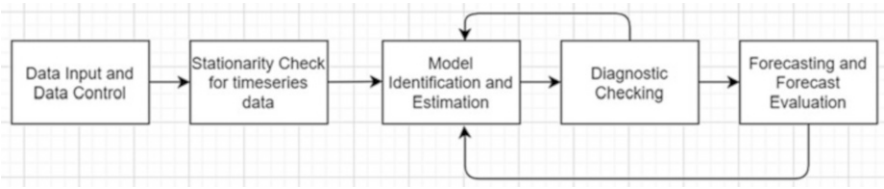

Fig. 2 ARIMA forecasting procedure

predict () function. In this project, (p, q, d) order considered as (5,1,0) for forecasting cryptocurrencies closing prices.

Convolutional Neural Network Model

Convolutional Neural Network (CNN) on other hand is extremely popular artificial neural network technique initially developed for image recognition tasks. However, they can be used to predict cryptocurrency prices after data has been pre-processed. Chen et al. (2016) has used proposed planar feature representation methods and CNN to improved algorithmic trading framework. Notable key benefits using CNN is it uses fewer parameters to learn than a fully connected network and can automatically learn and generalize features from the input domain. Figure 3 shows the CNN feature extraction and classification. CNN has three types of layers including convolution layer comprising of filters and feature maps, pooling layer and fully-connected layer. Filters have both weighted inputs and generate output value like a neuron. Feature map is the output of one filter applied to previous layer. Each position results in an activation of neuron and output are collected in feature map. Pooling layers may be considered as technique to generalize or compress feature representations and reduce overfitting of the training data. Pooling layers takes the average or maximum of input value to create its own feature map. Fully connected layer is normal flat feedforward neural network layer and has non-linear activation function to output probabilities of class predictions.

As the CNN expects the data to have shape of [samples, timesteps, features], the shape of the training dataset used is [400, 100, 6]. Then we iterate over timesteps such that each timestamp predicts next 100 ticks of data and then divide data into overlapping windows. Because we have parametrized our inputs and outputs as 100 ticks, we can keep track of start and end indices. We then fit the model on training data. The convolution layer has 10 filters and kernel size is 5 meaning the input sequence will read with convolution operation 5 times steps at a time and the operation is performed 10 times. Then pooling layer reduces feature maps and fully connected layer interprets it before output layer predicts 100 ticks in sequence. The efficient "Adam implementation"[5] is used and fit model with 20 epochs with batch size of 4. We are using walk forward validation for predicting the 100 ticks meaning we have prior 100 ticks of data.

[5]https://machinelearningmastery.com/adam-optimization-algorithm-for-deep-learning/.

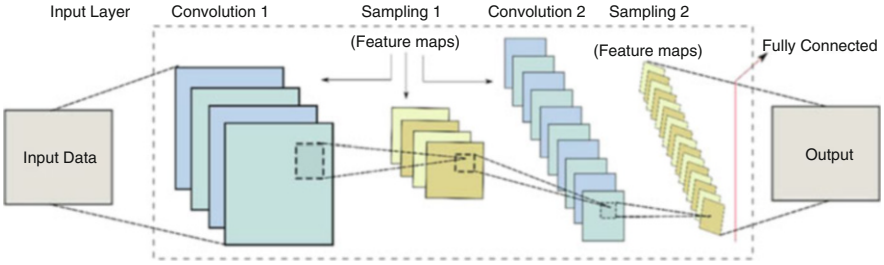

Fig. 3 CNN feature extraction and classification

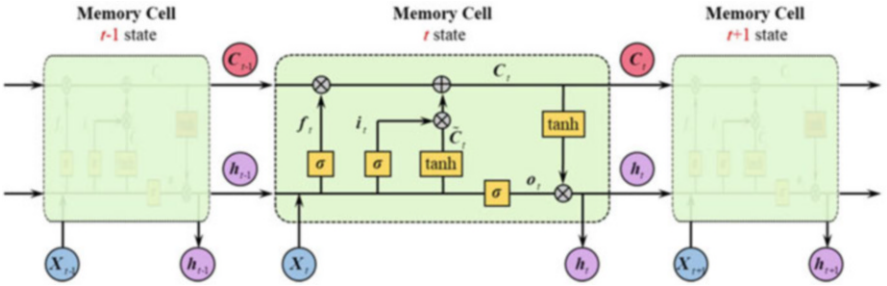

Fig. 4 LSTM memory cell illustration

Long Short-Term Memory Model

Long short-term memory (LSTM) is special kind of RNN capable of learning long term dependencies. One of the default behaviours of LSTM is remembering the information for long period of time. The LSTM network has an input layer, a hidden layer including memory cells and an output layer. Each of the memory cells has three gates for maintaining and adjusting its cell state s_t: a forgot gate (f_t) to decide the fraction of information to be allowed, an input gate (i_t) consisting the input and output gate (o_t) consisting the output generated by LSTM. Figure 4 illustrates computation carried out in LSTM memory cell.

LSTM model maps a sequence of past observations as inputs to an output observation. split_sequence () function is used to split the input series to output samples where each sample will have input timesteps and output timestep. In this project, we have used the efficient "Adam implementation" and fit model with 20 epochs with batch size of 32. For the timesteps, hidden neurons used is 100 and dropout ratio is 0.2.

From the ARIMA, CNN and LSTM methods, forecasted prices of different cryptocurrency assets of choice with least average RMSE scores is considered for portfolio construction.

3.3 Portfolio Construction Methods

Portfolio construction refers to process of selecting the optimum mix of assets for the purposes of achieving maximum returns by minimizing risk. Mean variance approach has been standard approach in portfolio construction. Despite its rationality and theoretical appeal, it does not hold well in practice (DeMiguel et al. 2009; Broadie 1993). Michaud (1989) has also referred mean-variance optimization approach as "Error Maximization" procedure as it is shown a small change in expected return assumptions lead to different efficient portfolios. Hence in this project apart from constructing a minimum variance portfolio and maximum sharpe ratio portfolio, additional portfolios are constructed by equal weight method, risk parity, kelly criteria, cointegrated pairs and apply portfolio performance measures to validate the results.

Equal weight method is one of naive portfolio methods where investors allocate capital and every asset has weight w = 1/N where N being number of assets. DeMiguel et al. (2009) suggests portfolio manager is not required to make assumptions on the distribution of the assets returns. These equal weighted portfolios are widely used in practice (Benartzi and Thaler 2001; Windcliff and Boyle 2004) and have shown promising out-of-sample results (DeMiguel et al. 2009).

MPT developed by Harry Markowitz and published under the title "Portfolio Selection" in the Journal of Finance in 1952. As per mean-variance optimization concept, a portfolio is constructed by means of vector of weights $w = (w_1, w_2, \ldots w_N)$, with the constraint given $\sum_{i=1}^{N} w_i = 1$. With N dimensional vector denoted as I, the constraint can be written as $w^T I = 1$. Let the random returns of crypto assets denoted as $r_1, r_2, \ldots r_N$ and the vector of expected return denoted as $\mu = (\mu_1, \mu_2, \ldots \mu_N)$ with $\mu_i = E(r_i)$ for i = 1, 2. . .N. The covariances are denoted by $\sigma_{ii} = \sigma_i^2 = Var(r_i)$. The N × N covariance matrix ϕ.

Expected return of portfolio is given by $\mu_p = E(R_p)$ and variance of portfolio is given by $\sigma_p^2 = Var(R_p)$.

$$\mu_p = \sum_{i=1}^{N} w_i \mu_i = w^T \mu \tag{2}$$

$$\sigma_p^2 = Var(R_p) = \sum_{i,j=1}^{N} w_i w_j \sigma_{ij} = w^T \phi w \tag{3}$$

Then classical mean-variance problem can be written as,

$$Minimize\,(w) = w^T \phi w, w^T \mu = r_{target}, w^T I = 1$$

The choice of minimum variance portfolio is it can be easily derived from mean-variance optimization approach (Jagannathan and Ma 2003) and its property of not requiring information on expected returns makes it easy to compute. Behr et al. (2008) find that minimum variance portfolio outperforms higher returns and better

risk adjusted. In this project, we use scipy 'minimize' function[6] to calculate portfolio choice with maximum sharpe ratio and minimum volatility.

Kelly Criteria is a formula for bet sizing that has been very successful for trading in long run. The Kelly bet size is found by maximising the expected logarithm of wealth which is equivalent to maximising the expected geometric growth rate. In this project, the daily percentage change in a portfolio's value can be calculated by multiplying asset weight that is percentage capital allocation and forecasted crypto asset rate of return that is percentage change of price. Once the daily percentage change is calculated, final portfolio value is then calculated by compounding the daily values. While building a portfolio, the past daily returns of each crypto asset in the portfolio is known but the weights are unknown and need to be optimised. To simplify, we can take the logarithm of the final portfolio value and then optimize it. Maximise (A *B) = Maximise (Log (A *B)) = Maximise (Log(A) + Log (B)) While optimising for the best weights of crypto assets in a portfolio, we use the logarithmic sum of returns. Since the maximisation of the logarithm of portfolio returns would give the same results as the maximisation of compounded returns, one will be using the sum of logarithmic returns to solve for the best weight combination. Hence Kelly criteria can be shown as,

$$\sum_j \left[\log \left(1 + \sum_i w_i * r_i \right) \right] \tag{4}$$

$\sum$ is the sum of the logarithm of the daily portfolio values; w is asset weights; r is forecasted crypto asset rate of return.

Risk parity is an investment management approach coined by Edward Qian of PanAgora Asset management.[7] It is a conceptual approach to investing which attempts to provide a lower risk and lower fee alternative to the traditional portfolio allocation. The main goal of risk parity portfolio is no asset contribute more to total risk of portfolio than any other asset. Maillard et al. (2010) and Qian (2005) have extensively investigated the theoretical foundations in their literature. Portfolio weights for a two-asset portfolio used in this project is calculated as,

$$W_1 = \frac{\frac{1}{\sigma_1}}{\frac{1}{\sigma_1} + \frac{1}{\sigma_2}} \tag{5}$$

σ is the standard deviation of asset return.

Mean-reversion trading strategies are widely researched by practitioners to understand long term co-movement of different asset prices and arbitrage from mean-reversion property of price spread. Theoretical framework for constructing cointegrated pairs are created from the forecasted crypto asset dataset using Engle-

[6] https://docs.scipy.org/doc/scipy/reference/generated/scipy.optimize.minimize.html.

[7] https://www.panagora.com/members/edward-qian-ph-d/.

Table 1 Portfolio performance measures

Portfolio performance measures	Formula used
Annualized volatility	$\sqrt{252}\sqrt{variance}$
Sharpe ratio	$\frac{R_p - R_f}{\sigma_p}$
Sortino ratio	$\frac{R_p - R_f}{\sigma_d}$
Beta	$\beta_p = \frac{Cov(R_p, R_m)}{var(R_m)}$
Treynor ratio	$T_p = \frac{R_p - R_f}{\beta_p}$
Information ratio	$I_p = \frac{R_p - R_m}{\sigma_{p,m}}$
Maximum drawdown	$MD = \frac{L-P}{P}$

R_p,R_f, σ_p, σ_d, R_m, $\sigma_{p,\,m}$, L, P represents Portfolio returns, Risk free returns, standard deviation of portfolio returns, standard deviation of negative asset returns, market returns, Standard deviation of the difference between portfolio and market returns, Lowest value before the new high and Maximum value before the largest drop

Granger test. As per Engle-Granger test, we can calculate the spread by using linear regression to get the coefficient for linear combination between the cointegrated pair. Alternatively, we can also use ratio of the cointegrated pair. In other words, we construct the spread in such way that yields highest profit when trading the mean-reverting crypto-portfolio.

3.4 Portfolio Performance Measures

Portfolio analysis is the guide to investors to study certain portfolio regarding its performance. The main objective of portfolio performance is to minimize the risk and maximize the returns. Some of the performance analysis measures used in this project is provided in Table 1.

4 Dataset and Results

This section covers the dataset used first and results on forecasting methods using CNN and LSTM. Then different portfolios are constructed using techniques in the likes of equal weighted portfolio, minimum variance, maximum sharpe ratio, cointegrated pairs, Kelly criterion and risk parity are elaborated next. The results are discussed using portfolio performance measures.

4.1 Dataset

In general, tick by tick data includes every changed, added or removed bid and ask to an order book thus helping end users to reconstruct the market states at any given

time. Tick by tick data for this project is sourced from binance exchange for the month of March 2020. The choice of selecting tick by tick data for the month of March is because cryptocurrency markets suddenly collapsed with bitcoin prices getting halved in less than a day on 12th March as shown in Fig. 5. This phenomenon dubbed as "Black Thursday" raised several questions on valuation mechanisms as well as absence of circuit breakers in financial markets, although distributed denial-of-services (DDoS) that brought BitMEX down (BitMEX 2020) acted as an implicit circuit breaker. The base assets used are binancecoin, bitcoin, bitcoincash, chainlink, EOS, ETH, Litecoin, MCO and XRP and quotation is in USD. The choice of cryptocurrencies is purely based on availability of data and average transaction volume increase including crash period. Only 10% snapshot is considered for this project meaning bids/asks placed within 10% of the mid-price at the time the order book snapshot was taken was considered and aggregated for 1 min.[8] It is well known that technical indicators are heuristic signals produced from price, volume and/or open interest and is widely popular in analyzing future prize movements. Table 2 explains selected technical factors[9] and deterministic trend signals calculated from the exchange data.

4.2 Results

Table 3 explains average RMSE scores for different cryptocurrencies using CNN and LSTM compared with ARIMA.

As per Table 3, we can see the forecasting techniques have achieved better results and very low RMSE scores implies the accuracy and precision of the prediction is high. The choice of epochs used in CNN and LSTM is just to ensure the curve is close to optimal (not overfitting) and reduces the error. It is also worth noticing that CNN with fewer batch size has outperformed LSTM in few cryptocurrencies. The overall performance of neural network is better than traditional methods like ARIMA, the results of ARIMA are low and it is self sufficient to forecasting problem for this project. Because of the close results from three machine learning techniques, we can take CNN forecasted data for portfolio construction analysis. Figure 6 represent equal weighted portfolio return with each cryptocurrencies assigned a weight $=1/9$.

As per histogram in Fig. 6, we can see the average returns is hovering around 0. For this project let us assume market returns for comparing other portfolios. Figure 7 explains the calculated portfolio optimization based on efficient frontier. In Scipy[10] optimise funtion, there is no 'maximize', so objective function used in this project is to minimize the "negative Sharpe ratio".

[8]The data was sourced from kaiko and aggregated 1 min bucket with 10% snapshot of different cryptocurrencies are calculated by data provider.

[9]https://school.stockcharts.com/doku.php.

[10]https://www.scipy.org/.

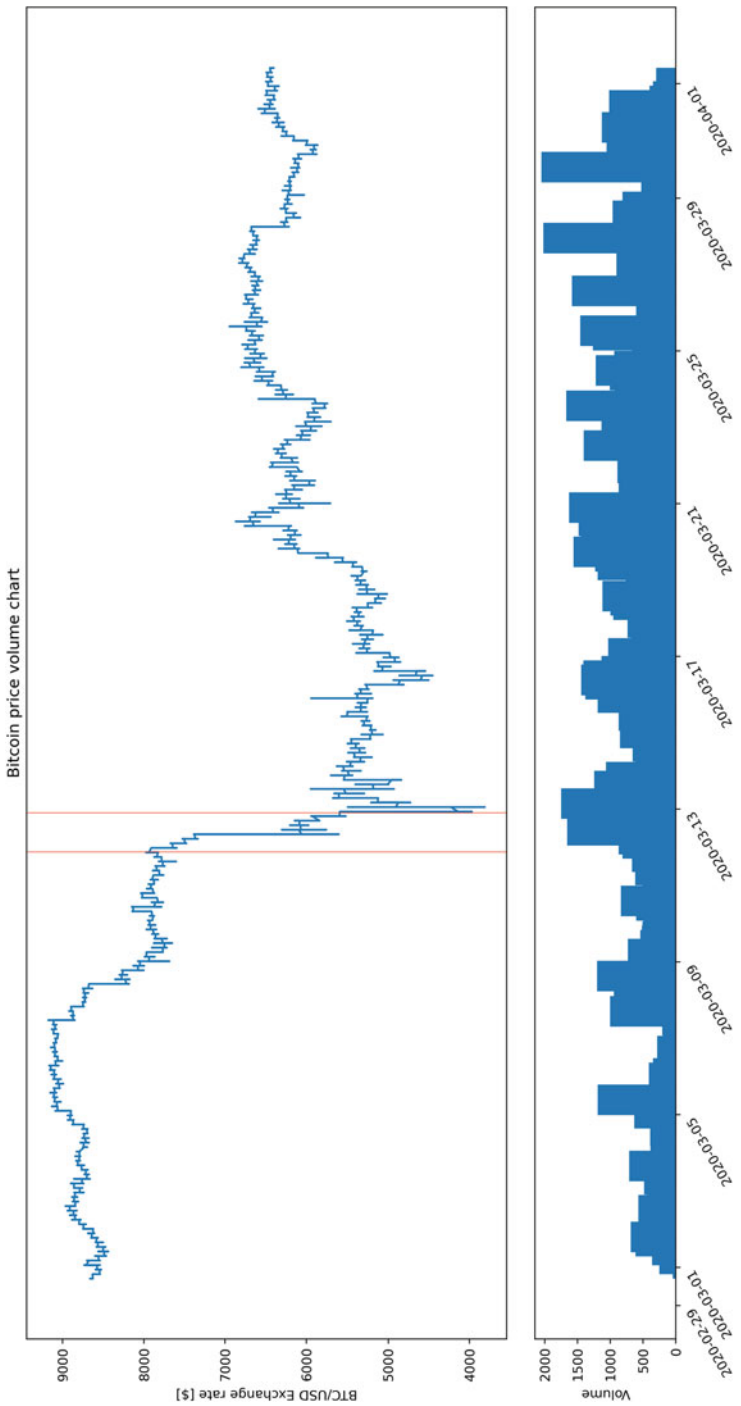

Fig. 5 Bitcoin price volume chart for month of March 2020

Table 2 Technical factors with deterministic trend signal

Technical factors	Formulas	Trend signals
Simple moving average (SMA)	$SMA_t = C_t + C_{t-1} + \cdots + C_{t-n}/n$	If $\mathbf{C_t}$, signal "1"; otherwise signal "0".
Commodity channel Index (CCI)	$TP_t = H_t + L_t + C_t/3$ $CCI_t = \frac{TP_t - SMA_n(TP_t)}{0.015 * \frac{\sum_{j=t-n+1}^{t} \lvert TP_t - SMA_n(TP_t) \rvert}{n}}$	If $\mathbf{CCI_t}$, signal "1"; otherwise signal "0".
Momentum (M)	$M_t = C_t + C_{t-n}$	If $\mathbf{M_t}$, signal "1"; otherwise signal "0"
Exponential moving average (EMA)	$EMA_t = EMA_{t-1} + \alpha * (x_t - EMA_{t-1})$ $\boldsymbol{\alpha = \frac{2}{n+1}}$	If $\mathbf{C_t}$, signal "1"; otherwise signal "0".

H_t, L_t, C_t being the High, Low and close price. x_t is past value. n is the period for which calculations are done

Table 3 Average RMSE scores

Crypto asset	ARIMA	CNN	LSTM
Binance coin	0.416	0.175	0.028
Bitcoin	26.923	47.12	12.764
Bitcoin cash	2.248	1.941	0.033
Chainllink	0.192	0.018	0.041
EOS	0.411	0.007	0.031
ETH	0.96	0.857	0.029
Litecoln	1.241	0.55	6.229
MCO	0.114	0.104	0.05
XRP	0.043	0.001	0.029

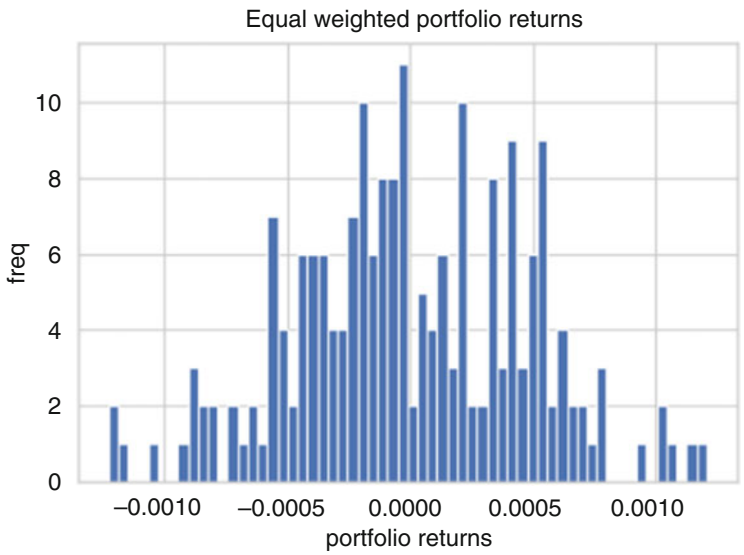

Fig. 6 Equal weighted portfolio return

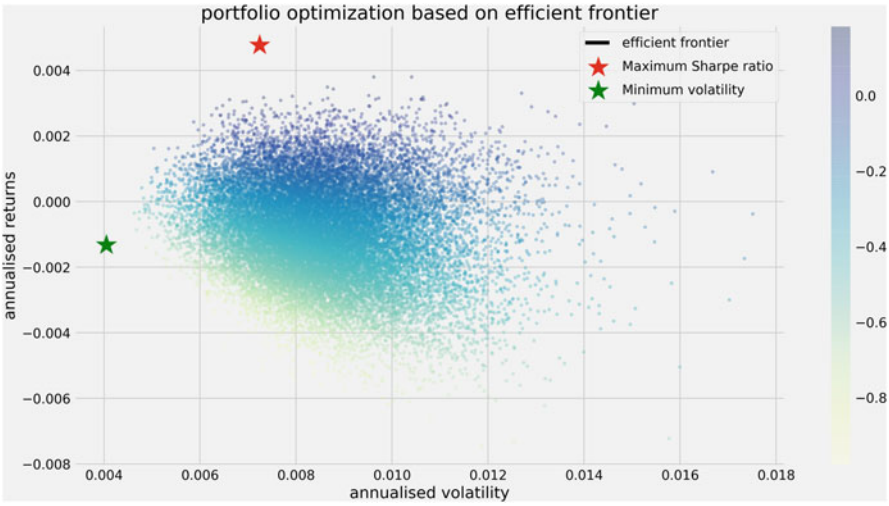

Fig. 7 Portfolio optimization based on efficient frontier

Table 4 Portfolio 1 with associated weights

Cryptocurrencies	Max Sharpe Portfolio (PORTFOLIO 1)
Binance Coin	0
Bitcoin	0
Bitcoin Cash	0.005
Chainlink	0
EOS	0.315
ETH	0
Litecoin	0.201
MCO	0
XRP	0.477

As per the above Fig. 7, annualized return is slightly over 0 for maximum sharpe ratio portfolio allocation and slightly less than 0 for minimum volatility portfolio allocation. Tables 4 and 5 are the maximum Sharpe ratio portfolio labelled portfolio 1 with allocated weights and minimum volatility portfolio allocation with allocated weights labelled portfolio 2.

Figure 8 explains three cointegrated pairs of cryptocurrencies with pvalue less than 0.5. Lower pvalues mean high cointegration and Engle-Granger test is used to check cointegrated timeseries. Portfolio 3, portfolio 4 and portfolio 5 is created in the likes of [binance coin, EOS], [binance coin, litecoin] and [EOS, litecoin] with equal weights allocated for each cryptocurrencies in pairs.

Figure 9 explains the portfolio optimization based on Kelly criterion. As seen in Fig. 9 it is evident Kelly criterion has outperformed the equal weighted portfolio.

Table 5 Portfolio 2 with associated weights

Cryptocurrencies	Min Vol Portfolio (PORTFOLIO 2)
Binance coin	0.364
Bitcoin	0.142
Bitcoin cash	0.001
Chainlink	0.002
EOS	0.006
ETH	0.005
Litecoin	0.004
MCO	0.002
XRP	0.267

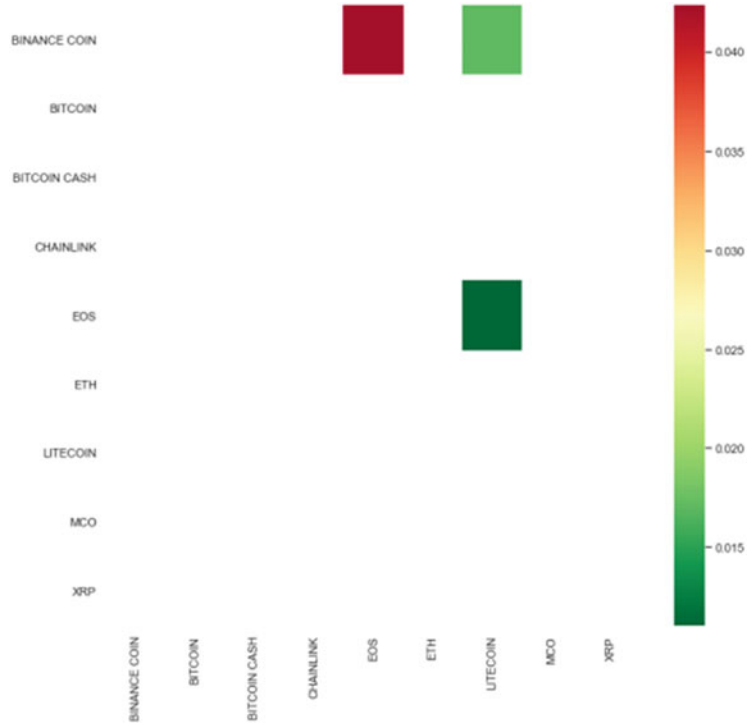

Fig. 8 Cointegrated pairs of cryptocurrencies

Thus portfolio 6 is created using kelly criterion and the weights are allocated using "cvxpy" function[11] in Python.

Portfolio 7 and portfolio 8 are formed by selecting random cryptoassets and portfolio weights are allocated using risk parity approach. Figures 10 and 11 explains portfolio 7 in the likes of [XRP, bitcoin cash] and portfolio 8 in the likes of [ETH, litecoin].

[11] https://www.cvxpy.org/install/.

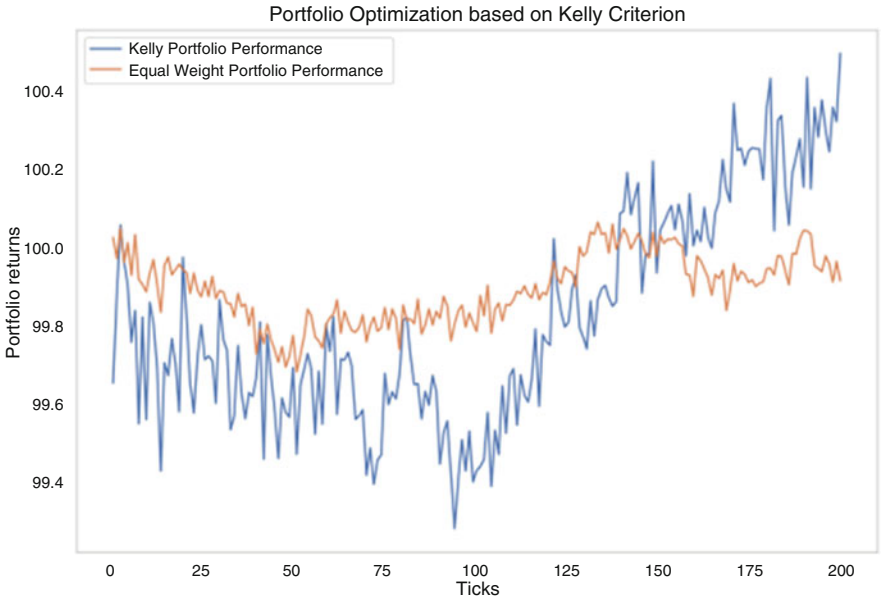

Fig. 9 Portfolio performance (portfolio 6 vs equal weighted portfolio)

crypto Assets	Standard deviation	weights
XRP	0.00810318	0.823253
BITCOIN CASH	0.037743	0.176747

Fig. 10 Portfolio 7 with associated weights

crypto Assets	Standard deviation	weights
ETH	0.0170704	0.561261
LITECOIN	0.0218374	0.438739

Fig. 11 Portfolio 8 with associated weights

Portfolio performance measures are then used in the eight portfolios as shown in Fig. 12. The methodology is mentioned in Sect. 3.3.

As seen in Fig. 12, we can see the portfolio 5 and portfolio 6 has highest annualised returns. Portfolio 5 has higher Sharpe ratio than other portfolio as Sharpe ratio tells whether the returns on a portfolio are due to good investment decision or the result of excessive risk taken. Sortino ratio determines an investment's risk-adjusted returns as it relates to downside risk. Portfolio 5 has highest Sortino ratio implying higher returns per unit of downside risk. Beta captures the relationship between the benchmark returns and the portfolio returns. Treynor Ratio is the variation in the denominator of the Sharpe ratio that tells investors how good the

Parameters	PORT 1	PORT 2	PORT 3	PORT 4	PORT 5	PORT 6	PORT 7	PORT 8
Annual Returns	0.477	-0.146	-0.055	-0.015	0.621	0.661	0.321	0.341
Annual Volatility	0.722	0.365	0.832	1.113	1.344	2.183	0.965	1.438
Sharpe Ratio	0.381	-0.947	-0.307	-0.193	0.311	0.21	0.125	0.097
Sortino Ratio	0.549	-1.33	-0.427	-0.275	0.442	0.3	0.178	0.139
Beta	0.362	0.066	0.158	0.511	0.7	1.053	0.522	0.975
Treynor Ratio	0.007	-0.052	-0.016	-0.004	0.005	0.004	0.002	0.001
Information Ratio	0.698	-0.06	0.041	0.075	0.57	0.372	0.441	0.354
Skewness	0.054	-0.077	-0.1	0.035	-0.017	0.005	-0.092	0.052
Kurtosis	-0.486	-0.065	-0.309	0.108	0.242	0.256	0.721	0.316
Maximum Drawdown	-0.287	-0.27	-0.287	-0.441	-0.444	-0.778	-0.445	-0.73

Fig. 12 Portfolio performance measures on all eight portfolios

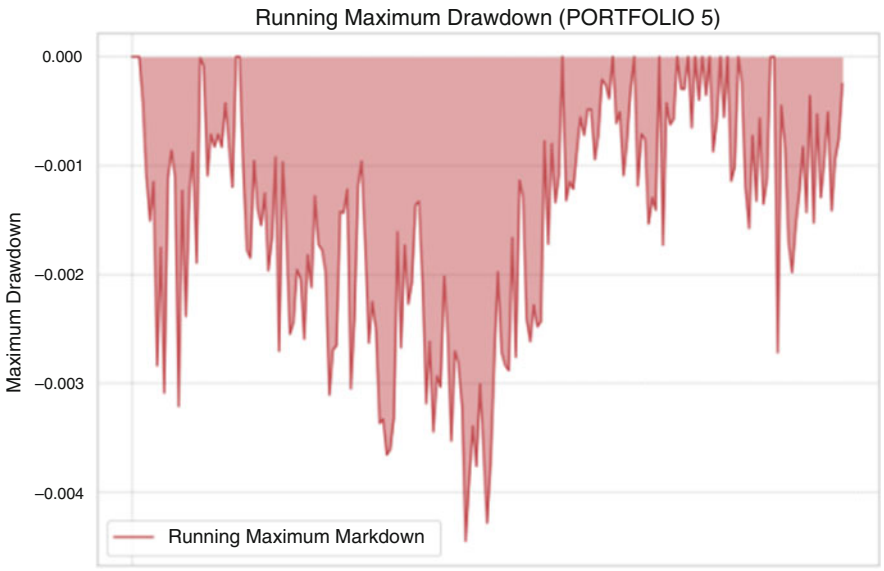

Fig. 13 Running maximum drawdown for portfolio 5

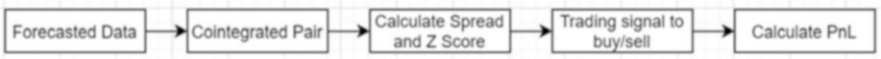

Fig. 14 Pair trading strategy

investment though it does not quantify how much good the investment. Information ratio tells the portfolio's return in excess of the benchmark's return with respect to the volatility of these returns. Higher information ratio implying consistency and better performance. A positively skewed investment in the portfolio indicates frequent small losses and few large gains and vice versa. Kurtosis, like skewness, is a measure of distribution. kurtosis tells about the heaviness in the tails while skewness talks about the symmetry. Maximum Drawdown measures the peak-to-trough decline in the value of the portfolio and is quoted as the percentage of the peak

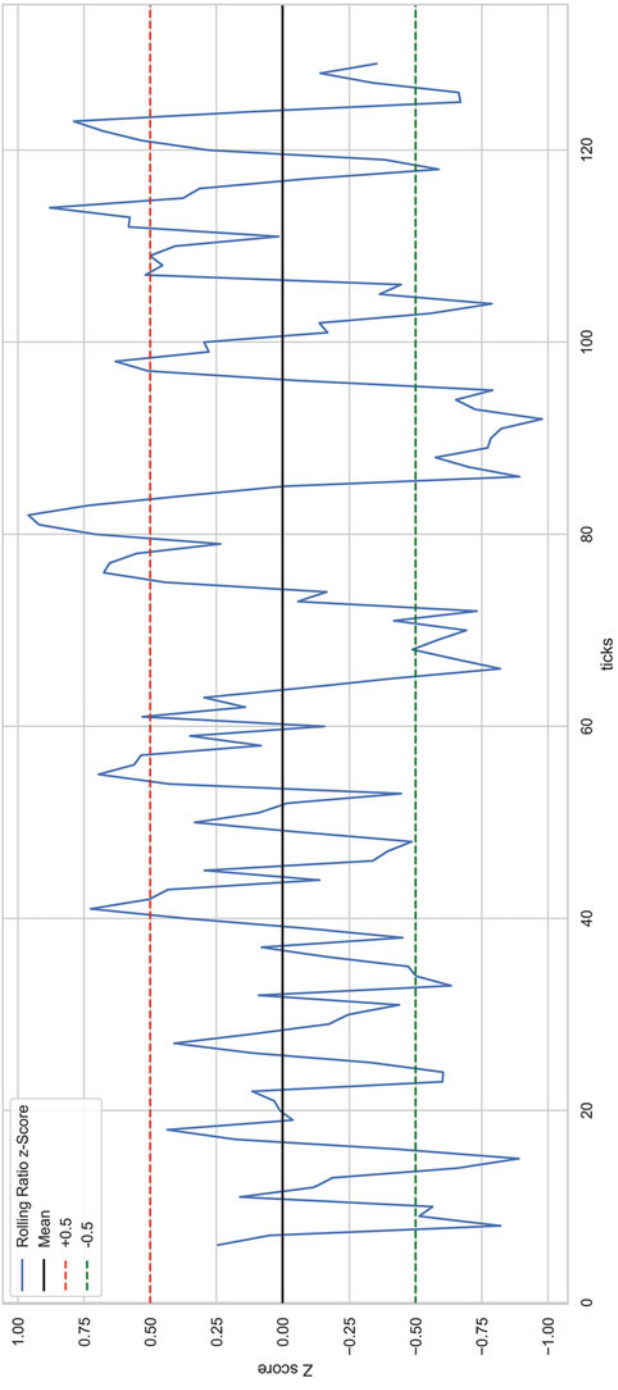

Fig. 15 Rolling ratio z score

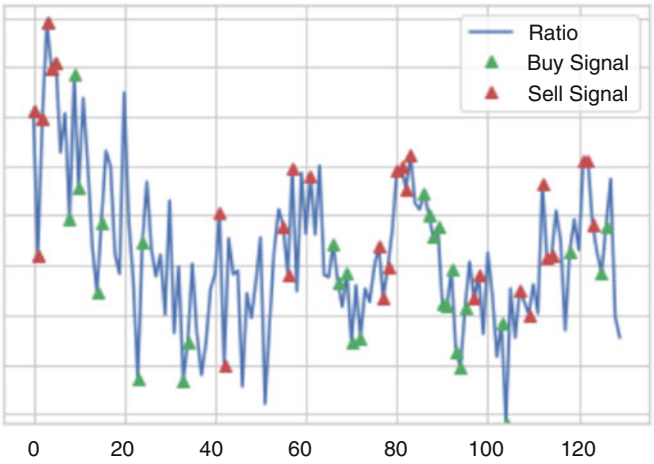

Fig. 16 Buy and sell signal on ratio

value. Maximum Drawdown doesn't say how frequently the losses are occurring and how much time it took to recover from those losses. It only measures the size of the largest loss. A low value of maximum drawdown is preferred. As seen in Fig. 12, almost all the portfolios have negative drawdown. Figure 13 shows the running maximum drawdown for portfolio 5. Overall, Portfolio 5 has comparatively fared better than other portfolios.

As portfolio 5 is created using cointegrated pairs, it is possible to perform a pair trading strategy to maximise the returns. Pair trading is a high alpha strategy that has distinct advantage being hedged against market movements. It is a form of mean-reversion and based on mathematical analysis. Figure 14 illustrates the pair trading strategy. Once the spread or ratio of the cointegrated pair is calculated, Z score is calculated to standardize the ratio.

$$Z_i = \frac{x_i - \overline{x}}{s} \tag{6}$$

A z-score is the number of standard deviations a datapoint is from the mean. More importantly, the number of standard deviations above or below the population mean is from the raw score.

Trading signals are indicators to trading strategy to buy or sell assets. In this project, once the z score is calculated, we will create "buy" signal on calculated ratio when z score is below −0.5 and "sell" signal when z score is above 0.5. The training and testing data is split 60/40. Additional features like 3 day moving average, 7 day moving average and z score is added to determine the direction of z-score movement. Then returns are calculated for all cointegrated cryptocurrency pairs. Figures 15 and 16 represent Rolling ratio Z score and buy and sell signal on the ratio.

As seen in Fig. 15, if the timeseries moves beyond 0.5 standard deviation beyond the mean, it tends to revert back and Fig. 16 shows the trading signals on the ratio

over the timeseries.The annual returns for this portfolio has improved to 1.309 when using pair trading strategy for portfolio 5 implies that any right trading strategy with trading signal can maximise the return. Thus the paper will be extended in the future to include multiple trading strategies.

5 Conclusion

This paper presented deep learning neural network models like CNN and LSTM to predict cryptocurrency prices. Though, the overall performance of neural network models are better than traditional methods like ARIMA, the results of ARIMA are comparitively low and it is sufficient. Different portfolios are created using equal weighted portfolio, modern portfolio theory, cointegrated pairs, Kelly criterion and risk parity. Portfolio performance measures like annualized returns, annualized volatility, Sharpe ratio, Sortino ratio, beta, treynor ratio, information ratio and maximum drawdown for all the portfolios are analysed and best portfolio is selected. To maximise the return, a high alpha strategy like pair trading is used.

In the future work, it will be a challenge to consider proprietary factors from order book analytics to forecast the data and implement different trading strategies and use sophisticated portfolio optimization techniques to maximise the return.

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Part II
Banking

Development Factors of Blockchain Technology Within Banking Sector

Monika Kołodziej

1 Introduction

Blockchain is currently considered as disruptive technological concept with huge implementation potential and numerous of applications. Especially for banking and global financial ecosystem, blockchain can be treated as a promise of safety, trust, stability, transparency, immaturity, availability, cost reduction and efficiency. However, in the global environment exists a lack of understanding where and how technology is applicable and where it can produce practical and measurable effects. Over 10 years ago, when Satoshi Nakamoto presented *White Paper* with blockchain's thesis, the technology is still in growth phase. Although blockchain technology is considered to be potential driver within digital economy, applications built on blockchain are still not commercially available (Axios 2018). To complete process of adoption, implementation and diffusion it is require rebuilding business models and rules, create governance architecture, identify the proper blockchain application sectors that adds value, prepare methods to describe the technology and educate new human resources.

Currently blockchain is receiving a lot of public attention as advocates argue that it constitutes the foundation for truly trust-fee economic transactions based on its unique technological characteristics (Glaser 2017). Blockchain technology can be applied to a certain application scenario provided the scenario has one of the following properties: multiparty interaction, creditability, disintermediation, atomicity and privacy (Zheng et al. 2017). Much of the attention on blockchain technology is focused on its ability to redefine currently meaning of banking industry. As per study described by Cocco, Pina and Marchesi blockchain possesses

M. Kołodziej (✉)
Wroclaw University of Economics and Business, Wroclaw, Poland
e-mail: monika.kolodziej@ue.wroc.pl

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a potential to create value to several financial service activities, from payments to compliance. They also highlighted a role of blockchain in overcoming some traditional banking inefficiencies (Cocco et al. 2017). Nevertheless, each organization taking the patch to blockchain adoption must confront the business need, require resources, time range (scope), risk and potential benefits.[1] Implementation potential of blockchain technology for banking sector can be outline by establish a credit mechanism in a situation where there is a lack of mutual trust among parties, thereby resolving the high costs caused by the non-technical aspects of centralization (Guo and Liang 2016). A recent World Economic Forum report showed that over 40 central banks are researching distributed ledger technology for a variety of use-cases (WEF 2019).

The article shows the flow of blockchain implementation process dedicated for banking sector. In this paper has been prepared literature review with focus on the newest publications and case study. The main aim of the article is to outline financial determinates of blockchain technology development within banking industry and to clarify meaning of blockchain technology implementation for banking sector.

2 Blockchain Beyond Solution to Support Cryptocurrencies

Blockchain is emerging technology with huge implementation potential. However, expectations without researches and tests can caused a risk of failure in implementation process. Every disruptive technology (like blockchain) makes first impact in this area of industry that stands at the leading edge of adoption. Only particular group of companies and customers understand that technology's long-term value and the ways it might upend current thinking. Based on Deloitte's 2019 Global Blockchain Survey, blockchain is going through a path of diffusion far beyond cryptocurrencies and initial fintech application (Deloitte 2019). In the moment of article's preparation, the applications are modest so far. Reach further than cryptocurrencies (Eyal 2017), there are many investments in blockchain within banking sector (including Initial Coin Offerings), supply chain documentation (including logistic), asset registries (land ownership), health care (medical records), proof of origin (diamonds market), smart contracts and build on blockchain basis platform (Ethereum). Second generation of blockchain technology allows the carrying out of computation of network and includes third party data ledgers (Peters and Panayi 2016). Blockchain should be treated as a transformative technology, which conform trust as the crucial lubricant to economic transactions and empower an era

[1]Based on Accenture's "Building Value with Blockchain" survey, more than 64% of blockchain projects are being funded by IT or research/innovation budgets—implying that the focus is on technology, rather than on aligning with the main areas of opportunity for the organization. For further information: http://www3.weforum.org/docs/WEF_Building_Value_with_Blockchain.pdf (access: 22.06.2020).

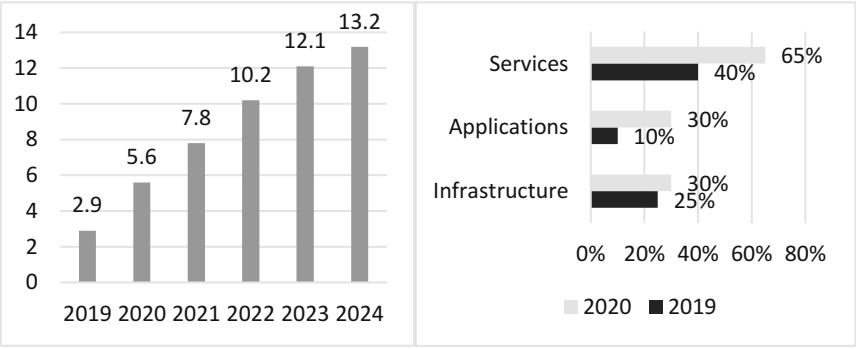

Fig. 1 Blockchain market growth, 2019–2024 and market share, 2019–2014. Source: Pelz-Sharpe (2019)

of decentralized and independent business models (Välikangas 2020). Figure 1 represents market scope for blockchain technology for years 2019–2024.

2.1 Genesis of Blockchain Technology and Development Path

To outline blockchain's genesis, it must be emphasized that blockchain is not innovation, rather combination of well-known technological concepts with innovative character. A blockchain era had begun in 2008 with financial crisis. Most probably the moment of publication blockchain thesis was an attempt to refute financial systems rules. Global financial crisis exposed instability and infectivity of financial sector. As a key issue related to financial crisis should be provided the asymmetry of information that characterized the cooperation line client/investor and financial industry. While crisis circumstances, many criticisms have formulated against the existing financial practices leading to a call for more transparency and higher inclusion of investors into banking or financial ecosystem (Schinckus 2020). In this context blockchain technology appears to cover requirements claimed by financial market. The technology should outweigh challenges associated with traditional meaning of business models and processes with third party related to. Nevertheless, blockchain is only technological concept, a tool dedicated to improving, support and probably (in the future) to replace currently existing business models. Blockchain technology is the resultant of many IT concepts. It has been built on the basis of Merkle tress, blind signatures, consensus protocol, Proof-of-Work mechanism, e-cash systems, peer-to-peer networks and cryptography rules to maintain safety. The core ideas of blockchain have been developed in the late 1980s and early 1990s (Drescher 2018). The growth in the interest among researches and tests

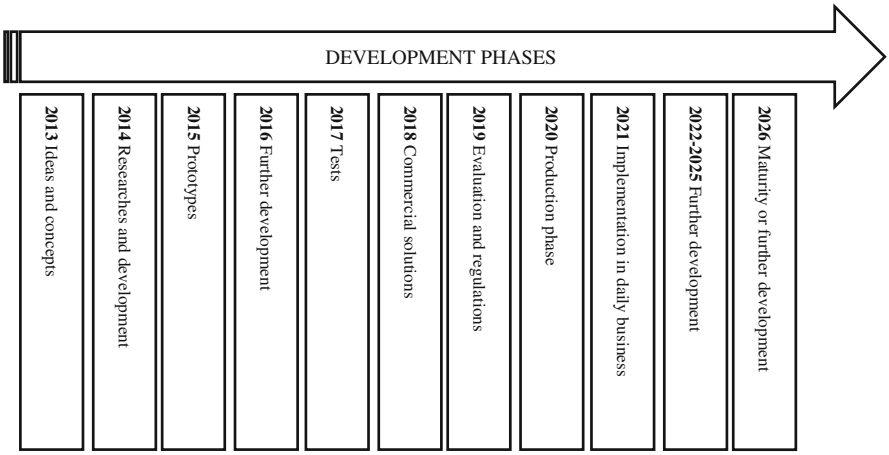

Fig. 2 Blockchain technology maturity flow. Source: https://www.researchgate.net/figure/Blockchain-development-and-utilization-timeline-with-power-system-concertation_fig3_333627407 (accessed: 20.12.2020); https://medium.com/thundercore/thundercore-blockchain-roadmap-aaddb8b3d2ca (accessed: 20.12.2020)

has been noticed since 2013, when stakeholders (industries, banks, financial institution etc.) understood implementation potential of blockchain technology. The flow of blockchain technology development has been presented on Fig. 2.

Around implementation of blockchain technology into banking services have been created many problems. First of all, risk which has been compound by immaturity of this disruptive technology and instability related to fluctuations of Bitcoin's value. Then many inconsistencies caused by lack of knowledge, clarity and relevant governments rules (Hassani et al. 2018). This caused many difficulties in identifying and developing applications dedicated for banking industry. Moreover, the way in which blockchain technology works in short- and long-term horizon is not clear. From banking sector perspective security and privacy are crucial. In general, blockchain technology delivers safety due to cryptography and real-time stamping. However, security risk is significant when miners (users) control more than 51% of the computing power. Counterproductive issue is immutability, which not allows remove data upon client's request (Upadhyay 2020). The last important thing related to blockchain implementation in banking industry is capacity and performance. On the other hand, blockchain promises following spectrum of benefits: cutting timeframes in financing, cost reduction, increasing processes efficiency, simplifications of services. As it has been mentioned by Guo and Liang, banking industry needs urgent transformation and is seeking new growth path (Guo and Liang 2016).

2.2 Principles of Blockchain Technology

Blockchain technology can introduce really disruptions to the currently existing models due to decentralized way of processing with the same level of certainly. This technology can be treated as a huge, distributed database that is organized as a list of ordered blocks, where the committed blocks are immutable. Some researchers consider blockchain technology as ideal solution in the banking industry because banks can cooperate under the same blockchain and push their customers' transactions. On this way, beyond transparency blockchain can facilitate transactions' auditing (Casino et al. 2018).

In general, a blockchain technology is a distributed database of records or a public ledger of all transactions or digital events that have been processed and shared among authorized users. Each transaction in the public ledger have to be verified by consensus mechanism resulted by the majority of users. Data inputted into the ledger cannot be modified (Crosby 2015). Blockchain is a peer-to-peer (P2P), distributed data structure which allows transactions to be recorded chronologically and stored securely in a sequence or chain of blocks via cryptography rules (Li et al. 2018). Due to combination of P2P network and the distributed nature of server that marks the timeshare transactions, has been prepared a database that is autonomous and shared among all network members (Knezevic 2018). Blockchain puts focus around distribution, sharing and encryption (Guimarães et al. 2020). Blockchain is an encrypted digital ledger stored in a private or public network on numerous computers. A structure of blockchains includes nodes located on those networks that use a common communication protocol. Each node in the network contains a complete copy of the transactions saved in chain. A consensus mechanism is used to validate transactions to ensure the immutability of the chain (Bashir 2018). Nodes within blockchain contain a copy of encrypted data blocks (records) chained by hash codes to each other (Swan 2015). Blockchain technology can be seen as a variant of distributed ledger technology (DLT)[2] where the data are presented in a linear chain of blocks that are cryptographically linked to make them resilient against unintentional or malicious manipulation (Huth et al. 2020).

From business perspective, blockchain technology can be described as a platform which allows value and money transfer using transactions and any central trust party is needed. For instance, by money transfer, third party (intermediary) is bank. Elimination of intermediaries makes that blockchain can be decentralized

[2]Distributed ledger technology (DLT) essentially can be described as a database which works across several locations or among multiple participants. An advantage of DLT means an elimination of trusted third party from transaction ecosystem. DLT use independent computers to build network in which transactions are recorded, shared and synchronized in their respective electronic ledgers. Sometimes DLT an blockchain are treated synonymously, however blockchain is only a type of DLT. An impact of DLT for financial sector has been described by The World Bank in: *Blockchain & Distributed Ledger Technology (DLT),* 2018 available in: https://www.worldbank.org/en/topic/financialsector/brief/blockchain-dlt (access: 02.07.2020).

Table 1 Elements of blockchain

Name	Description
Block	A selection of transactions bundled together and organized logically. Blocks are made from transactions. Each block contains a copy of database. First block in the blockchain is called a genesis block.
Transaction	A recorded event (for example: transferring cash from sender's account to a beneficiary's account). It is a representation of value transfer from one address to another one.
Nonce	A unique number generated only once. Nonce is used extensively in many cryptographic operations to provide replay protection, authentication and encryption.
Merkle root	A hash of all of the nodes of a Merkle tree. Merkle trees are used to validate the large structures of data securely and efficiently. A main aim of the Merkle root is efficient verification of transactions in a block.
Peer-to-peer network	A network topology means that all peers can communicate with each other and send or receive information.
Node	A node is responsible for proposing and validation of transactions and for performing mining to facilitate consensus and secure the blockchain. A way to achieve this goal is a consensus protocol. Transactions are first created by nodes and digitally signed using private keys to proof the legitimation of owner of the asset transferring to another blockchain user. This asset is usually token or virtual currency.

Source: https://users.cs.fiu.edu/~prabakar/cen5079/Common/textbooks/Mastering_Blockchain_2nd_Edition.pdf (access: 03.07.2020)

mechanism ruled by consensus where no one is responsible for database (Bashir 2018). Key elements of blockchain has been presented in the Table 1.

2.3 *Advantages of Blockchain Technology Crucial for Banking Sector*

Blockchain technology can be applied as a digital backbone for projects, models and operations within banking sector. The potential of blockchain technology in the financial sector can be described by smart technology solutions, applications as well as new business opportunities. Blockchain delivers a technology platform dedicated for stock trading, record keeping, smart contacts and cryptocurrencies. Harris and Wonglimpiyarant (2019). The technology can improve efficiency and transparency in global banking systems. Nevertheless, in global business exist many technological concepts there are not blockchains but only benefits some from blockchains rules. To clarify, the key features proving that the solution is strictly blockchain have been gathering and systematizing in Table 2.

Despite growing interest in the technology, stakeholders and organizations raise a problem related to lack of knowledge, rules and methods. The issue has been also highlighted by Zhou et al. (2020). The research team noticed limitations in existing

Table 2 Key features of blockchain technology

Feature	Clarifications
Distributed database	Each participant in a blockchain has access to the entire database and no one controls the data. Every single transaction can be verified directly without a need for third-party intermediaries.
Peer-to-peer transaction	Communication occurs directly between peers without the need for central coordination. Peer nodes simultaneously functioning as both "clients" and "servers" to the other nodes on the network.
Immutability of data	Once stored data cannot be modified. Various computational algorithms are developed to ensure that the recording on the database is permanent and available to all network users.
Consensus mechanism	Each record of data is updated based on consensus mechanism. That means no central authority. Every data entry are verified by criteriums defined in protocol.
Real time review	Documents accessible through blockchain are reviewed and approved in real time. All parties work on same ledger, all online and instant. No risk of duplication or loss.
Cryptography	A private key is known only to its owner and a public key is shared with the world. A private key is first generated in random method and is then used to create a public key. The private key is used to encrypt the transaction which can then be decrypted by the intended recipient using the sender's public key.

Source: Iansiti and Lakhani (2017)

studies, literature and models. Still exists too many unclearnesses therefore further works and tests are required. Blockchain faces many opportunities and many challenges. According to the studies conducted by Ajrun and Suprabha in the catalog of emerging areas of research should be included: business model transformations, market reaction of blockchain, digital platforms as infrastructure, regulatory landscape, infrastructure requirements, socio-economic drivers and social media leveraged predictions (Arjun and Suprabha 2020). The potential of blockchain technology means an added value created by implementation of blockchain technology for customers, stakeholders, workers and management.

3 Blockchain's Implementation Potential in Banking Industry

The value generated by implementation of blockchain technology within banking industry is related to the following determinates: ability to ensure data has not been tampered with, full traceability of any information on the blockchain, smart contracts and distribution, increased security and quality and new business products or services (WEF 2019). The key advantage of blockchain technology is data-sharing mechanism. Implementation potential of blockchain within banking sector has been

Table 3 Comparison of traditional banking and blockchain based banking

Factor	Traditional banking	Blockchain based banking
Customer experience	Uniform scenarios	Wide spectrum of possibilities
	Homogenous service	Personalized service
	Poor customer experience	Good customer experience
Efficiency	Many intermediaries	Disintermediation
	Complexity of clearing process	Distributed ledger, simplification
	Low efficiency	High efficiency
Costs	Manual processes caused issues	Automated
	High costs	Low costs
Safety	Data storage in centralized way	Distributed data storage
	High probability of attack	Asymmetric encryption
	Low level of safety	High level of safety

Source: Guo Y. and Liang Ch., Blockchain application and outlook in the banking industry. https://link.springer.com/article/10.1186/s40854-016-0034-9/tables/2 (access: 05.07.2020)

widely discussed as disruptive and consumptive (Deloitte 2019). However, this trend has been changed and banks and major financial institution are working on blockchain projects.

The implementation of blockchain technology within banking sector is essential for trade or credit financing, fractionalized asset trading, process automation and interbank or cross-border payments. Through looking at blockchain impact for banking sector there are some areas where added value is significant:

- Improving access to markets and funding.
- Increasing transparency, standardization, performance and quality.
- Maintain compliance with standards.
- Improving infrastructure operations, transactions and record keeping.
- Enhancing technological integration (OECD 2019).

From banking sector perspective implementation of blockchain technology can be a part of big changes and following a development path which contains standardization in infrastructure, stressing the importance of data transparency, risk management, cost reduction and increase efficiency of charges (G20 2018). Table 3 includes a quick comparison of traditional banking and new model of banking (includes blockchain).

Implementation potential of blockchain technology in banking sector is focused on the payment clearing and credit information systems. Additionally, banks are exploring an opportunity delivered by smart contracts. In huge finance ecosystem is required an extensive number of manual inspections and paper-based transactions. There are many processes in banking that require numerous of intermediaries, a high level of illegal transactions risk, high costs and low efficiency. The inclusion of blockchain can reduce manual work and employ smart contracts to improve procedures by reduction of paperwork. Whereas smart contracts confirm that payment has been processed automatically once a predetermined time. A key benefit of blockchain technology implementation is costs reduction to banks and trade

financing enterprises (Guo and Liang 2016). Blockchain can be also applied in the context of anti-money laundering and customer identification programs. The technology can minimalize frauds through establishing complete history of transactions within a single source of truth. A concept is very useful in increasing transparency between market participants (Attaran and Gunasekaran 2019). According to Buitenhek (2016) blockchain technology has been developed to resolve the following problems: double spending, the issue of trust, consensus on the latest correct version of the transaction history and maintenance of blockchain unchanged. Summarized, the value of blockchain technology can be described in four main areas: operational efficiency, risk mitigation, new business models and products and client experience.

4 Methodology

To understood, define and analyze impact of blockchain technology for banking sector have been created a procedure presented on Fig. 3. The main aim of the study was to find factors related to blockchain technology implementation process in banking sector. The research is based on literature review and case study analyses. Working on this material, the following research questions have been set up:

1. *What does implementation potential of blockchain technology mean?*
2. *What are the key benefits and challenges related to implementation process?*
3. *What factors are particularly important in banking sector?*

The study is explorative in nature however it has been based on scientific skepticism, therefore an author mentioned about opportunities and challenges resulting from implementation and diffusion process. Literature review combined with case study analyses is in a time range 2015–2020. In terms of case study an author analyzed 20 use cases in banking sector.

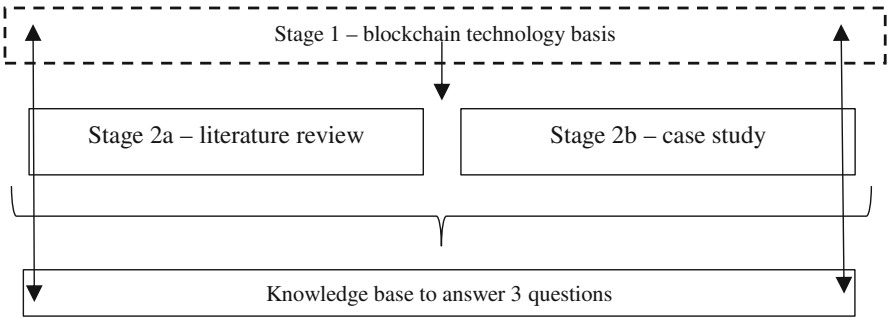

Fig. 3 The flow of research. Source: Own elaboration

4.1 Stages of the Research's Flow

The first stage of the research presented above includes blockchain's basis. This step was required to outline key advantages of blockchain technology which are important from banking sector perspective. In the catalog of blockchain features essential for blockchain implementation process are as follows: open distributed ledger, consensus mechanism, immutability of data and cost reduction. The second stage contains literature review and case study analyses. In this phase has been noticed that authors highlight a huge implementation potential of blockchain technology especially for finance sector. Most of articles raise that to adopt blockchain technology it is necessary to understand not only benefits but also challenges as blockchain is still immature (Fig. 3).

4.2 Extraction of Impact Factors from Case Studies

Case study analysis was carried out on 20 use cases, which are explored and popularized within banking sector on a global and local scale. Chosen use cases represent also possible way for blockchain technology's implementation. Use cases included to research have been presented in Table 4 and have been selected using the following criteria:

- **capability**: a tool can create in future the significant impact on financial sector's entities and services
- **duration**: a selected technological concept has been in existence for more than year
- **further development**: a concept possess a potential for further development and can be rebuild in the future
- **interoperability**: a use case can support and works with another systems
- **transparency:** available data and description reliably present the functioning mechanism

Each use case has been checked for the factors listed in Table 5. For each impact factor has been assigned the importance level which means number of cases in which a given in Table 5 impact factor occurs. The similar study has been conducted by Mohamad Osmani, Ramzi El-Haddadeh and Nitham Hindi. In this study have been following factors mentioned: privacy, transparency, security, efficiency, immutability and trust (Osmani et al. 2020). This stage gave a rise to the answers to the questions from phase 3.

In the last stage there are answers for additional questions prepared. All questions have been designed to gain a comprehensive overview of blockchain. Answering the first question it has been noticed that it does not exist a strict definition of implementation potential. This term can be described as combination of blockchain features, which properly implemented generate additional value for clients,

Table 4 Use cases within banking sector

Use case	Description
Abra (2017)	Abra is a secure mobile-based app which offers instant P2P money transfers without transaction fees.
Airfox (2016)	Airfox is solution offering inclusive financial services for emerging markets.
Atlas Money (2014)	Atlas Money is banking platform developed as P2P using blockchain technology.
Binance (2017)	Binance is the operator of a blockchain-based platform developed to facilitate cryptocurrency exchange.
Binkabi (2017)	Binkabi is a tool recommended for issuing, trading, and financing commodities on the blockchain.
Bitpesa (2013)	Bitpesa is dedicated for cross-border payments for business and individual level between African countries.
Blockchain Exchange Alliance (2018)	The Blockchain Exchange Alliance is a solution to develop a cryptocurrency trading platform designed to provide comprehensive financial services.
Bloom (2017)	Bloom is an end-to-end protocol created for identity attestation, risk assessment and credit scoring.
Colendi (2016)	Colendi is a protocol providing credit scoring evaluation.
CoMakery (2016)	CoMakery accelerates the value of blockchain projects. It is a community-based platform that helps contributors to be paid in tokens directly from the projects they have provided their expertise to.
Gauntlet (2018)	Gauntlet is a developer of a simulation platform created to monitor network activity and the fluctuation of asset values.
ICON (2017)	ICON is a decentralized network that allows independent blockchains with different governances perform transactions without intermediaries.
Inclusivity (2015)	Inclusivity delivers the inclusive banking and financial ecosystem based on blockchain technology.
MonetaGo (2014)	MonetaGo cooperates with financial institutions and central banks to provide private permissioned blockchain solutions.
Ripple (2012)	Ripple is a real-time gross settlement system, currency exchange, and remittance blockchain network.
Standard Kepler (2016)	Standard Kepler is the provider of a crypto-exchange platform that offers blockchain-based investment banking services (asset management, token financing, other customized financial products).
The Next Ventures (2018)	The Next Ventures is a solution which help startups get financial support.
Tiger Trade [Redds] (2014)	Tiger Trade is a full-service platform to buy and sell overstock merchandise worldwide.
Uulala (2017)	Uulala helps the underbanked communities of the world by giving an access to the financial tools they need and the entertainment they desire.
Wala (2015)	Wala helps emerging market consumers reach financial prosperity by eliminating barriers to banking.

Source: https://www.gsb.stanford.edu/faculty-research/publications/2019-blockchain-social-impact (access: 20.12.2020)

Table 5 Impact factors

Factor	Importance level
Process efficiency	18—in 18 of analyzed cases this factor was mentioned
Distributed systems	20—in 20 of analyzed cases this factor was mentioned
Manual work reduction	13—in 13 of analyzed cases this factor was mentioned
Transparency	10—in 10 of analyzed cases this factor was mentioned
Costs reduction	20—in 20 of analyzed cases this factor was mentioned
Stability	14—in 14 of analyzed cases this factor was mentioned
Improving access	17—in 17 of analyzed cases this factor was mentioned
Safety and trust	19—in 19 of analyzed cases this factor was mentioned

Source: Own elaboration

stakeholders and management. Key benefits result from blockchain technology implementation are as follows: cost reduction, disintermediation, transparency, possibility to register transactions in real-time dimension. Main challenges related to implementation of blockchain technology: lack of knowledge, insufficient infrastructure, scalability, reliability, lack of universal rules and standards. In the banking sector especially important are the following factors: efficiency, cost reduction, transparency, using cryptography and accessibility to data, resources etc.

5 Conclusion

The article began with a blockchain technology explanation. The main contribution of this paper lies in presenting the impact of blockchain technology on banking sector. As an emerging and disruptive concept, blockchain can redefine (in long term) currently existing business models. Nevertheless, the implementation and diffusion blockchain technology in banking require changes, time and investment expenditures. It must be highlighted that blockchain is still relatively immature solution. The implementation potential of blockchain technology in banking industry means—transparency, speed, safety, cost reduction, processes efficiency, data integrity, authentication and stability. Banks see in blockchain technology a solution of many organizational issues such as: manual work, complexity of processes, unclear procedures. Implementation of blockchain technology can be treated as a must due to competition from Fintech and another organization side. Being an early adopter can be risky, but it can also generate a huge competitive advantage.

The study described in the article includes literature review and case study. Based on that, it has been found that blockchain projects in banking are focused on deliver an added value for clients (end users) and processes efficiency. Very important are also cost reduction and data immutability. A literature review shows that authors are seeing and potential of blockchain technology in decentralized structure of data base and combination of technologies which are a guarantee of trust and stability (e.g. cryptography, consensus mechanism).

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Does Competition Matter for the Effects of Macroprudential Policy on Bank Asset Growth?

Małgorzata Olszak and Iwona Kowalska

1 Introduction

The aim of this paper is to determine to what extent competition in the banking sector affects effectiveness of countercyclical macroprudential policy. This research thus focuses on the role of competition in government economic (and regulatory) policy aimed at reduction of procyclicality of the banking activity. And it deserves highlighting that this procyclicality is considered to be one of major sources of financial instability of the banking sector, and of financial sector (Borio 2003; CGFS 2012; BIS, FSB, IMF 2011; ESRB 2014a, b). Therefore, it becomes the main driving force of financial crises which bring about undesirable real costs, in terms of reduced economic growth and thus diminished societal welfare (CGFS 2012).

To resolve this problem, we shall focus on the impact of competition intensity on the effect of macroprudential policy instruments on two areas of the banking activity, which are of huge significance from the point of view of financial stability, i.e. the general activity of banks proxied with assets growth and the sensitivity of asset growth to business cycle. As previous research shows, macroprudential policy instruments (see e.g. Lim et al. 2011; Cerutti et al. 2015; Claessens et al. 2014; Olszak et al. 2018) have been found to affect both banking growth and sensitivity of this growth to business cycle, with heterogenous results. We aim to test two sets of hypotheses, which explain the role of competition in the relationship between:

M. Olszak (✉)
Department of Banking and Money Markets, Faculty of Management, University of Warsaw, Warsaw, Poland
e-mail: molszak@wz.uw.edu.pl

I. Kowalska
Department of Quantitative Methods, Faculty of Management, University of Warsaw, Warsaw, Poland

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(1) bank asset growth and macroprudential policy; and (2) sensitivity of asset growth to business cycle (procyclicality of the banking activity) and macroprudential policy.

According to the first hypothesis (H1), intense bank competition increases bank incentives to invest in risky assets by increasing the costs of bank funding, and makes bank activity to grow more and to be more sensitive to business cycle. Consequently, effectiveness of countercyclical macroprudential policy is reduced. The explanation for such a role of bank competition in bank risk-taking is termed as "competition-fragility hypothesis" and is well established in the literature (see Keeley 1990; Beck 2008). Considering the fact that more intense competition in the deposit market results in greater risk-taking by banks (or inadequate risk-taking across the business cycle), we expect that in countries with more competitive banking markets, effectiveness of countercyclical macroprudential policy is reduced.

As for the second hypothesis (H2), intense bank competition reduces the risk of bank assets, and thus increases the effectiveness of countercyclical macroprudential policy. This expectation has its roots in the idea also named as the "competition-stability hypothesis" and has been developed by Boyd and De Nicoló (2005). The basic notion behind this explanation is that the classical argument that more bank market power in the deposit market reduces bank risk—taking ignores the potential impact of bank's lending rates on firms and consumers behavior (i.e. it does not consider the role of the demand side of the loan market). Boyd's and De Nicoló (2005) model shows that higher interest rates charged by banks may induce borrowers to assume greater risk, which results in a higher probability that bank loans turn non-performing. Therefore in countries with more intense competition in the loan market, banks engage in less risk-taking, consequently the effectiveness of countercyclical macroprudential policy is enhanced. In the opposite case, when banks operate in countries exhibiting less competition in the loan market, they tend to make more risky investments, therefore it is macroprudential policy that is the very salient factor behind reduced procyclicality. However, the effectiveness of this policy may be reduced by weak competition.

Contemporary research on macroprudential policy shows diversity of effects (Claessens et al. 2014; Cerutti et al. 2017; Gambacorta and Murcia 2020; Gomez et al. 2020). Several lines of research show that use of macroprudential policies may be even associated with increased procyclicality in banking activity (Cerutti et al. 2017; Gambacorta and Murcia 2020). Such results seem to be in line with suggestion of Danielsson et al. (2016), that the use of macroprudential policy instruments, in particular those oriented at taming financial cycle, may result in more procyclicality. Therefore, we expect that the support for particular hypotheses will be affected by the type of macroprudential policy instrument and its effects on procyclicality.

This paper makes three significant contributions to the literature. Firstly, this study is the first to relate competition to effects of macroprudential policy on bank asset growth. Second, there is no research on the role of competition in the sensitivity of asset growth to business cycle in countries which have applied macroprudential policy instruments. Previous literature shows that research on the role of banking sector competition in bank risk-taking focuses only on the level of bank-risk taking. There is only one study directly focusing on the role of competition in procyclicality

of credit by Leroy and Lucotte (2019). This study is however, considering only the sample of individual banks from 12 European countries. Finally, this research will put together the literature on countercyclical macroprudential policy, procyclicality and competition. Contemporary research shows that in countries in which macroprudential policy instruments have been applied in the pre-crisis period, balance sheet and leverage growth as well as procyclicality have been reduced to some extent (Lim et al. 2011; Cerutti et al. 2015, 2017; Claessens et al. 2014; Gambacorta and Murcia 2020). This research, however, does not consider that competition may be a factor affecting procyclicality, and thus, the force that has an impact on the effectiveness of countercyclical macroprudential policy. Consequently, this research should extend our knowledge on the nexus between competition and effectiveness of macroprudential policy, bridging the gap in the existing state of the arts.

The intensity of competition in the banking industry, as it is in other industries, is likely to have far-reaching implications for economic growth, productivity, financial stability and, consequently, consumer welfare. Theoretical and empirical research that can assess the extent to which competition in the banking sector affects procyclicality and effectiveness of countercyclical macroprudential policy, has important implications for government agencies responsible for the effective regulation and supervision of the financial system (Beck et al. 2004; Boyd and De Nicoló 2005; Berger et al. 2009). However, as noted above, the effects of competition, in particular on risk-taking and procyclicality of banks, are not obvious and potentially complex (see e.g. Acharya and Richardson 2009; Beck et al. 2013).

By affecting bank risk-taking competition has the potential to make pressure on the effects of macroprudential policies aimed at procyclicality. This motivates us to contribute to the long-lasting debate on the role of competition in bank risk-taking, by extending previous research in the area by testing the role of competition in procyclicality of the banking activity and the impact of competition on effectiveness of countercyclical macroprudential policy.

In this study we apply robust random effects estimator (as well as additional estimation techniques to test the sensitivity of results, i.e. OLS, FE and GMM two-step robust estimator) to a set of individual financial data of commercial banks operating in over 90 countries in 2004–2016.

The rest of the paper is structured as follows. Section 2 provides the review of relevant literature and develops our hypotheses. We describe our sample and research methodology in Sect. 3. We discuss results and robustness checks in Sect. 4. Section 5 concludes our work.

2 Literature Review

This study is related to two significant streams in the finance literature. The first is the stream which focuses on the links between competition and bank risk. The other, is the contemporary stream concentrating on the links between bank risk-taking and

procyclicality and the role of macroprudential polity in this link. The literature focusing on the link between competition and bank risk can be divided into three streams. As for the theoretical models, they have made contrasting predictions on the relationship between bank competition and bank risk (for in depth literature analysis see e.g. Carletti and Hartmann 2003; Allen and Gale 2004). In general, the theoretical literature may be summarized under two headings. The first, is called competition-fragility view, and predicts a positive relationship between competition and bank risk. The other, named competition-stability view, predicts a negative relationship between competition and bank risk.

A large academic literature provides support to the "competition-fragility" nexus. The argument goes that competition in deposit market erodes banks' profit margins and hence charter values, which increases risk-taking incentives because banks have less to lose in an insolvency (Marcus 1984; Keeley 1990; Allen and Gale 2004). Keeley (1990) shows that in a situation in which a large number of banks compete, profit margins are eroded and banks might take excessive risks to increase returns. As more poor quality loan applicants receive financing, the quality of the loan portfolio is likely to deteriorate and thereby increase bank fragility. Extended versions of the Keeley's framework also provide theoretical support for the competition-instability hypothesis (see e.g. Allen and Gale 2000; Hellmann et al. 2000; Repullo 2004). But, Repullo (2004) also shows that for intermediate levels of competition, both outcomes can occur. Empirical research on competition-fragility hypotheses suggests a negative relationship between competition and bank stability (see Keeley 1990; Dick 2006; Salas and Saurina 2003; for a thorough review refer to Kowalska et al. 2016). More recently, Cipollini and Fiordelisi (2012) find a negative link between bank market power and distress. Support for the competition-fragility view is also found in Beck et al. (2013), who analyze the heterogeneity of competition and stability nexus in a sample of banks from 79 countries. Also Mirzaei et al. (2013) find evidence that stability increases in less competitive environment in emerging markets. Craig and Dinger (2013) find a robust positive link between deposit market competition and asset risk, which they interpret as evidence for the risk-increasing effects of deposit market competition. Thus, the authors suggest that banks with less deposit market power are more likely to choose riskier strategies.

The competition-stability hypothesis contends that financial instability increases as the degree of competitiveness is lessened. Banks with market power will earn more rents by charging higher interest rates on business loans. In an important paper, Boyd and De Nicoló (2005) have shown that the competition-fragility trade-off is not robust to the introduction of competition in the loan market. Boyd and de Nicoló (2005) argue that banks which compete on deposits also provide loans and set prices for loans by taking into account the total amount of loans provided in the market. In line with Stiglitz and Weiss (1981), Boyd and de Nicoló (2005) assume that the risk of these loans is increasing along with the loan interest rate charged by banks. They argue it is the borrowers who choose the riskiness of their investment undertaken with bank loans. Generally, within the Boyd and de Nicoló's framework, lower levels of banking competition do not decrease bank risk but rather increase bank risk through the enterprises *risk shifting* channel. Empirical papers testing the

competition–stability hypothesis produce ambiguous results. Boyd et al. (2009) investigate the relationship between competition and bank risk in South East Asian banking sectors and find that competition does not increase or affect bank risk-taking. Another work by Schaeck et al. (2009) concludes that more competitive banking systems are more stable than monopolistic systems because of a lower likelihood of bank failure and a longer time to crisis. Some support for competition–stability view is found in Berger et al. (2009), as they show that increased competition in banking sectors operating in 23 industrial nations does not increase loan risk in these nations. Schaeck and Cihák (2010) in a study comprising European and US banks find that competition may have positive impact on bank soundness.

Martinez-Miera and Repullo (2010) extend the Boyd and de Nicoló (2005) framework by introducing an idiosyncratic risk factor for firms and build a model which predicts that the effect of bank competition on bank risk taking is non-linear. Results of simulations which account for this risk factor indicate that the risk-shifting effect of enterprises identified by Boyd and de Nicoló (2005) prevails, but another—the so-called margin effect—emerges. Thus, more competition leads to lower loan rates, and consequently lower margins from non-defaulting loans. This decreases bank's operating profits before taxes and provisions, which can be buffers against loan losses. In such circumstances, banks become riskier and more vulnerable for corporate failures which again increases bank risk. Generally, Martinez-Miera and Repullo (2010) model shows that, as competition increases, the margin effect eventually dominates the risk-shifting effect and leads to a U-shaped relationship between probability of bank failure and the number of banks (see Lee and Chiang 2012). Several papers challenge empirically the concept of *U-shaped relationship between competition and bank risk*. Liu et al. (2010) find that a U-shaped relationship exists between regional bank competition and stability. Bretschger et al. (2012) argue that the "concentration-stability" and the "concentration-fragility" hypotheses suggest opposing effects operating through specific channels. Their findings provide support for the assumption of channel effects in general and both the concentration-stability and the concentration-fragility hypothesis in particular. The effects are found to vary between high and low income countries. Tabak et al. (2012) also find that competition affects risk-taking behavior in a non-linear way as both high and low competition levels enhance financial stability. They find the opposite effect for average competition. In a recent paper Cuestas et al. (2020) find an inverse U-shaped relationship between competition and financial stability in Baltic countries. This contradicts the Martinez-Mierra and Repullo (2010) theory, which argues that both high and low competition endanger financial stability.

Contemporary research on procyclicality of the banking activity suggests that its driving force is inadequate response of banks towards risk-taking during the whole business cycle (Olszak et al. 2018; Borio et al. 2001; Borio 2014). This phenomenon may be explained to some extent with the economic theory (market-frictions and asymmetric information, moral hazard as a side effect of the information asymmetry, risk illusion, coordination problems) and using the theoretical background of psychology and behavioral finance. In the boom periods and in favorable macroeconomic conditions, banks perceive risk as marginally low, and therefore make more

investments (e.g. loans) ignoring prudent standards, e.g. using less restrictive rules for extending loans. The opposite approach is employed by banks during recessions and unfavourable conditions in the economy. Such changes in risk-taking result in amplification of lending in boom periods and excessive unwillingness to extend loans in recessionary periods (see also Minsky 1986), when bank lending is most needed to stimulate economic growth. Due to the fact that many economies around the globe have suffered from the effects of the recent financial crisis of 2007/2008, both academic researchers as well as regulatory standard setters, have started looking for policy instruments which could reduce the potential of the banking sector to be excessively (see Borio and Zhu 2012) procyclical. These instruments are currently named as countercyclical macroprudential policy tools, and include ratios which aim to reduce borrower risk taken by a bank (e.g. loan to value, LTV; debt to income, DTI), as well as bank risk-taking in general (e.g. countercyclical macroprudential policy instruments or dynamic provisions) (see Claseesns 2014). The empirical research on the effects of macroprudential policy in countries which applied macroprudential policy instruments before the financial crisis of 2007/2008, show that macroprudential policy has the potential to affect bank risk-taking and to some extent procyclicality of the banking activity (Lim et al. 2011; Cerutti et al. 2015).

The empirical evidence on the effectiveness of macroprudential policies in managing the resilience of the banking (and financial) sector and the credit cycle, and thus financial stability, is still preliminary. The literature presenting this evidence can be grouped into cross-country studies and micro-level evidence (mostly based on the use of one, or a few, macroprudential policy instruments). We shall focus on cross-country studies because this study is conducted in a cross-country context (for analysis of individual country evidence refer to Cerutti et al. 2015). One of the first cross-country studies was a paper by Lim et al. (2011), exploring the links between macroprudential policy instruments (LTV caps, DP, DTI caps, limits on FC, countercyclical capital; buffers, limits on credit growth) and developments in leverage and credit, using aggregated annual data from 49 countries in years 2000–2010. They document that the presence of ratios such as LTV and DTI limits, ceilings on credit growth, reserve requirements and dynamic provisioning rules can mitigate the procyclicality of credit and leverage (i.e. they reduce the positive sensitivity of credit and leverage to the business cycle, proxied by real GDP growth). This study also shows that reserve requirements and dynamic provisions are effective in reducing credit growth during booms. Caps on LTV are associated with generally higher loans growth. As for the leverage growth, they document that only reserve requirements reduce it in a significant way, both generally and in boom periods. In another study, IMF (2013) investigates the impact of changes in the use of macroprudential policy instruments on financial vulnerabilities (i.e. credit growth, house price inflation, and portfolio capital inflows) and on the real economy (real output growth and the share of residential investment). This study implies that both capital requirements and RR strongly influence credit growth. LTV limits and capital requirements are found to strongly affect house-price inflation rates. RR evidently reduce portfolio inflows in emerging markets with floating exchange rates. This study also considers whether

the effects are asymmetric between tightening and loosening, but finds no significant indication of such asymmetry.

Vadenbushce et al. (2012) find that capital ratio requirements and non-standard liquidity measures (such as marginal reserve requirements on foreign funding or linked to credit growth) helped slow down house-price inflation in Central, Eastern and Southeastern Europe. Dell' Ariccia et al. (2012) show that macroprudential instruments can reduce the incidence of general credit booms and decrease the probability that booms end badly. Specific policies, such as credit and interest controls and open foreign exchange position limits, are found to be effective in reducing the probability that booms ends up in a financial crisis or subsequent economic underperformance. This study implies that due to the fact that these policies reduce the risk of a bust, they simultaneously make the whole economy resilient to the disruptions in the financial system.

Claessens et al. (2014) investigate how changes in balance sheets—i.e. in leverage, assets and non-core liabilities growth, of some 2800 banks in 48 countries over 2000–2010, respond to specific macroprudential policy instruments. They find that borrower-targeted instruments—LTV and DTI caps, and CG and FC limits—are effective in reducing the growth in bank's leverage, asset and non-core liabilities. Countercyclical instruments (such as RR and DP) also help mitigate increases in bank leverage, but they are of little effect thorough the cycle. Some of policies are counterproductive during downswing, serving to amplify declines. In a related study, Kuttner and Shim (2013) using data from 57 countries find that housing credit growth is significantly affected by changes in the maximum debt-service-to-income (DSTI) ratio, the maximum loan-to-value ratio, limits on exposure to the housing sector and housing related taxes. However, only the DSTI ratio limit has a significant effect on housing credit growth when they apply mean group and panel event study methods.

Cerutti et al. (2015) document the use of macroprudential policies for 119 countries over the 2000–2013 period, covering many instruments. This study shows that usage of macroprudential policies is generally associated with lower growth in aggregated credit, notably in household credit. These effects are, however, less evident in more developed and open economies, in which the usage of macroprudential policies comes with greater cross-border borrowing, suggesting that these countries face issues of avoidance. Generally this study implies that macroprudential policies can help manage financial cycles, but they work better in the boom than in the bust phase of the financial cycle.

In a recent paper, Olszak et al. (2018) show that effectiveness of various macroprudential policy instruments in reducing the procyclicality of loan-loss provisions (LLPs) using individual bank information from over 65 countries and applying the two-step GMM Blundell and Bond (1998) approach with robust standard errors. They identify several new facts. Firstly, borrower restrictions are definitely more effective in reducing the procyclicality of loan-loss provisions than other macroprudential policy instruments. This effect is supported in both unconsolidated and consolidated data and is robust to several robustness checks. Secondly, dynamic provisions, large exposure concentration limits and taxes on specific assets

are effective in reducing the procyclicality of loan-loss provisions. They also find that both loan-to-value caps and debt-to-income ratios, are especially effective in reducing the procyclicality of LLP of large banks. Concentration limits and taxes are also effective in reducing the procyclicality of LLP of large banks. Dynamic provisions reduce the procyclicality of LLP independently of bank size.

3 Methodology and Data

3.1 Methodology

To measure the impact of macroprudential policy instruments on the banking activity and on procyclicality of the banking activity we need to have access to data on the actual use of macroprudential policy instruments across countries. Information on the actual use and effects of macroprudential policies and some data have nevertheless been collected recently for 119 countries by the IMF (see Cerutti et al. 2015, 2017) for 2000–2016 period, which is the best and most comprehensive database on these instruments, applied in recent banking research (e.g. Gaganis et al. 2020). Analysis of the data-set developed in Cerutti et al. (2015, 2017) shows that many of instruments whose nature is macroprudential were applied in years 2000–2015, which covers the economic and financial boom period of 2001–2006/2007 and the crisis and its direct side-effects period (2008–2010). The number and diversity of these macroprudential policy instruments has evolved in recent years. Some of them have been in use in many countries definitely before the crisis (see Cerutti et al. 2015, 2017 database), whereas several are relatively new tools implemented after the crisis, i.e. in 2011. In our study, we consider the instruments which were in effective use in the period of our analysis (2004–2016) and following Altunbas et al. (2018) we divide them into two groups: cyclical (affecting cyclicality of banking activity) and resilience oriented (affecting directly balance-sheets and income statements, and therefore the bank-capital base). Cyclical instruments include: loan to value caps (denoted as ltv_cap), debt to income ratios (denoted as dti), foreign currency limits (fc), credit growth limits (cg) and FX and/or countercyclical reserve requirements (rr_rev). Resilience oriented tools include: dynamic provisions (denoted as dp), leverage ratios (denoted as lev), interbank operations limits (inter), concentration limits (conc), levies/taxes on financial institutions (tax). All instruments are binary variables, which take the value of 1 if the instrument is applied in a country, and 0 if it is not applied. Some of them have been applied for the whole period in some countries (e.g. ltv, dti, conc, lev, see the Cerutti et al. 2017, database) and are therefore time invariant. We also use aggregated macroprudential policy indices as defined in Cerutti et al. (2017). Borrower covers ltv_cap and dti, and takes values of 0, 1 or 2. Financial covers macroprudential instruments affecting the balance sheets of financial institutions, with values ranging between 0 and 8. In our sample the highest value is 5, showing that some countries have applied 5 balance-sheet oriented macroprudential policy instruments.

To identify competition intensity, we use traditional Lerner index (available in the World Bank Global Financial Development database). To measure relative intensity of competition across countries we divide countries in two sets, of which the first covers countries with less market power, and thus with stronger competition, and the other covers countries with relatively weak competition. To identify banking sectors with intense competition we introduce the dummy variable taking the value of 1 in countries in which the Lerner index is below the 30% of the countries. We denote this measure as *High competition*. To identify low competition countries we use the dummy equal to 1 in the 30% of countries in which the Lerner index takes highest values. This binary variable is denoted as *Low competition*. The rest of the sample includes 40% of countries with medium intensity of competition.

To test our hypotheses we apply the following model:

$$\begin{aligned} Asset\ growth_{i,j,t} = {} & \alpha + \beta_1 MPI_{\ j,t} + \beta_2 CompetitionLevel_{\ j} + \beta_3\ MPI_{\ j,t} \\ & \times CompetitionLevel_{\ j} + \beta_4 GDPG_{\ j,t} + \beta_5\ MPI_{\ j,t} \\ & \times GDPG_{\ j,t} + \beta_6 CompetitionLevel_{\ j} \times GDPG_{k,t} \\ & + \beta_7 CompetitionLevel_{\ j} \times MPI_{k,t} \times GDPG_{k,t} \\ & + \gamma BSOC_{i,k,t-1} + \varepsilon_{i,t} \end{aligned} \quad (1)$$

where: Asset $growth_{i,j,t}$—asset growth of the i-th bank in country j in moment t; $CompetitionLevel_j$—competition intensity in the banking sector in country j. We will use two types of this measure, in separate models, *High competition* and *Low competition*, as defined in the previous paragraph; BC—the measure of the business cycle, proxied with real GDP growth rate; MPI—dummy variable denoting whether the macroprudential policy instrument is applied (or not) in a given country or the number of macroprudential policy instruments applied (in models with aggregated measure of MPI); BSOC—bank-specific and other control variables, which include loans growth rate, deposits growth rate, loans to customer deposits (as a proxy for liquidity risk), growth of leverage and logarithm of assets (to proxy bank size), lagged asset growth and the country level Lerner index.

The β1 regression coefficient on MPI informs about asset growth in countries using macroprudential policy instruments. Following previous evidence, mostly on credit growth (Aiyar et al. 2014; Gomez et al. 2020) and some on asset growth (Claessens et al. 2014), we expect a negative coefficient on this coefficient as denoting reduced growth in countries using macroprudential instruments. In models in which we will include interaction term between *MPI* and *Competition level* this coefficient informs about the role of MPI in countries in which competition level as defined in the interaction is equal to 0. If we consider *High competition* in the interaction, this coefficient on MPI informs about asset growth in low and medium level competition countries.

The β_2 is our measure of the role of competition level in asset growth. A positive (negative) sign on high (low) competition denotes increased asset growth in more competitive banking sectors. In models including interaction term between *MPI* and

Competition level this coefficient informs about the role of High (low) competition in countries in which macroprudential instruments are not applied (i.e. MPI = 0).

The β_3 on the interaction term between *MPI* and *Competition level* informs about the asset growth in countries using macroprudential instruments (*MPI* = 1) under given competition intensity. Thus, if competition is high and this coefficient is positive, it implies that in countries using macroprudential instruments asset growth is increased in high competition countries. This would be our test of hypothesis H1. In contrast, a negative coefficient on this term informs about decreased asset growth in countries applying macroprudential policy instruments in highly competitive banking industry. Such a result is a support for hypothesis H2.

The β_4 on GDPG informs about sensitivity of asset growth to business cycle. A positive (negative) sign denotes procyclicality (countercyclicality) of asset growth. Following previous research (mostly) on bank credit growth (Lim et al. 2011; Cerutti et al. 2017; Gambacorta and Murcia 2020) we expect a positive effect of business cycle on asset growth.

The β_5 coefficient on double interaction term between *MPI* and *GDPG* informs about the sensitivity of asset growth to business cycle in countries using macroprudential policy instruments and in which the competition intensity measure equals 0. Although macroprudential policy instruments are expected to reduce procyclicality, Danielsson et al. (2016) suggest that their final effect may be increased procyclicality. Thus, in such a case, we expect to obtain a positive coefficient on GDPG. However, as Danielsson's et al. (2016) focus mainly on cyclical instruments, we envisage that the results may differ between cyclical and resilience-oriented instruments.

The β_6 on double interaction term of *Competition level* and *GDPG* informs about the sensitivity of asset growth to business cycle under high (low) competition in the banking industry in countries which do not use macroprudential instruments (i.e. *MPI* = 0). Following Leroy and Lucotte (2019) for credit growth in individual banks in European countries, we expect that increased competition reduces procyclicality of asset growth. Thus, this coefficient will be negative for interaction between *High competition* and *GDPG* and positive for interaction between *Low competition* and *GDPG*.

The β_7 on triple interaction term between *MPI* and *Competition level* and *GDPG* informs about the sensitivity of assets growth to business cycle in countries using macroprudential policy instruments and differing in terms of competition intensity (high versus low competition). Looking first at High competition, we expect a negative coefficient if increased competition reduces procylicality of asset growth in countries using MPI. This would be in line with hypothesis H2. In contrast, a positive coefficient on this term would be in line with hypothesis H1, that increased competition is associated with more procyclicality of banking growth in countries using macroprudential policy. We expect that the role of competition level may differ between cyclical and resilience oriented instruments.

In the estimation of baseline version of model expressed with Eq. (1) we do not include interaction terms, and only use bank level asset growth regressed on bank level control variables real GDP growth and Lerner. We shall use several estimation

techniques in base estimations, i.e.: ordinary least squares panel estimation (OLS), FE and RE as well as we use a simple dynamic identification scheme based on Blundell and Bond's (1998) GMM approach. The proper use of GMM models requires robust selection of instruments (Roodman 2009). Considering the heterogeneity of the sample applied in our study, this requirement is difficult to fulfill. Thus, the GMM approach will not be applied in our analysis.

As in our estimations we use time invariant variables to measure intensity of competition (*High competition and Low competition*) and to identify the use of individual macroprudential policy instruments (such as ltv_cap, dti, etc.), the fixed effects estimator is also not adequate, because we will not be able to show the regression coefficients on both, competition dummies and individual macroprudential policy instruments. We need these coefficients (β_1, β_2) to test our hypotheses about the role of macroprudential instruments and of competition level in the asset growth. Therefore, in the final estimations of Eq. (1) we shall use the robust random effects estimator.

In our analysis we use both individual macroprudential policy and aggregated macroprudential policy indices (i.e. borrower and financial). Therefore in our analysis we will run separate models for aggregated tools. This analysis will inform us about the role of more intensive use of macroprudential policy (in terms of the number of instruments applied) in asset growth and in sensitivity of asset growth to business cycle. We will also run models expressed with Eq. (1) for each individual macroprudential instrument.

3.2 Data

We use pooled cross-section and time series data of individual banks' balance-sheet items and profit and loss accounts from over 90 countries and country-specific macroeconomic indicators for these countries, over a period from 2004 to 2016. The data on commercial banks are taken from unconsolidated financials available in the Bankscope database, whereas the macroeconomic data were accessed from the World Bank and the IMF web pages. We apply several filters to remove potential data errors and outliers. We exclude outlier banks from our sample by eliminating the extreme bank-specific observations when a given variable adopts extreme values (e.g. negative capital ratios which may be the result of misreporting or other data problems). Due to the fact that we are interested in the role of macroprudential policy in reducing the growth of banking activity or in reducing the procyclicality of the banking activity, we focus on those banks for which we have at least 6 years of observations on asset growth (and loans growth)—to take into account the whole business cycle. Our final sample consists of over 90,000 observations (over 9000 banks) (see Table 1, PANEL A) operating in 107 countries (see Table 6 in Appendix).

We conduct our analysis for the whole sample of countries instead of using country subsamples (e.g. Asia, European Union, Latin America, or high versus

low income countries), because we need to have access to data about diversity across countries in terms of competition intensity (high versus low competition) and of the use of macroprudential policy instruments. In our sample we have over 30 countries denoted as High competition countries and over 30 countries with low competition intensity. The other countries are denoted as having medium level of competition. The use of macroprudential instruments has evolved in the period of analysis years, with more countries using greater range of instruments recently. Considering this we need to use as more countries as possible to be able to identify relively large subsamples covering more and less competitive banking industries. In previous research it would be interesting to test the role of country clustering to find out how this affects the links between competition and cyclicality of banking activity in countries using macroprudential policy instruments.

Table 1 (PANEL A) provides some descriptive statistics about variables in our estimation sample. Looking at variable of interest to our study we find that the mean asset growth equals to 7.66%, suggesting that on average banking sectors tend to grow. The correlations indicate at statistically-significant association between asset growth and each of the explanatory variables. In particular, the correlation coefficient for GDPG is positive, suggesting that asset growth is procyclical. The correlation between asset growth and Lerner index is (see Table 1, PANEL B) is positive, suggesting that increases in competition are related with decreased asset growth. Of macroprudential policy instruments, mainly restrictions targeted at bank balance-sheets (Financial) tend to be negatively correlated with asset growth, which may potentially imply that they work countercyclically.

4 Estimation Results

4.1 Baseline Results

Table 2 reports the base results. The coefficients on bank-specific control variables are largely as expected when significant. Banks with higher values of loans to deposits, which is a proxy for liquidity risk, grow faster. This means that greater liquidity risk is related with increased asset growth. Leverage does not affect bank asset growth in our sample. Large banks are growing faster because regression coefficient on bank size (proxied with bank assets) is positive and statistically significant in all estimations presented in Table 2. Bank asset growth is procyclical because in all statistically significant specifications in Table 2, the coefficient on *GDPG* is positive, and ranges between 0.11 and 0.13. Looking now at the role of macroprudential policy in reducing asset growth we find that both, borrower targeted macroprudential policy index which covers instruments targeted on taming the risk-taking by borrowers (Borrower) as well as macroprudential index which covers instruments targeted on taming the risk-taking by financial institutions, in particular by banks (Financial) reduce asset growth, with stronger effect of Borrower than

Table 1 Descriptive statistics (PANEL A) and correlation matrix (PANEL B) for the full sample

Variable	Δassets	Δloan	Δdeposits	loans/deposits	Capital ratio	Log (assets)	GDPG	Lerner	borrower	financial
Panel A: Descriptive statistics										
Mean	7.66	8.08	7.66	100.99	−0.54	12.53	2.30	0.22	0.04	1.84
Std. dev.	22.03	31.73	31.63	103.43	13.03	1.87	2.87	0.30	0.23	1.12
Min	−661.91	−777.38	−830.50	0.00	−946.52	3.65	−14.81	−8.66	0.00	0.00
Max	687.32	906.47	978.71	999.93	518.4	21.89	34.50	0.94	2.00	5.00
No of obs.	95,240	95,024	95,109	94,019	74,840	972,630	109,908	108,350	109,944	1,099,440
No of banks	9154	9150	9152	9074	7983	9155	9159	9145	9162	9162
Panel B: Correlation matrix										
Δassets	1									
Δloan	0.69***	1								
Δdeposits	0.83***	0.63***	1							
loans/deposits	0.03***	0.05***	−0.02***	1						
Capital ratio	−0.33***	−0.55***	−0.51***	−0.02***	1					
Log(assets)	0.06***	0.03***	0.04***	−0.02***	0.04***	1				
GDPG	0.17***	0.17***	0.12***	0.07***	0.00	0.05***	1			
Lerner	0.03***	0.02***	0.02***	−0.03***	−0.01	−0.06***	0.06***	1		
borrower	0.00	0.00	0.00	0.06***	0.00	0.08***	0.06***	0.02***	1	
financial	−0.05***	−0.04***	−0.02***	−0.17***	0.02***	−0.21***	−0.03***	0.25***	0.05***	1

*, **, *** denote an estimate significantly different from 0 at the 10%, 5% and 1% levels, respectively

Table 2 Baseline results

	OLS	FE	RE	GMM	RE	RE	GMM	GMM
	1	2	3	4	5	6	7	8
Δassets(t−1)	0.027***	0.011***	0.019***	0.027**	0.019***	0.019***	0.023	0.024*
	(0.001)	(0.001)	(0.001)	(0.011)	(0.001)	(0.001)	(0.014)	(0.014)
Δloan	0.108***	0.104***	0.107***	0.035	0.107***	0.106***	0.048	0.04
	(0.001)	(0.001)	(0.001)	(0.048)	(0.001)	(0.001)	(0.041)	(0.039)
Δdeposits	0.732***	0.731***	0.729***	0.777***	0.732***	0.732***	0.752***	0.749***
	(0.002)	(0.002)	(0.002)	(0.036)	(0.002)	(0.002)	(0.05)	(0.052)
loans/deposits	0.001	0.005***	0.002***	0.018	0.003***	0.002***	0.03**	0.024*
	(0)	(0.001)	(0.001)	(0.016)	(0.001)	(0.001)	(0.014)	(0.013)
Capital ratio	0.217***	0.205***	0.211***	0.064	0.214***	0.214***	0.029	0.01
	(0.003)	(0.003)	(0.003)	(0.067)	(0.003)	(0.003)	(0.096)	(0.066)
log_assets	0.076***	0.804***	0.109***	0.262	0.118***	0.103***	0.085	0.077
	(0.012)	(0.069)	(0.017)	(0.28)	(0.017)	(0.018)	(0.421)	(0.381)
GDPG	0.15***	0.115***	0.131***	0.11***	0.131***	0.133***	0.124***	0.12***
	(0.008)	(0.01)	(0.009)	(0.031)	(0.009)	(0.009)	(0.032)	(0.033)
borrower					−0.312		−1.609	
					(0.2)		(3.155)	
financial						−0.144***		0.033
						(0.028)		(0.115)
Lerner					0.74***	0.844***	−0.357	−0.516
					(0.08)	(0.082)	(0.581)	(0.5)
cons	−0.628***	−9.791***	−1.025***	−4.102	−1.384***	−0.899***	−2.654	−2.102
	(0.143)	(0.864)	(0.214)	(3.14)	(0.22)	(0.237)	(4.625)	(4.4)
p-value F test	0.00	0.00						
p-value Wald test			0.00		0.00	0.00		

p-value Sargan test				0.00			0.00	0.00
p-value AR(2) test				0.01			0.02	0.01
R-sq: within		0.87	0.87		0.87	0.87		
R-sq: between		0.89	0.90		0.90	0.89		
R-sq: overall	0.88	0.88	0.88		0.88	0.88		
No of observations	73,650	73,650	73,650	73,650	73,066	73,066	73,066	73,066
No of banks		7942	7942	7942	7918	7918	7918	7918
No of instruments				193			193	193

t-Statistics are included in parentheses. *, **, *** denote an estimate significantly different from 0 at the 10%, 5% and 1% levels, respectively

Financial. Generally, our baseline results seem to be in line with previous evidence (see Claessens et al. 2014; Cerutti et al. 2017).

Looking at the link between Lerner index and asset growth we find that it is positive and ranges between 0.74 (see regression 5 in Table 2) and 0.84 (see regression 6 in Table 3), suggesting that higher levels of Lerner index (i.e. lower competition intensity) are related with higher asset growth. Therefore, we might expect that intense competition (i.e. low Lerner index) shall be related with decreased asset growth.

4.2 Competition Intensity and Bank Asset Growth and Sensitivity of Asset Growth to Business Cycle in Countries Applying Macroprudential Instruments

In Table 3 we present results of the analysis of the role of competition intensity and aggregated instruments of macroprudential policy—borrower and financial. Looking first at the role of macroprudential policy for asset growth we find that countries using more macroprudential policy instruments denote reduced asset growth, independent of the competition intensity (see columns 1–8 in Table 3). These results are line with previous evidence for asset growth (Claessens et al. 2014) and for bank lending activity, showing that macroprudential policy effective in reducing credit growth (Cerutti et al. 2017; Gomez et al. 2020; Gambacorta and Murcia 2020).

High competition intensity is related with increased asset growth in countries applying more financial instruments than low and medium level competition in the banking industry because the coefficient β_1 on financial is negative and statistically significant in less competitive countries (compare columns 2 and 6) than in more competitive countries (compare columns 4 and 8). This finding is further supported by the β_3 regression coefficient on double interaction term of *MPI x High competition* which is positive and statistically significant—taking the value of 0.39 (columns 2) and 0.291 (column 6). This result thus seems to support expectation expressed in hypothesis H1, that increased competition is associated with weakened effectiveness of macroprudential policy. But the results are binding only for financial index, because we do not find support for this view for countries using more borrower targeted instruments (ltv caps and dti). However, competition level does not matter significantly for the effects of borrower on asset growth.

Turning to analysis of procyclicality of asset growth we find that it is still supported with all regressions included in Table 3, because the β_4 regression coefficients on GDPG are positive and statistically significant. In line with suggestion of Danielsson et al. (2016) we find support for the view that countries using more macroprudential instruments exhibit increased procyclicality. In our study we find that β_5 regression coefficient on double interaction term of *MPI x GDPG* is positive and statistically significant in all models (see columns 5–8).

Table 3 Role of aggregated macroprudential policy indices in asset growth and in sensitivity of asset growth to business cycle under high (low) competition intensity

			High competition intensity		Low competition intensity		High competition intensity		Low competition intensity	
	MPI instrument:		borrower	financial	borrower	financial	borrower	financial	borrower	financial
			1	2	3	4	5	6	7	8
The role of MPI and competition for assets growth	MPI	β_1	−0.05	−0. 2323***	−0.263	−0.14***	−0.125	−0.329***	−0.268	−0.145***
			(0.285)	(0.033)	(0.214)	(0.028)	(0.285)	(0.034)	(0.215)	(0.028)
	High competition	β_2	−0.541***	−1.29***			−0.236**	−0.95***		
			(0.097)	(0.128)			(0.103)	(0.136)		
	MPI × High competition	β_3	−0.32	0.39***			0.419	0.291***		
			(0.401)	(0.084)			(0.521)	(0.102)		
	Low competition	β_2			0.282*	0.29			−0.526***	−0.73*
					(0.155)	(0.312)			(0.189)	(0.409)
	MPI × Low competition	β_3			−0.381	−0.048			−0.252	0.098
					(0.617)	(0.175)			(1.109)	(0.232)
Analysis of the role of MPI and competition for sensitivity of assets growth to business cycle	GDPG	β_4	0.129***	0.132***	0.128***	0.131***	0.154***	0.164***	0.101***	0.045***
			(0.009)	(0.009)	(0.009)	(0.009)	(0.01)	(0.02)	(0.009)	(0.017)
	MPI × GDPG	β_5					0.068***	0.003	0.026*	0.027***
							(0.014)	(0.007)	(0.015)	(0.006)

(continued)

Table 3 (continued)

			High competition intensity		Low competition intensity		High competition intensity		Low competition intensity	
	MPI instrument:		borrower	financial	borrower	financial	borrower	financial	borrower	financial
			1	2	3	4	5	6	7	8
	High competition × GDPG						−0.188***	−0.243***		
							(0.022)	(0.027)		
	MPI × High competition × GDPG	β_7					**−0.129**	**0.069*** **		
							(0.084)	(0.019)		
	Low competition × GDPG	β_6							0.169***	0.199***
									(0.027)	(0.05)
	MPI × Low competition × GDPG	β_7							−0.023	−0.009
									(0.182)	(0.031)
	Wald test p-value		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	R-sq: overall		0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
	No of observation		73,066	73,066	73,066	73,066	73,066	73,066	73,066	73,066
	No of banks		7918	7918	7918	7918	7918	7918	7918	7918

Notes: This table presents a reduced view of model Eq. (1). Regression coefficients correspond to β_1–β_7 as presented in Sect. 3.1; t-statistics are included in parentheses. *, **, *** denote an estimate significantly different from 0 at the 10%, 5% and 1% levels, respectively

In line with findings of Leroy and Lucotte (2019), our results give support to the view that more competitive banking industry is associated with decreased procyclicality. As we can see, the β_6 regression coefficients are negative and statistically significant in more competitive banking industry (see the interaction term of *High competition x GDPG*) and positive and statistically significant in low competition industries (see the interaction term of Low competition x GDPG).

Intense competition is associated with decreased procyclicality of assets growth in countries using more Borrower instruments, because the β_7 regression coefficient on triple interaction of *MPI x High competition x GDPG* is negative and statistically significant. This results seems to support hypothesis H2, that intense competition reduces the risk of bank assets, and thus increases the effectiveness of macroprudential policy to reduce procyclicality. In contrast, for countries using more Financial instruments we find support for hypothesis H1 that intense bank competition is associated with increased procyclicality in countries using more such instruments.

In Tables 4 and 5 we present the effects of macroprudential policy on cyclicality of asset growth for each instrument one by one. We present separate analysis for cyclical instruments in Table 4 (as defined in previous research, e.g. by Altunbas et al. 2018) and for resilience-oriented tools in Table 5. Therefore we omit the analysis of the role of competition intensity for asset growth (regression coefficients from β_1 to β_3).

For the sake of simplicity we shall focus here on the links between macroprudential policy instruments and the sensitivity of asset growth to business cycle. As the results for β_4–β_6 confirm our analysis presented for Table 3, we shall concentrate only on β_7 to find out how competition affects the procyclicality of assets growth in countries using individual macroprudential instruments. Intense competition in the banking industry is associated with decreased procyclicality of assets growth in countries using ltv caps, dti, fc and rr rev, because the regression coefficients on triple interaction terms of *MPI x High competition x GDPG* are negative (columns 1, 2, 3 and 5 in Table 4)—ranging between −0.74 and −0.251, and significant (but for ltv cap, in column 1). Such a result is in line with hypothesis H2, that intense competition reduces procyclicality of assets of banks in countries applying macroprudential instruments. This expectation is further supported for low competition in the banking industry in countries using dti, because the β_7 regression coefficient is positive and significant at 10%.

Turning our attention to resilience-oriented macroprudential instruments (see Table 5) we find support for hypothesis H1, that intense competition increases procyclicality of asset growth in countries using dp, lev, inter and conc because the β_7 coefficients on triple interaction terms of *MPI x High competition x GDPG* are positive and statistically significant. This result is additionally supported in less competitive banking sectors in countries using conc, because the β_7 on the triple interaction term is negative and statistically significant and equals −0.511.

Two individual macroprudential policy instruments work countercyclically independent of the competition level. They include fc (see columns 3 and 8 in Table 4) and tax (see columns 5 and 10 in Table 5). Foreign currency limit are associated with stronger reduction in procycality of asset growth in low competition countries than

Table 4 Role of competition intensity for the links between individual cyclical macroprudential policy instruments and asset growth and association between cyclical instruments ant sensitivity of asset growth to business cycle

			Role of high competition intensity					Role of low competition intensity				
	MPI instrument:		ltv cap	dti	fc	cg	rr rev	ltv cap	dti	fc	cg	rr rev
			1	2	3	4	5	6	7	8	8	10
The role of MPI and competition for assets growth	MPI	β_1	−1.246***	−1.526***	−0.968***	0.864	−0.807**	−0.824***	0.204	−1.441***	−0.023	−0.297
			(0.27)	(0.39)	(0.353)	(0.632)	(0.35)	(0.238)	(0.313)	(0.308)	(0.506)	(0.293)
	High competition	β_2	−0.293***	−0.294***	−0.239**	−0.25**	−0.335***					
			(0.104)	(0.104)	(0.103)	(0.104)	(0.105)					
	MPI × High competition	β_3	1.286***	2.383***	0.701	−0.75	1.742***					
			(0.464)	(0.537)	(0.583)	(0.812)	(0.528)					
	Low competition	β_2						−0.568***	−0.383*	−0.696***	−0.64***	−0.424**
								(0.196)	(0.196)	(0.191)	(0.194)	(0.202)
	MPI × Low competition	β_3						0.23	−1.64***	4.818***	1.55*	−0.14
								(0.615)	(0.624)	(0.943)	(0.827)	(0.602)
Analysis of the role of MPI and competition for sensitivity of assets growth to business cycle	GDPG	β_4	0.153***	0.156***	0.161***	0.167***	0.151***	0.1***	0.102***	0.098***	0.103***	0.099***
			(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.009)	(0.009)	(0.009)	(0.01)
	MPI × GDPG	β_5	0.212***	0.261***	0.163***	−0.05	0.207***	0.098**	0.008	0.127***	−0.03	0.076*
			(0.038)	(0.049)	(0.046)	(0.082)	(0.035)	(0.043)	(0.058)	(0.045)	(0.097)	(0.043)
	High competition × GDPG	β_6	−0.198***	−0.192***	−0.18***	−0.202***	−0.187***					
			(0.022)	(0.022)	(0.022)	(0.022)	(0.023)					

	MPI × High competition × GDPG		**−0.074**			**0.172**	**−0.22*** **					
			(0.08)	(0.084)	(0.093)	(0.128)	(0.077)					
	Low competition × GDPG	β_6						0.149***	0.161***	0.205***	0.199***	0.156***
								(0.029)	(0.029)	(0.026)	(0.026)	(0.029)
	MPI × Low competition × GDPG	β_7						**0.062**	**0.169***	**−0.559*** **	**−0.16**	**0.04**
								(0.08)	(0.087)	(0.13)	(0.129)	(0.068)
	Wald test p-value		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	R-sq: overall		0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
	No of observation		73,066	73,066	73,066	73,066	73,066	73,066	73,066	73,066	73,066	73,066
	No of banks		7918	7918	7918	7918	7918	7918	7918	7918	7918	7918

Notes: This table presents a reduced view of model Eq. (1). Regression coefficients correspond to β_1–β_7 as presented in Sect. 3.1.; t-statistics are included in parentheses. *, **, *** denote an estimate significantly different from 0 at the 10%, 5% and 1% levels, respectively

Table 5 Role of competition intensity for the links between individual resilience oriented macroprudential policy instruments and asset growth and association between cyclical instruments ant sensitivity of asset growth to business cycle

			Role of high competition intensity					Role of low competition intensity				
	MPI instrument:		dp	lev	inter	conc	tax	dp	lev	inter	conc	tax
			1	2	3	4	5	6	7	8	8	10
The role of MPI and competition for assets growth	MPI	β_1	−1.314***	0.629***	0.318**	0.36	−3.101***	−0.55	0.306***	−0.472***	0.396***	−0.835***
			(0.423)	(0.141)	(0.151)	(0.224)	(0.514)	(0.612)	(0.097)	(0.107)	(0.105)	(0.14)
	High competition	β_2	−0.231**	0.281*	0.449**	−0.045	0.057					
			(0.103)	(0.156)	(0.182)	(0.242)	(0.127)					
	MPI × High competition	β_3	−0.988	−1.296**	−0.897***	−0.342	2.626***					
			(1.543)	(0.625)	(0.221)	(0.328)	(0.541)					
	Low competition	β_2						−0.463**	−0.388*	−0.834***	−1.23**	−0.749***
								(0.195)	(0.201)	(0.212)	(0.503)	(0.19)
	MPI × Low competition	β_3						−0.583	−0.918	−0.186	0.66	4.299***
								(0.877)	(0.982)	(0.607)	(0.541)	(1.277)
Analysis of the role of MPI and competition for sensitivity of assets growth to business cycle	GDPG	β_4	0.159***	0.277***	0.249***	0.26***	0.161***	0.103***	0.09***	0.081***	−0.053***	0.118***
			(0.01)	(0.018)	(0.019)	(0.034)	(0.01)	(0.009)	(0.015)	(0.017)	(0.019)	(0.01)
	MPI × GDPG	β_5	0.223***	−0.154***	−0.112***	−0.099***	0.423***	−0.023	0.025	0.032	0.197***	−0.086**
			(0.054)	(0.021)	(0.022)	(0.035)	(0.064)	(0.138)	(0.019)	(0.02)	(0.022)	(0.042)
	High competition × GDPG	β_6	−0.186***	−0.312***	−0.214***	−0.392***	−0.141***					
			(0.021)	(0.026)	(0.029)	(0.041)	(0.025)					

	MPI × High competition × GDPG		**0.309**	**0.595*****	**0.052*****	**0.439*****						
			(0.362)	(0.151)	(−0.55)	(0.058)	(0.081)					
	Low competition × GDPG	β_6						0.157***	0.194***	0.197***	0.629***	0.174***
								(0.029)	(0.028)	(0.03)	(0.079)	(0.026)
	MPI × Low competition × GDPG	β_7						**0.193**	**0.141**	**0.149**	**−0.511*****	**−0.252***
								(0.156)	(0.13)	(0.107)	(0.084)	(0.147)
	Wald test p-value		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	R-sq: overall		0.88	0.89	0.89	0.89	0.88	0.88	0.89	0.88	0.89	0.88
	No of observation		73,066	73,066	73,066	73,066	73,066	73,066	73,066	73,066	73,066	73,066
	No of banks		7918	7918	7918	7918	7918	7918	7918	7918	7918	7918

Notes: This table presents a reduced view of model Eq. (1). Regression coefficients correspond to β_1–β_7 as presented in Sect. 3.1.; t-statistics are included in parentheses. *, **, *** denote an estimate significantly different from 0 at the 10%, 5% and 1% levels, respectively

in high competition countries, because the β_7 the triple interaction term of MPI x Low competition x GDPG is higher in absolute terms than respective coefficient on MPI x High competition x GDPG. The opposite result is found for tax, which is associated with stronger reduction of procyclicality in more competitive banking industries.

5 Conclusions

This paper attempts to find out what is the role of competition in the effects of macroprudential policy in a cross-country sample of commercial banks in the period of 2004–2016. We focus on two areas of work of macroprudential policy that may be potentially affected by competition. The first one is the area of banking activity growth proxied with asset growth. The other is procyclicality proxied with the link between bank asset growth and business cycle.

Our results show that competitive environment in the banking industry does affect the conduct of macroprudential policy. High competition is associated with increased asset growth in countries applying more macroprudential policy instruments affecting risk taking by banks.

The association between competition and effects of macroprudential policy on sensitivity of asset growth to business cycle differs between cyclical and resilience-oriented tools. Intense competition in the banking industry is associated with decreased procyclicality of assets growth in countries using cyclical instruments including loan to value caps, debt to income ratios, credit growth limits and reserve requirements. Such a result is line with competition-stability hypothesis, that intense competition reduces procyclicality due to declined risk-taking incentives of banks in more competitive industries.

In contrast, more competitive banking industry is associated with increased procyclicality of asset growth in countries using resilience-oriented tools. Thus, for these tools competition—fragility hypothesis is supported. In particular, this expectation is verified in countries using dynamic provisions, leverage limits, interbank transaction limits and concentration limits.

Our results therefore imply that the conduct of macroprudential policy may be affected by the intensity of competition in the banking industry. However, the association between competition and effects of macroprudential policy instruments on cyclicality of banking growth depends on the type of instrument.

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Appendix

Table 6 Descriptive statistics per country

Country	Obs	Δassets	GDPG	Lerner_index	borrower	financial	Country	Obs	Δassets	GDPG	Lerner_index	borrower	financial
ALBANIA	77	19	3.55	0.26	0	0.42	KENYA	260	16.84	5.33	0.37	0	2
ALGERIA	142	16.87	3.29	0.53	1.42	1	KOSOVO	10	14.17	3.85	0	0	2
ANGOLA	108	31.67	9.72	0.41	0	1.58	KUWAIT	20	10.13	3.82	0.56	0	2
ARGENTINA	532	9.21	4.23	0.27	0	5	KYRGYZSTAN	34	27.07	4.5	0.44	0	2
ARMENIA	133	27.39	5.69	0.32	0	3	LAO PEOPLE'S DEM. REP.	12	25.17	7.71	0	0	2
AZERBAIJAN	106	33.84	11.03	0.3	0	0.69	LATVIA	171	13.04	3.06	0.31	0	2
BAHAMAS	41	1.69	0.62	0.34	0	0	LEBANON	135	14.11	4.77	0.04	0	2
BAHRAIN	43	16.23	5	0.28	0	3.07	LESOTHO	27	13.63	4.13	0	0	2
BANGLADESH	267	18.38	6.15	0.23	0	3.83	LITHUANIA	77	14.49	3.43	0.24	0	2
BELARUS	71	21.71	5.32	0.26	0	3.83	MACEDONIA (FYROM)	112	12.62	3.48	0.3	0	1.33
BELGIUM	186	4.43	1.49	0.14	0	3.32	MALAWI	44	10.23	5.52	0.25	0	1
BELIZE	18	10.95	2.89	0.29	0	1	MALAYSIA	255	9.84	5.1	0.2	0	1
BHUTAN	22	10.01	7.37	0	0	1	MALTA	52	9.72	3.4	0.28	0	1
BOTSWANA	72	17.78	4.61	0.21	0	0	MAURITIUS	135	14.24	4.37	0.37	0	1
BRAZIL	691	15.16	3.11	0.22	0	0	MEXICO	142	20.22	2.4	0.62	0	1
BRUNEI DARUSSALAM	11	6.91	0.33	0	0	0	MONGOLIA	11	28.11	8.52	0.6	0	1
BULGARIA	150	16.59	3.27	0.34	0	0	MONTENEGRO	70	23.31	3.11	0.02	0	1
BURUNDI	28	16.89	3.48	0.32	0	0	MOROCCO	45	9.07	4.43	0.26	0	1
CAMBODIA	118	23.38	7.77	0.38	0	0	MOZAMBIQUE	99	19.17	7.43	0.25	0	1
CANADA	97	12.42	1.94	−0.02	0	0.4	NEPAL	233	18.66	4.34	0.18	0	1.14
CAPE VERDE	42	11.61	4.55	0	0	0.67	NETHERLANDS	160	10.01	1.24	0.14	0	0.47
CHILE	85	17.32	4.29	0.23	0.71	1.43	NEW ZEALAND	88	9.51	2.45	0.18	0	0

(continued)

Table 6 (continued)

Country	Obs	Δassets	GDPG	Lerner_index	borrower	financial	Country	Obs	Δassets	GDPG	Lerner_index	borrower	financial
CHINA	881	23.81	9.79	0.35	0.04	1.71	NORWAY	85	11.53	1.68	0.38	0.06	0.44
COSTA RICA	148	15.72	4.23	0.25	0	2	PAKISTAN	216	11.09	4.35	0.17	0	0.64
CROATIA	282	8.48	0.87	0.28	0.02	1.74	PARAGUAY	135	21.16	4.73	0.19	0	0.92
CURACAO	19	15.57	0	0.3	0.08	1.33	PERU	140	18.97	5.82	0.3	0	1.93
CYPRUS	45	6.92	1.08	0.3	0.06	1.78	PHILIPPINES	219	14.08	5.49	0.21	0	0.52
CZECH REPUBLIC	138	10.81	2.71	0.36	0	2.15	POLAND	275	13.18	3.97	0.31	0.67	0.73
DEM. REPUBLIC OF CONGO	71	22.02	6.62	0.14	0	3	PORTUGAL	150	−0.03	0.12	0.19	0	1
DOMINICAN REPUBLIC	329	14.27	5.54	0.12	1.24	2.81	REPUBLIC OF KOREA	132	7.82	3.71	0.32	0	1
ECUADOR	186	11.69	4.41	0.23	0.5	1.33	REPUBLIC OF MOLDOVA	111	16.9	4.29	0.3	0	1
ELSALVADOR	104	6.26	2.11	0.38	0.5	1.33	ROMANIA	147	18.11	3.4	0.25	0	1.81
ESTONIA	32	2.59	2.85	0.24	0.5	1.33	RUSSIAN FEDERATION	7116	10.02	3.4	0.21	0.06	1.15
ETHIOPIA	84	15.53	10.91	0.54	0.5	1.33	SAINT KITTS AND NEVIS	22	11.04	2.75	0	0	1
FINLAND	67	6.2	0.94	0.09	0.5	1.33	SERBIA	239	16.58	2.51	0.2	0	1
FRANCE	907	5.91	1.1	0.2	0.47	1.39	SINGAPORE	80	8.31	6.09	0.77	0	1
GAMBIA	20	14.23	3.41	0.24	0	0.42	SLOVAKIA	57	7.53	4.09	0.27	0	1
GEORGIA	17	10.72	5.55	0.31	0	0.42	SLOVENIA	126	3.82	1.65	0.21	0	1
GERMANY	10,775	4.02	1.39	−0.11	0.01	0.4	SOUTH AFRICA	130	8.07	3.05	0.16	0	1
GHANA	148	21.34	6.88	0.37	0	0	SPAIN	254	9.96	0.96	0.33	0	1
HAITI	6	10.14	1.58	0.18	0	0	SRILANKA	130	16.7	6.21	0.22	0	1
HONDURAS	177	13.22	4.02	0.26	0	0	SWEDEN	193	9.34	2.19	0.32	0	1
HONGKONG	246	7.91	4.23	−1.06	0	0	SWITZERLAND	962	8.39	2.1	0.16	0.2	0.53
HUNGARY	104	7.36	1.53	0.22	0	0	TAJIKISTAN	22	27.81	7.08	0	0	0
ICELAND	6	4.58	2.88	0.21	0	0	THAILAND	214	13.47	3.68	0.39	0.85	1.7

INDIA	566	14.57	7.75	0.27	0	0	TRINIDAD AND TOBAGO	26	12.33	3.14	0.35	1	2
INDONESIA	477	15.67	5.59	0.36	0	0	TUNISIA	128	5.54	3.46	0.43	1	2
IRELAND	71	7.69	4.6	0.25	0	0	TURKEY	185	10.8	5.92	0.21	1	2
ISRAEL	88	7.04	3.87	0.22	0	0	UGANDA	123	15.95	6.72	0.28	1	2
ITALY	555	7.58	−0.14	0.14	0	1.07	UKRAINE	284	10.41	0.92	0.25	0.73	1.73
JAMAICA	45	4.21	0.26	0.34	0	2	UNITED ARAB EMIRATES	29	16.63	4.41	0.5	0	0
JAPAN	1343	2.21	0.81	0.36	0	2	UNITED KINGDOM	857	5.2	1.47	0.31	0	0
JORDAN	12	4.78	5.13	0.36	0	2	UNITED STATES OF AMERICA	59,138	6.67	1.83	0.27	0	2.41
KAZAKHSTAN	134	26.75	6.19	0.34	0	2							

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Systemic Risk in Selected Countries of Western and Central Europe

Marta Karaś and Witold Szczepaniak

1 Introduction

Monitoring and maintaining financial stability is one of the goals of central banks around the world. The experience shows that monetary authorities are even willing to adjust short- and medium-term inflation targets to avoid destabilization. Such an approach was uncommon before the global financial crisis. Financial stability authorities aim to oversee systemic risk. To be successful in this respect, they need to employ various methods to identify, measure, and manage risks that encompass the financial systems under their jurisdiction. To form informed views on risk, the regulators and supervisors should combine the probability aspect with the impact aspect. In simple terms, they need to know the likelihood, the expected magnitude, and the expected impact of risk materialization on the financial system and the real economy. Despite a heated dispute, no single golden standard on quantifying systemic exists (for an overview, see Bisias et al. (2012), Hattori et al. (2014), or Benoit et al. (2017) or Karaś (2019).

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M. Karaś (✉) · W. Szczepaniak
Department of Financial Investment and Risk Management, Wrocław University of Economics, Wrocław, Poland
e-mail: marta.karas@ue.wroc.pl

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The paper adds to the dispute by presenting the empirical results of systemic risk measured based on the changing prices of assets of systemically important financial institutions in the studied countries. The research is the first attempt to measure systemic risk with quantile-based methods for this particular set of countries using the data related to systemically important financial institutions and a methodology that compares the results on a cross-country level.

The layout of the paper is a follows. First, we define systemic risk and outline the methods of its quantification used in the study. Then we present and briefly discuss the results obtained for Germany, Poland, Slovakia, Hungary, Romania, and Bulgaria. We conclude with indications, suggestions, and further research ideas.

2 Relevant Definitions

Commonly, the literature defines financial stability by associating it with some lack of (negative) risk materialization or with the system's low sensitivity to adverse events (see, e.g., Cihak 2007; Liang 2013). Additionally, from the macroprudential viewpoint, one thinks of lowering the possible threat of the financial crisis.

Following this concept, we define systemic risk as a risk that "concerns a large part of the financial system or a significant number of financial institutions and is considered to disrupt the performance of the financial system and its functions, such as financial intermediation" (Smaga 2014, p. 4). This definition allows us to model systemic risk like the reaction of financial systems to low probability events (i.e., systemic triggers) related to the losses exceeding the Value at Risk at financial institutions.

We define the financial system as a system of interconnected financial institutions and markets (cf. Matysek-Jędrych 2007; Jajuga et al. 2017). More precisely, we treat each financial system as a collective of (only) Systemically Important Financial Institutions (SIFI). Each national macroprudential regulator identifies such institutions for their country, and we use these institutions in the study (see Table 2 in the Appendix). Therefore, we take the macroprudential approach, according to which only SIFIs play a prominent role in the transmission of the systemic risk triggers:

> Systemically Important Financial Institutions are institutions whose distress or disorderly failure, because of their size, complexity, and systemic interconnectedness, would cause significant disruption to the wider financial system and economic activity. To avoid this outcome, authorities have all too frequently had no choice but to forestall the failure of such institutions through public solvency support. (Financial Stability Board 2011, 1).

A crucial characteristic of the studied emerging financial systems is their structure. They are not very complex, with relatively small stock exchanges and a limited number of financial instruments in use. In effect, the intermediation of funds in these countries tends to concentrate in the banking sector. These characteristics are especially true for the emerging countries studied in this paper. Consequently, we

focus on the condition of the banking sector, which is the most relevant systemic risk area for the studied region.

3 Challenges of Quantile-Based Systemic Risk Measurement in Developing Europe

For emerging Europe, the banking sector is the most central part of the financial system and "the main source of risk for financial stability" (Karkowska 2013, 4). Moreover, in this region, foreign owners control over 90% of the total banking assets (Radulescu et al. 2018, 7–8). As a consequence, European emerging countries have relatively homogeneous financial systems, where foreign-owned banks are the primary credit suppliers (Dumicic 2018, 2).

In all analyzed countries (except Poland that has the most developed stock exchange in the sample), almost none of these foreign-owned banks are locally listed. This characteristic renders quantile-based systemic risk measures unsuitable since they require a rich pole of stock-market data. We overcome this issue by applying the methodology outlined in Karaś and Szczepaniak (2020).

Since 2015, the European Union requires national macroprudential bodies to identify Other Systematically Important Institutions (O-SIIs). These are the "institutions that, due to their systemic importance, are more likely to create risks to financial stability whilst maximizing private benefits through rational decisions [and] these institutions may bring negative externalities into the system and contribute to market distortions" (European Banking Authority 2014). Said identification is made based on Systemic Importance Scores (SIS).

The regulators in emerging Europe do not use quantile-based systemic risk measures that combine bank-level and market-level data. One exception is the National Bank of Poland that uses a relatively elaborate early warning model based on the estimated output gap (Narodowy Bank Polski 2019). Research-wise, only a handful of studies attempt to apply quantile-based systemic risk measures in the studied region. In all these cases, a significantly limited sample of systemically important banks was used: they exclude many foreign-owned banks that are not listed on the domestic stock exchanges. On the other hand, some of the studies include the banks that are not systemically important, potentially blurring the systemic risk view. Thus, the previous results are incomparable to the results presented in this paper.

Table 1 presents the overview of all the studies published in the last decade that use the described type of systemic risk measures for the region, to the best of our knowledge.

Table 1 indicates that previous studies were ineffective in capturing the effect of O-SIIs. In all cases except Poland, the O-SIIs fraction is marginal. The last column indicates that our methodology significantly increases the number of the analyzed OSII-s, making SRISK and CoVaR effectively applicable for Central and

Table 1 The systemic risk measures that combine bank-level and stock market data: application to selected emerging European countries

	Bulgaria	Hungary	Poland	Romania	Slovakia			
Number of O-SIIs in the system	10	8	12	9	5			
The number of analyzed O-SIIs per study:						Period	Frequency	Measure
Karkowska (2013)	3	1	8	1	0	2006–2012	Quarterly	CCA
Engle et al. (2019)	0	1	8	2	1	2000–2019	Monthly	SRISK
Jajuga et al. (2017)	2	1	8	2	2	2005–2016	Daily	SRISK, CoVaR
Andrieş et al. (2018)	3	1	9	2	2	2005–2012	Weekly	
This paper	9	6	8	7	4	2006–2018	Daily	

Source: own elaboration based on lists of O-SIIs 2015–2019 (European Banking Authority 2019) and sources cited in the table

South-Eastern Europe. The banks that remain beyond the scope of the study are institutions whose ownership structure changed during the sample period (due to, e.g., mergers) or is else incompatible with the assumed methods (e.g., credit unions).

4 Selected Risk Measures and Estimation Methods

The study applies two types of well-established quantile-based risk measures: one derived from Value at Risk and three based on Expected Shortfall. The models selected for the empirical analysis include[1]:

- Conditional VaR (CoVaR) (Adrian and Brunnermeier (2016); as modified by Karaś and Szczepaniak (2017, 2020)),
- Expected Shortfall, Marginal Expected Shortfall (Acharya et al. 2017),
- the Long Run Expected Shortfall of the system (Acharya et al. 2012),
- SRISK (Brownlees and Engle 2017).

The selection of these measures is not incidental. On the one hand, these measures have the advantage of having been successfully used to measure systemic risk around the time of the global financial crisis for advanced economies, such as e.g., the USA, the U.K., or France. Moreover, all the selected measures allow producing currency-valued outputs, providing transparent comparative results on a cross-country level.

Moreover, we expect these measures to produce varying results because they measure different aspects of systemic risk. CoVaR is a contagion-focused measure that measures risk conditionally on its co-occurrence in multiple financial institutions. At the same time, SRISK is a fragility-focused measure that depends heavily on leverage.

Finally, it is worth investigating whether the more complex measures, such as those mentioned above, give a different overview of systemic risk than the relatively more straightforward measures, such as the Expected Shortfall. Such property is reported for advanced economies (Acharya et al. 2017; Adrian and Brunnermeier 2016; Benoit et al. 2017; Brownlees and Engle 2017). However, it may not necessarily be valid for emerging markets.

We apply several computation modifications, inter alia, using[2]:

[1]This paper presents a fraction of a larger-scale research project and is based on the solutions developed and results obtained previously (c.f. Karaś and Szczepaniak 2017; Jajuga et al. 2017; Karaś and Szczepaniak 2020).

[2]The methodology has been developed in the course of the larger research project. A paralely printed paper (Karaś and Szczepaniak 2020) presents the details regarding mentioned modifications, their justification and the analysis on how the introduced changes affect the data input and output. It is an elaborate discussion incompatibile with the space limits and the nature of the current empirical paper, and as such it is beyond the scope of the study presented here.

– econometric GARCH models (as Engle et al. 2019),
– stock market data to obtain CoVaR values (same as Benoit et al. 2014 or Karaś and Szczepaniak 2017),
– Systemic Importance Scores for weights of financial institutions in the financial system model (Karaś and Szczepaniak 2020), and
– a set of proxying methods (Karaś and Szczepaniak 2020).

Marginal Expected Shortfall (MES) (Acharya et al. 2017) indicates the system's extreme contribution to systemic risk. Thus, MES indicates if the expected shortfall of the system S will change once the i entity's share in it changes in the extreme. It is the marginal measure of the Expected Shortfall (ES):

$$ES_{St}(C) = E_{t-1}(r_{St}|r_{St} < C) = \sum\nolimits_{i=1}^{N} w_{it} E_{t-1}(r_{it}|r_{St} < C),$$

where C—a quantile of the distribution of system returns r_S equal to $VaR_{s,t}^{q}$, for $q = 1\%$.

The Marginal Expected Shortfall (used to compute the Long Run MES (LRMES) in this study (c.f. Acharya et al. 2012) is defined as a partial derivative:

$$MES_{it}(C) = \frac{\partial ES_{St}(C)}{\partial w_{it}} = E_{t-1}(r_{it}|r_{St} < C).$$

LRMES equals:

$$LRMES_{it}(C) \approx 1 - \ exp\,(-\gamma \cdot MES_{it}(C)),$$

where γ—is the correcting factor relative to the length of the assumed horizon.

The SRISK (Brownlees and Engle 2017) determines the expected shortage of equity in the event of a systemic crisis. It is based on LRMES that indicates the expected decline in the equity of an institution if the equity of the financial system falls below the assumed marginal threshold (within the next 6 months). The following formula defines this measure:

$$SRISK_{it} = \ max\,[0; \mathrm{k}(D_{it} + (1 - LRMES_{it}(C))W_{it}) - (1 - LRMES_{it}(C))W_{it}],$$

where:

$D_{i,\,t}$—value of debt
$W_{i,\,t}$—market value of equity,
k—prudential capital fraction.

The last measure used in the study is CoVaR (Adrian and Brunnermeier 2016). It is a Conditional Value at Risk to the system, provided that there is a threat to the financial condition in the analyzed entity (cf. Benoit et al. 2014):

$$P\left(r_{St} \leq CoVaR_{St}^{q} | r_{it} \leq VaR_{it}^{q}\right) = q.$$

We apply Delta CoVaR (c.f. Karaś and Szczepaniak 2017) for empirical comparisons. It is the difference between the system's value at risk if the given financial institution is financially at risk and the system's value at risk if the financial position of the given entity is normal (average, for instance, median):

$$\Delta CoVaR_{it}^{q} = \left(CoVaR_{St}^{q} | r_{it} = VaR_{it}^{q}\right) - \left(CoVaR_{St}^{q} | r_{it} = VaR_{it}^{0.5}\right).$$

In order to estimate the analyzed systemic risk measures, a two-dimensional process of retaining the rates of return of the system S and institution i was adopted:

$$r_t = \sqrt{H_t}\upsilon_t,$$

where

r_t—the vector of $(r_{s,\,t}, r_{i,\,t})$,
H_t—the conditional variance-covariance matrix of the form:

$$H_t = \begin{pmatrix} \sigma_{St}^2 & \sigma_{it}\sigma_{St}\rho_{it} \\ \sigma_{it}\sigma_{St}\rho_{it} & \sigma_{it}^2 \end{pmatrix},$$

with a conditional standard deviation of the rate of return of the system σ_{St} and the institution σ_{it}, and the conditional correlation ρ_{it}; while υ_t is a vector $(\varepsilon_{it},\ \varepsilon_{St})$ of independent random variables with the same distribution, such that $E(\upsilon_t) = 0$ and $E\left(\upsilon_t \upsilon_t'\right) = I_2$ is a two by two unit matrix (cf. Benoit et al. 2014). Conditional volatility of the rates of return of the system σ_{st} and institution σ_{it} was estimated based on the GJR-GARCH model. In contrast, the conditional correlation of the institution and the system ρ_{it} is based on the GJR-GARCH DCC model (cf. Engle et al. 2019). To obtain the individual conditional expected value for the institution *i,* we use the estimator:

$$VaR_{it}^{q} = \sigma_{it} {F_i}^{-1}(q)$$

For the institution's contribution to the CoVaR of the system, we adopt the estimator:

$$\Delta CoVaR_{it}^{q} = \widehat{\gamma}\left(VaR_{it}^{q} - VaR_{it}^{0.5}\right),$$

where: $\widehat{\gamma} = \frac{\widehat{\rho_{it}}\widehat{\sigma_{St}}}{\widehat{\sigma_{it}}}$. The MES was estimated based on the estimator:

$$MES_{it}\left(VaR_{St}^{q}\right) = \widehat{\sigma}_{it}\widehat{\rho}_{it}\widehat{E}_{t-1}(\varepsilon_{St}|\varepsilon_{St} < \kappa) + \widehat{\sigma}_{it}\sqrt{1-\widehat{\rho}_{it}^{2}}\widehat{E}_{t-1}(\varepsilon_{it}|\varepsilon_{St} < \kappa),$$

where:

$$\widehat{E}_{t-1}(\varepsilon_{St}|\varepsilon_{St} < \kappa) = \frac{\sum_{t=1}^{T} K\left(\frac{\kappa-\varepsilon_{St}}{h}\right)\varepsilon_{St}}{\sum_{t=1}^{T} K\left(\frac{\kappa-\varepsilon_{St}}{h}\right)},$$

$$\widehat{E}_{t-1}(\varepsilon_{it}|\varepsilon_{St} < \kappa) = \frac{\sum_{t=1}^{T} K\left(\frac{\kappa-\varepsilon_{St}}{h}\right)\varepsilon_{it}}{\sum_{t=1}^{T} K\left(\frac{\kappa-\varepsilon_{St}}{h}\right)},$$

for $\kappa = \frac{VaR_{St}^{q}}{\sigma_{St}}$, $K(x) = \int_{-\infty}^{\frac{x}{h}} k(u)du$ for normal distribution density function $k(u)$ and $h = T^{\frac{-1}{5}}$. In turn, the long-term marginal shortfall for the surveyed institutions was determined based on the following estimator, as proposed originally by the authors of the SRISK measure:

$$LRMES_{it}(C) \approx 1 - exp\left(-18 \cdot MES_{it}(C)\right).$$

The measures put forward allow calculating the risk from the perspective of an individual financial institution. However, they can be used to measure the risk of the whole system (see: the applications developed by Jajuga et al. (2017, pp. 54–62) and by Karaś (2019)). This process is a two-step calculation. Firstly, we measure the risk of each OSII. Secondly, we aggregate the results, taking into account the relevance of the individual institutions in each financial system, proxied with their Systemic Importance Score. The choice of institutions follows the regulators' suggestions who identify OSIIs for the analyzed region (European Banking Authority 2019). The set of such largest and most interconnected financial institutions, i.e., the banks included in the study, is presented in Table 2 in the Appendix.

5 Empirical Results

The following section entails the discussion of the empirical results obtained in the course of the study. The sample period includes the years 2006–2018. Interesting sub-periods are:

- the global financial crisis,
- the public debt crisis,
- the related economic slowdown.

The raw data used for our calculations include the quotations from the stock markets. Data were obtained from the Thomson Reuters Datastream, while all the calculations were conducted in the MATLAB environment. In the remainder of the paper, we discuss the results ordered per the measurement method.

5.1 Expected Shortfall of the Financial Systems

Expected Shortfall (ES) of the financial system depicts the average of all the losses which are greater or equal to 1% Value at Risk, realized by financial institutions systemically important for a given country. Plotted as a time series, the aggregate ES shows the financial system's exposure to a loss, conditional on the institutions' equity being in distress relative to its average condition.

ES may be analyzed in nominal terms—we use local currencies, as the local perspective on risk is taken. This way, we observe the size of the total potential loss relative to the total financial institutions' equity value. Therefore, the levels of systemic risk measured with ES are high only when a distressful state concerns either a very large financial institution or many smaller institutions at the same time.

As presented in Fig. 1, we observe the most significant risk peaks around the global financial crisis for all the countries. The increased risk is also visible between 2010 and 2014. However, in this case, the moments of the risk peaking vary between the analyzed countries. The earliest reaction is observed for Germany and the latest for Bulgaria, suggesting that economic proximity to most indebted European countries might have worked as a catalyst for the distress. Notably, all countries recorded a significant lowering of volatility clustering and of the absolute level of risk after 2010.

The scale of systemic risk is closely related to the total value of assets in a given financial system. Thus, the highest risk peaks are significantly high in nominal terms for Germany, medium for Poland, and smaller for Bulgaria, Romania, Hungary, and Slovakia.[3] Nonetheless, when we refer these levels to the size of each economy, we see that the potential burden of systemic risk materialization in each of the countries is similar.

5.2 Long Run Marginal Expected Shortfall of the Financial Systems

Marginal Expected Shortfall measures the institution's expected equity loss when the market falls below a certain threshold over a given time horizon. If computed as an aggregate of all systemically important financial institutions in a given country, it indicates the total loss of the financial system conditional on a marginally probable systemic event. When the long-run perspective is considered, only the most pessimistic scenarios for the market return are considered, i.e., the market index falling by 40% over the next 6 months.

[3]The size of the highest peak observed for Slovakia is driven by one outlaying observation. Given the model specificity it cannot be excluded that it is a result of model risk materialization, and as such is not interpreted here. The remaining peaks correspond to fundamental events as is the case for all other observation for the remaining countries.

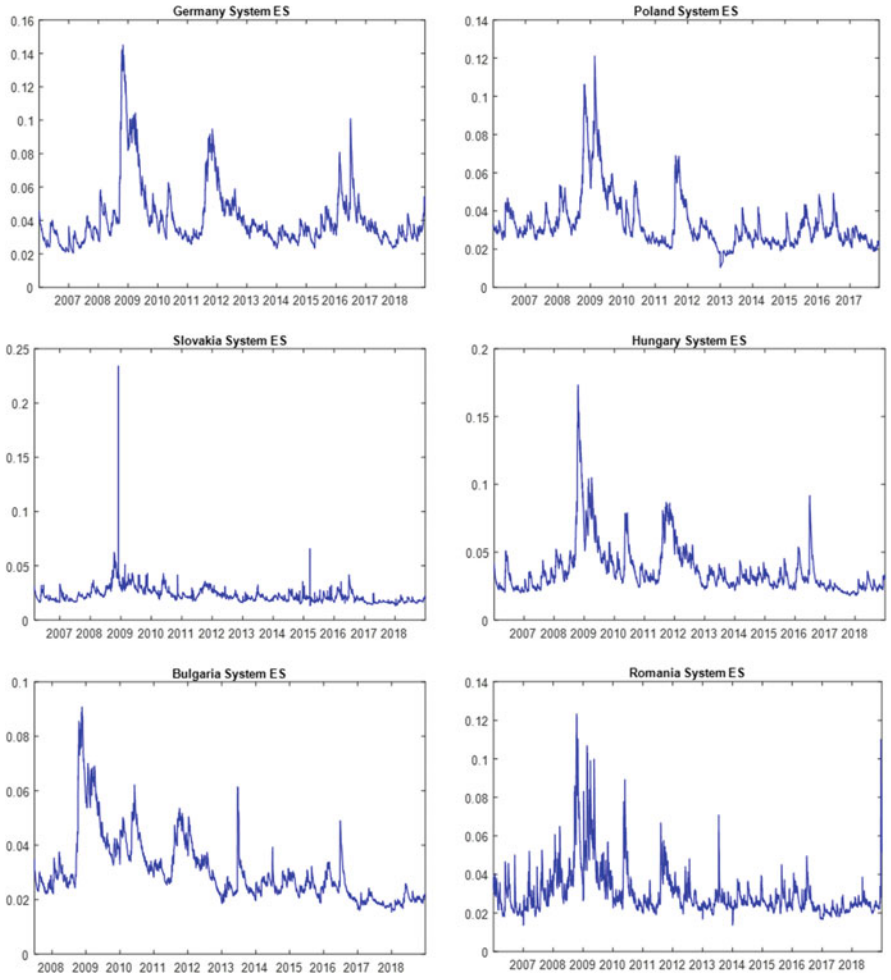

Fig. 1 ES of selected financial systems for years 2006–2018

The empirical results show an interesting pattern of relative changes in systemic risk. When we consider the marginal scenario, the potential losses are almost the same for all the analyzed counties. This observation suggests a high level of convergence between all the studied systems when facing a financial crisis (Fig. 2).

The long-run perspective significantly changes the systemic risk horizon, pointing to the fact that simple risk measures, such as the Expected Shortfall aggregated over a set of SIFIs, are not broad enough to effectively measure systemic risk for the analyzed region—which is in accordance with the expectations based on the literature review.

In all the observations (all the measures), Slovakia and Romania stand out with the highest mean volatility but much less time-persistent peaks. For Slovakia, this

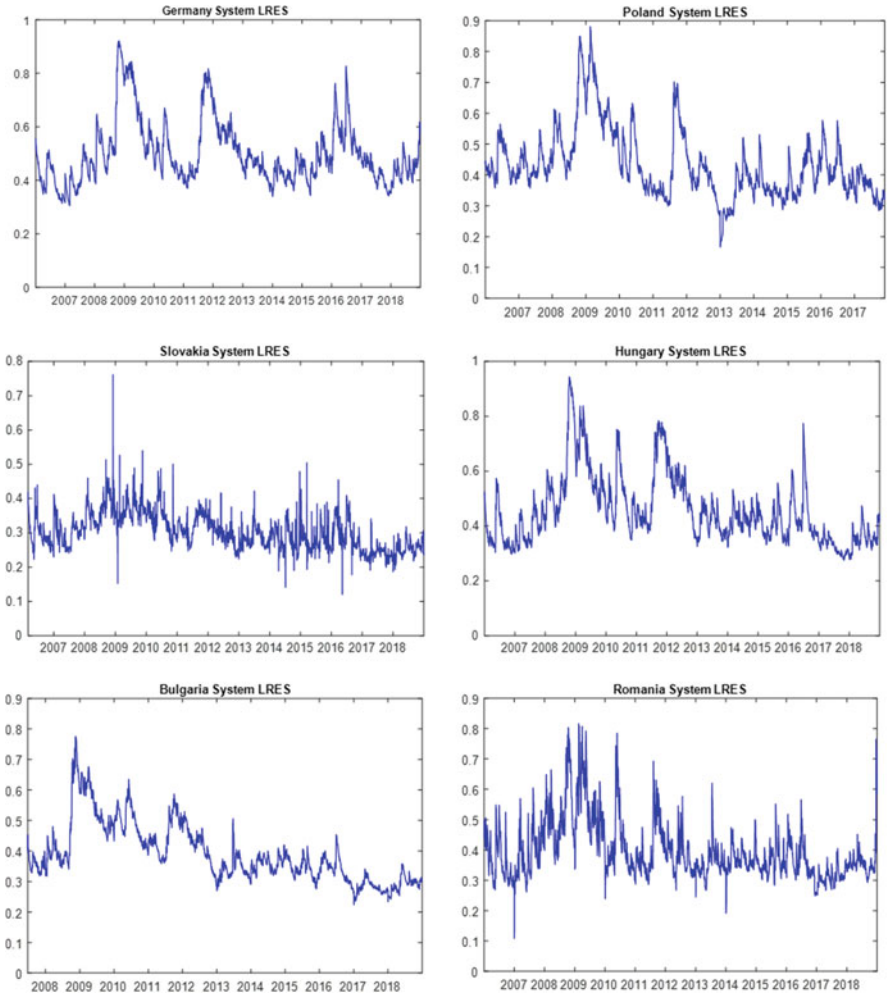

Fig. 2 LRMES of selected financial systems for years 2006–2018

may be explained by a smaller number of OSIIs. For Romania, the unstable flow of foreign investment and variable currency may be responsible. In these systems, the reactions to changes in the funding structure (as is the case in the second quarter of 2013) show a significant effect on the equity value. Thus, even if the size of the negative peaks should be interpreted with caution, the general characteristics of the systemic risk drivers in Slovakia and Romania seem different than elsewhere in the geographical neighborhood.

5.3 SRISK of the Financial Systems

SRISK, an extension of the measures presented above, allows us to consider the liabilities and size of each system's financial institutions. In other words, it enables considering the levels of leverage, so crucial for the systemic risk perspective. Here the expected capital shortfall of a given financial institution is conditional on the systemic event. As such, it allows computing the capital that the financial system (e.g., the regulator) is expected to need (for a possible bailout) if the systemic risk materializes into a financial crisis (Fig. 3).

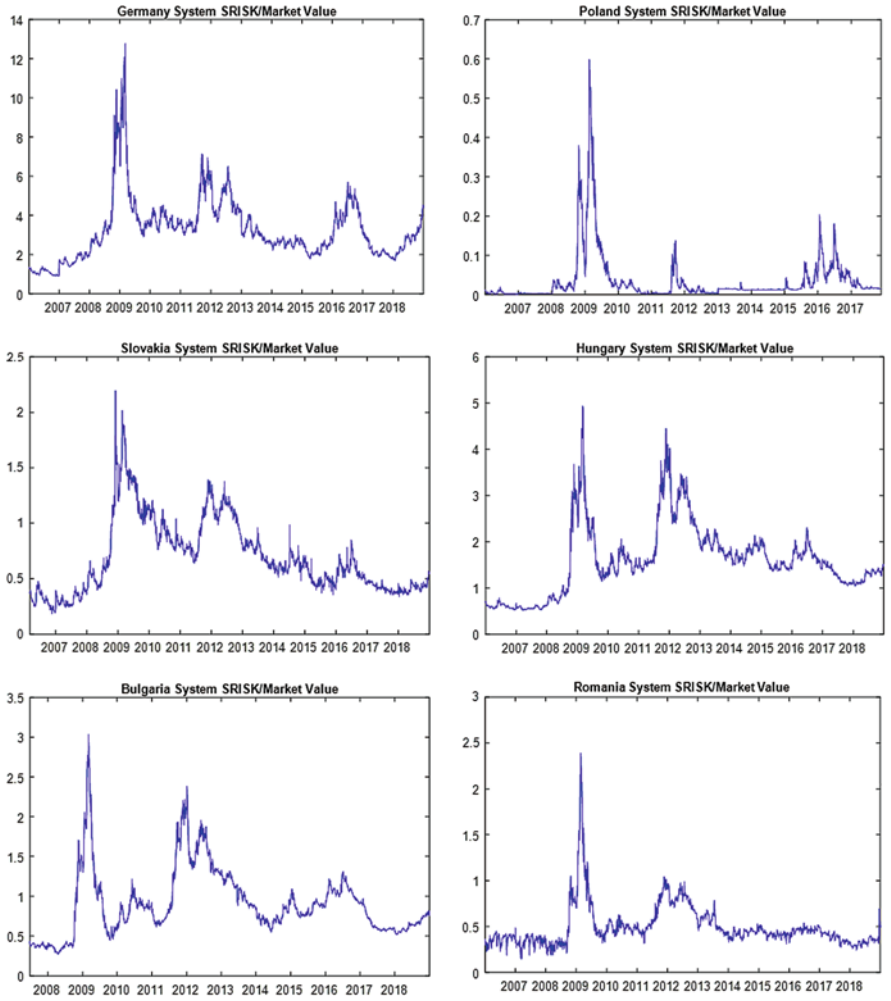

Fig. 3 SRISK of selected financial systems for years 2006–2018

It seems interesting to investigate the size of such potential losses in nominal terms and relative to each financial system size. We present the results relative to the capitalization of each financial system. This way, we show the scale of the potential losses relative to the system's total capacity to handle them (market depth).

There seem to be two types of different countries. The first one relates to Poland that has a rather stable and safe condition in quiet times (very low base-line SRISK), and reacts in a significant manner only to global events. Meanwhile, Hungary, Romania, Slovakia, and Bulgaria show properties of oversized and overleveraged financial sectors, where the loss potential remains high at all times. That is notwithstanding also very significant reactions to global events. Germany has incomparably higher nominal SRISK, which relates to the size of its financial system.

Another interesting observation is that SRISK truly individualizes between the countries and monitors the risk changes over time quite smoothly. This is evident, for instance, when we look at Germany and Hungary, where the significant trending growth of leverage in the financial system is visible. Such an observation is not present for other measures in the sample period.

5.4 Conditional Value at Risk of the Financial Systems

The final measure analyzed in this study, CoVaR, also corresponds to the Value at Risk of the given financial system, conditional on its financial institutions' distress. However, in this case, the institution's contribution to systemic risk is computed as the difference between the CoVaR conditional on the institution's equity quoted below VaR and the CoVaR of this institution with equity prices being in the median state.

The results point to the same periods of distress for the analyzed countries as other measures. However, they show similar risk patterns for Germany, Poland, and Hungary, with higher variability for Romania and Bulgaria. Also, the scale of risk seems to be directly related to the number and the total size of internationally connected banks in a given financial system, showing high contagion potential among the emerging European countries, a similar size in scale as for Germany (Fig. 4).

Importantly, we may note that the peaks in the emerging financial systems follow the peaks of the German system. As the CoVaR is a risk-spillover measure, it is not surprising that it allows capturing sequentiality of the systemic risk peaks. Such sequentiality might be indicative of an existing contagion channel, which should be investigated further in future studies.

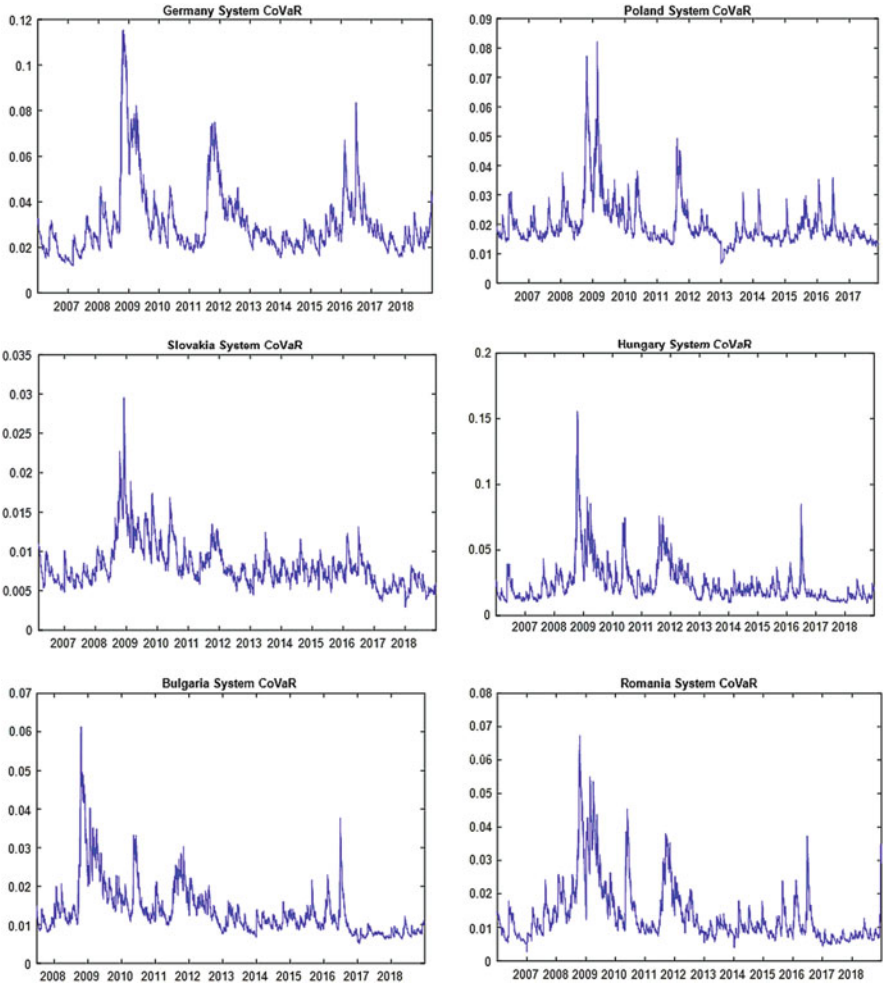

Fig. 4 CoVaR of selected financial systems for years 2006–2018

6 Conclusions

The analysis presented in the paper focuses on measuring the levels of systemic risk for selected countries of the Central part of Europe. The study covered geographically affiliated countries that are developed differently and have very diverse financial systems in terms of complexity and innovation. Several applied measures showed commonalities in terms of risk between various countries. The results also indicate that these commonalities are not persistent when we use different systemic risk measures.

From the policymakers' perspective, this gives several vital conclusions. Above all, the measures presented in the paper can be successfully used in systemic risk monitoring in all studied countries. The second conclusion is that further studies are required to specify what differentiates the results produced by various measures. Such studies would conclusively indicate which of the measures would best serve each specific goal of the regulators and monetary authorities.

What is visible, fragility and contagion relate directly to the size of leverage relative to the size of the financial system and the presence (importance measured with SIS) of internationally linked big banks. We also see that the scale of risk in Central and South-Eastern Europe is as big as in Germany. At the same time, we know that emerging European countries cannot carry the same bailout burden in case a crisis materializes. All of this sheds light on the directions that regulators should take in their macroprudential policies for the analyzed region.

The results show that the global financial crisis and the European debt crisis have affected the levels of risk in all the analyzed countries, while the scale of risk is much bigger for these countries where the financial system is more interconnected with the global markets. Additionally, the role of the German financial system might be significant for systemic signal transmission, especially given the pace of reaction to adverse global events. This observation calls for further research into Germany as a contagion channel for the analyzed countries and the whole CEE region.

Appendix

Table 2 Systemically Important Institutions for the analyzed region listed in stock markets (directly or by proxy)

	Bank	Score	Ultimate E.U. Parent (owns or controls)
Bulgaria	UniCredit Bulbank A.D.	1880	UniCredit S.p.A.
	United Bulgarian Bank A.D.	1120	KBC Group N.V.
	First Investment Bank A.D.	1100	**X**
	DSK Bank A.D.	1040	OTP Bank Nyrt.
	Societe Generale Expressbank A.D.	720	Société Générale S.A.
	Raiffeisenbank (Bulgaria) A.D.	670	Raiffeisen Bank International A.G.
	Eurobank Bulgaria A.D.	630	Eurobank Ergasias S.A.
	Central Cooperative Bank A.D.	520	**X**
	Piraeus Bank Bulgaria A.D.	310	Piraeus Bank S.A.
Hungary	OTP Bank Nyrt.	3095	**X**
	UniCredit Bank Hungary Zrt.	960	UniCredit S.p.A.
	Kereskedelmi és Hitelbank Zrt.	830	KBC Group N.V.
	ERSTE BANK HUNGARY Zrt.	655	Erste Group Bank A.G.
	Raiffeisen Bank Zrt.	600	Raiffeisen Bank International A.G.
	CIB Bank Zrt.	420	Intesa San Paolo S.p.A.

(continued)

Table 2 (continued)

	Bank	Score	Ultimate E.U. Parent (owns or controls)
Poland	PKO BP S.A.	1580	**X**
	Bank Polska Kasa Opieki S.A.	1050	**X**
	Bank Zachodni WBK S.A.	960	Banco Santander
	ING Bank Śląski S.A.	950	ING Bank N.V.
	mBank S.A.	930	Commerzbank A.G.
	Millennium Bank S.A.	424	Banco Comercial Portugues
	Bank Handlowy w Warszawie S.A.	440	**X**
	Deutsche Bank Polska S.A.	400	Deutsche Bank A.G.
Romania	Banca Transilvania S.A.	1620	**X**
	UniCredit Bank S.A.	1525	UniCredit S.p.A.
	Banca Comercială Română S.A.	1390	Erste Group Bank A.G.
	BRD—Groupe Societe Generale S. A.	1165	Société Générale S.A.
	Raiffeisen Bank S.A.	1000	Raiffeisen Bank International A.G.
	Alpha Bank România S.A.	445	Alpha Bank
	OTP Bank Romania S.A.	305	OTP Bank Nyrt.
	Garanti Bank S.A.	300	Turkiye Garanti Bankasi A.S.
Slovakia	Všeobecná Úverová Banka A.S.	2070	Intesa San Paolo S.p.A.
	Slovenská Sporiteľňa A.S.	1800	ERSTE Group Bank A.G.
	Tatra Banka A.S	1390	Raiffeisen-Landesbanken-Holding GmbH
	Československá Obchodná Banka A.S.	1205	KBC Group N.V.
Germany	Deutsche Bank A.G.	2765	**X**
	Commerzbank A.G.	830	**X**
	Unicredit Bank A.G.	470	UniCredit Group
	ING DiBa A.G.	145	ING Bank N.V.

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Part III
Corporate Finance

Industry and Size Effect in the Relation Between Corporate Material and Financial Decisions: Findings from the EU Countries

Julia Koralun-Bereźnicka

1 Introduction

Are companies with high operational risk more likely to be conservative in terms of financial policies? Or does aggressive operational strategy imply similar behaviour when it comes to financing decisions? Does this relationship depend on firm size, or is it more likely to be industry-dependent? Interactions of real and financial decisions have been focus of multiple studies, e.g. by Ravid (1988), Campello and Giambona (2013), or Ortiz-Molina and Phillips (2014), who found operating inflexibility an economically important source of risk.

However, despite the profusion of corporate finance literature dedicated to asset flexibility as a factor affecting capital structure, some questions in the field remain at least partly unanswered. Specifically, it seems that little attention has been paid to the notion that the way in which the commonly recognized factors impact leverage may vary depending on some other, indirect circumstances or features, such as the firm size or its industrial classification. This study adds to the existing literature by addressing the issue with yet another approach, i.e. by searching for the indirect factors of debt. The applied method can be considered as contributive to the vast majority of empirical research, where the significance and the direction of the asset tangibility impact on capital structure, along with other factors, is usually verified directly, i.e. without introducing any additional categories, which could potentially affect the analysed relationships.

J. Koralun-Bereźnicka (✉)
University of Gdańsk, Gdańsk, Poland
e-mail: julia.koralun-bereznicka@ug.edu.pl

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2 Theoretical Background and Hypotheses Development

Asset tangibility, also known as collateral, is one of the key determinants of corporate financing policies recognized by the two main capital structure theories, i.e. the static trade-off theory (TOT) developed through the dispute over the capital structure irrelevance proposition by Modigliani and Miller (1958), and the pecking-order theory (POT) by Myers and Majluf (1984). The two theories offer different explanations of the direction in which financial leverage is affected by asset tangibility. According to the TOT, since tangible assets can be pledged as collateral, as they are easier to value and therefore more easily convertible to cash in the case of default, their share in total assets affects potential bankruptcy costs. As a result, a higher proportion of tangible assets should make lenders more willing to supply loans. The positive tangibility–leverage relation might also stem from the inclination of firms to follow the maturity matching principle, according to which assets with a certain degree of liquidity should be financed with liabilities of corresponding maturity. Thence, since the fixed assets constitute long-term items of the firm property, they should be covered by long-term liabilities, such as equity or at least fixed capital, i.e. equity and long-term debt.

The POT predictions on the asset structure–leverage relation are more ambiguous in terms of its sign. On the one hand, as argued by Weill (2002), asset tangibility can mitigate the information asymmetry between firms and creditors by allowing lenders to better evaluate the quality of businesses. Therefore, tangibility can act as a means of controlling such problems as adverse selection or moral hazard. On the other hand, however, an inverse relationship between firm leverage and asset tangibility could result from the fact that large holdings of tangible assets may be used as a source of internally generated funds and thus discourage firms from turning to external financing (Daskalakis and Psillaki 2008). A negative relation can also be attributed to low information asymmetry associated with tangible assets, which should make equity issuances less costly (Sibindi 2016). Finally, the inverse relation between the asset structure and capital structure may originate from the tendency of firms to maintain a reasonable balance between operational and financial risk. Therefore, the negative tangibility–leverage relation may be characteristic for companies which tend to compensate high operational risk resulting from a larger share of long-term fixed assets by lower financial risk associated with reduced indebtedness.

Another capital structure determinant considered in this study is the firm size, whose positive relation with debt expected by TOT is associated with the usually lower risk of large companies (Frank and Goyal 2009; Kurshev and Strebulaev 2008). The issue of the firm size significance as an indirect determinant of capital structure has been addressed e.g. by Daskalakis and Thanou (2010). Their study of the Greek SMEs broken into size classes of medium, small and micro-enterprises, indicates that, although the firm size does affect its debt level, no such influence was found with respect to the relation between other determinants of leverage and the use of debt. Authors conclude that companies belonging to different size groups behave

similarly in terms of the relationship between debt and factors such as e.g. size or asset structure. However, the opposite evidence is reported by Ramalho and Silva (2009) in their study of different sized firms in Portugal. The authors found that the determinants of leverage differ between micro, small, medium and large-sized companies.

Along with the firm-level variables, financial leverage can also be determined by external factors, such as the industrial specifics. The significance of the industrial classification in terms of debt has been reported e.g. by Harris and Raviv (1991), Phillips and Mackay (2005), Talberg et al. (2008), Degryse et al. (2012), or more recently by Stancic et al. (2017) and is attributed to such industry features as the assets flexibility (Shleifer and Vishny 1992), technological differences (Maksimovic and Zechner 1991), or industrial competition (Leibenstein 1966). Corporate decisions concerning their assets and the corresponding liabilities are taken with the consideration of similar decisions taken by other companies in the industry. This might result in more diversified financial structures within a given sector, rather than in a target debt ratio common to the entire industry. As evidenced by Almazan and Molina (2005), the leverage diversity is higher in concentrated industries, as well as those with more freedom in terms of corporate governance practices and greater assets liquidity. The authors also found greater diversity of capital structure in industries, where companies use different production technology, in older industries and in sectors with significant growth opportunities.

It appears, however, that the influence of firm size or industry on capital structure may be dual (De Jong et al. 2008). Apart from their direct impact on debt, they may also affect leverage indirectly, i.e. by influencing the way in which direct capital structure determinants, such as asset tangibility, impact debt level.

Taking into account the main theories and previous empirical evidence, the three research hypotheses are formulated: (1) the asset tangibility–capital structure relation depends on the firm size; (2) the asset tangibility–capital structure relation depends on the firm industrial classification; (3) the industry specifics is more important than the firm size effect in the relation between corporate material and financial decisions. The verification of these hypotheses, based on reliable European data, would provide more insights into the indirect effect of firm size and industry in capital structure.

3 Data and Methods

The data is retrieved from the BACH-ESD (Banque de France 2019), which provides harmonized and aggregated corporate financial information from Austria, Belgium, Czech Republic, Denmark, France, Germany, Italy, Luxemburg, Poland, Portugal, Slovakia and Spain. The data is also broken by size groups (small, medium, and large firms), by industries according to the NACE classification at the section level, and by years (2000–2017). Several industries were excluded from the analysis due to either data gaps or lack of cross-industry comparability. The ratios are calculated with the use of median balance sheet data for a given category of

Table 1 Construction of variables

Variables	Definition
Debt to assets ratio (D/A)	Total debt/assets
Assets tangibility (TNG)	Tangible fixed assets/assets
Size dummies (D_SIZE)	SM, ME, LA
Industry dummies (D_IND)	A, B, C, D, E, F, G, H, I, J, L, N, P, Q, R, S
Tangibility–size interactions	TNG*SM, TNG*ME, TNG*LA
Tangibility–industry interactions	TNG *A, TNG *B, . . ., TNG *S

Notes: *SM* small, *ME* medium, *LA* large, industry symbols by NACE (Nomenclature Statistique des Activités économiques dans la Communauté Européenne), i.e. A—Agriculture, forestry and fishing, B—Mining and quarrying, C—Manufacturing, D—Electricity, gas, steam and air conditioning supply water, E—Water supply, sewerage, waste management and remediation activities, F—Construction, G—Wholesale and retail trade, repair of motor vehicles and motorcycles, H—Transportation and storage, I—Accommodation and food service activities, J—Information and communication, L—Real estate activities, N—Administrative and support service activities, P—Education, Q—Human health and social work services, R—Arts, entertainment and recreation, S—Other service activities

country, size, industry, and year. Due to the missing data for Q2 in the Czech Republic and Slovakia, the means of ratios were used instead. The variables employed in the study are defined in Table 1.

Initially, the descriptive statistics of the main variables were analysed in the three sections, i.e. across size groups, countries and industries. This preliminary analysis was meant to discover the basic regularities concerning the main asset structure and liabilities structure within the analysed population. Then, in order to identify the industry and size effect in the tangibility–capital structure relation, panel regression models with interactions between variables were estimated, as specified by formula (Almazan and Molina 2005):

$$\begin{aligned}\left(D/A\right)_{icst} = {} & \alpha + \beta_1 TNG_{icst} + \beta_2 D\_SIZE_{icst} + \beta_3 D\_IND_{icst} \\ & + \beta_4 (D\_SIZE_{icst} \cdot TNG_{icst}) + \beta_5 (D\_IND_{icst} \cdot TNG_{icst}) + \xi_{icst} \end{aligned} \quad (1)$$

where i denotes industry ($i = 1, \ldots 16$), c—country ($c = 1, \ldots 12$), s—size group ($s = 1, 2, 3$), and t—year ($t = 1, \ldots 18$). The estimation method was OLS with standard errors robust for heteroscedasticity and autocorrelation of error terms (Baltagi 2008).

4 Results

The descriptive statistics of the two main variables, i.e. debt ratio and asset tangibility, are shown in Tables 2 and 3, respectively.

It can be seen from the descriptive statistics of the dependent variable shown in Table 2 that small companies have the highest mean value of the debt ratio.

Table 2 Descriptive statistics of the debt to asset ratio

Size group, country, industry	N	Mean value	Median	Minimum value	Maximum value	Standard deviation
ALL	6451	0.637	0.653	0.051	1.748	0.142
SM	2334	0.640	0.657	0.106	0.960	0.130
ME	2249	0.634	0.645	0.120	1.108	0.134
LA	1868	0.638	0.656	0.051	1.748	0.164
AT	732	0.692	0.695	0.355	0.978	0.091
BE	659	0.595	0.618	0.106	0.919	0.136
CZ	596	0.537	0.529	0.051	1.710	0.181
DE	711	0.675	0.678	0.392	0.944	0.112
ES	682	0.589	0.588	0.199	0.971	0.106
FR	745	0.689	0.688	0.465	0.981	0.086
IT	650	0.717	0.719	0.395	0.973	0.074
NL	269	0.603	0.599	0.120	0.978	0.166
PL	499	0.494	0.503	0.079	0.973	0.143
PT	594	0.713	0.716	0.239	0.994	0.123
SK	314	0.636	0.662	0.155	1.748	0.161
A	370	0.553	0.583	0.051	1.108	0.162
B	369	0.556	0.567	0.120	0.981	0.150
C	456	0.604	0.610	0.308	0.815	0.083
D	454	0.610	0.624	0.106	0.956	0.163
E	418	0.610	0.646	0.226	0.942	0.146
F	456	0.731	0.761	0.143	1.748	0.123
G	456	0.672	0.676	0.279	0.858	0.081
H	456	0.641	0.659	0.237	0.994	0.134
I	435	0.667	0.676	0.119	0.978	0.137
J	454	0.626	0.643	0.192	0.905	0.115
L	380	0.630	0.667	0.079	1.710	0.171
N	442	0.740	0.755	0.336	1.051	0.116
P	219	0.611	0.615	0.347	0.882	0.116
Q	350	0.586	0.579	0.142	0.973	0.134
R	402	0.657	0.669	0.155	1.560	0.142
S	334	0.656	0.666	0.254	0.973	0.119

Notes: N stands for the number of companies in each category, i.e. ALL—in all countries, industries, and size groups; SM, ME, LA—in size groups as defined in Table 1; AT-SK—in countries defined in Table 1; A-S—in industrial sections defined in Table 1

However, the average debt level is very similar across size groups of firms. The same regularity can be noticed when the median is compared across size groups.

As for the assets tangibility measure (TNG), shown in Table 3, a negative correlation between firm size and assets structure can be identified; the average relation of fixed to total assets decreases along with the firm size. Consequently, small enterprises are characterised by the highest share of fixed assets. However, the pattern between corporate material decisions measured by TNG and capital structure

Table 3 Descriptive statistics of the asset tangibility ratio

Size group, country, industry	N	Mean value	Median	Minimum value	Maximum value	Standard deviation
ALL	6467	0.386	0.370	0.014	0.917	0.195
SM	2342	0.414	0.407	0.021	0.856	0.175
ME	2250	0.384	0.367	0.014	0.910	0.196
LA	1875	0.353	0.310	0.018	0.917	0.210
AT	732	0.455	0.463	0.080	0.836	0.174
BE	659	0.300	0.280	0.036	0.762	0.157
CZ	596	0.479	0.490	0.014	0.917	0.204
DE	712	0.421	0.434	0.074	0.836	0.210
ES	685	0.379	0.349	0.053	0.822	0.162
FR	745	0.290	0.269	0.036	0.749	0.158
IT	650	0.318	0.316	0.051	0.666	0.151
NL	273	0.272	0.214	0.021	0.832	0.187
PL	502	0.485	0.491	0.019	0.867	0.200
PT	599	0.380	0.350	0.042	0.884	0.196
SK	314	0.478	0.478	0.082	0.875	0.189
A	370	0.438	0.456	0.080	0.917	0.164
B	369	0.385	0.393	0.021	0.856	0.160
C	456	0.281	0.275	0.059	0.497	0.098
D	454	0.518	0.553	0.028	0.910	0.172
E	422	0.505	0.472	0.111	0.881	0.191
F	456	0.195	0.159	0.037	0.581	0.118
G	456	0.185	0.186	0.038	0.336	0.066
H	456	0.494	0.494	0.091	0.875	0.145
I	435	0.485	0.504	0.042	0.804	0.186
J	454	0.214	0.180	0.032	0.810	0.112
L	380	0.609	0.640	0.018	0.909	0.181
N	447	0.353	0.329	0.019	0.832	0.137
P	219	0.355	0.353	0.036	0.884	0.150
Q	352	0.444	0.468	0.108	0.795	0.164
R	406	0.406	0.423	0.057	0.818	0.170
S	335	0.356	0.363	0.014	0.791	0.152

Notes: N stands for the number of companies in each category, i.e. ALL—in all countries, industries, and size groups; SM, ME, LA—in size groups as defined in Table 1; AT-SK—in countries defined in Table 1; A-S—in industrial sections defined in Table 1

is less evident. Although small companies are clearly the riskiest in terms of leverage and assets structure, the mean and median values for medium and large-sized firms do not reveal any clear regularities in terms of the trade-off between operational and financial risk.

The level of debt seems much more varied across countries than across size groups of firms. Companies in Italy and Portugal rely on debt considerably more than in Poland, where the share of debt is clearly the lowest of all countries.

Some clearer patterns in the relation between capital and assets structure can be observed in the international cross-section than across size groups. The two countries with the lowest leverage, namely Poland and the Czech Republic, are at the same time those with the highest share of fixed assets, which suggests a negative relation between debt ratio and assets tangibility. However, the cross-industry comparison of descriptive statistics does not provide support for the above rule. As for the industrial cross-section, it is clear that firms from the sections of administration and construction follow the most aggressive financing strategies with the highest mean level of debt, whereas agricultural and mining companies tend to be more conservative in terms of leverage. The highest intra-industry variation of capital structure is observed for the accommodation industry. The accommodation industry is the one with distinctly highest share of fixed assets, as opposed to the sections of construction and trade, characterized by larger flexibility of assets.

This indicates that the impact of asset structure on debt varies both across industries and size groups of firms. Certainly, the values of R^2 would be far form satisfactory if the aim was to fully explain the capital structure variability. This study, however, is only meant to analyze in detail the impact of just one of the many factors affecting leverage, along with its size and industry interactions. The estimation results of model (Almazan and Molina 2005) are shown in Table 4.

In order to capture the relative importance of size and industry interactions, the model was estimated first only with size-tangibility interactions, then only with industry-tangibility interactions, and finally with both. All three estimations reveal significant negative relation between asset tangibility and debt ratio. Also, both types of interactions prove significant, although only in the model where both size and industry interactions were included.

In order to verify which category of interactions is more relevant, the AIC values were compared. The omission of industry interactions has more considerable effect on the AIC than the omission of size interactions, which indicates lower importance of the size effect in the relation between asset tangibility and capital structure within the analyzed sample.

The impact of tangibility on total debt ratio is also visualized by Fig. 1, which shows that the direction of the relation between TNG and D/A is clearly industry-dependent, although with only two sections (A—agriculture and L—administrative activities) deviating from the generally negative relation.

However, in all cases the relation remains unchanged across size groups for a given industry. Moreover, a characteristic feature noticeable in all industries with negative tangibility-leverage relation is the weakest impact of asset structure on debt level in small-sized companies. On the contrary, in the two industries for which the positive impact is observed, the relation occurs the strongest for small firms.

Table 4 Estimation results of panel regressions explaining D/A

Variable	Model (Almazan and Molina 2005) (size interactions)		Model (Baltagi 2008) (industry interactions)		Model (Banque de France 2019) (both interactions)	
	Estimate	Std. error	Estimate	Std. error	Estimate	Std. error
Const.	0.680***	0.028	0.699***	0.026	0.693***	0.027
TNG	−0.236***	0.038	−0.280***	0.038	−0.270***	0.037
ME	0.055***	0.019	0.035***	0.011	0.081***	0.024
LA	0.063***	0.019	0.040***	0.012	0.093***	0.025
B	−0.051*	0.031	−0.077*	0.044	−0.107**	0.043
C	−0.039	0.026	−0.053	0.037	−0.086**	0.039
D	0.046	0.033	−0.037	0.050	−0.059	0.050
E	0.010	0.031	0.085*	0.051	0.057	0.053
F	0.043	0.027	0.070**	0.033	0.031	0.038
G	0.004	0.026	0.012	0.037	−0.024	0.039
H	0.058**	0.029	0.048	0.060	0.009	0.061
I	0.062**	0.028	0.040	0.043	0.013	0.044
J	−0.062**	0.029	−0.067	0.044	−0.092**	0.045
L	0.078**	0.037	−0.010	0.067	−0.053	0.068
N	0.045	0.029	−0.107**	0.043	−0.139***	0.046
P	−0.059*	0.033	−0.021	0.056	−0.034	0.054
Q	−0.081***	0.030	−0.095	0.063	−0.121*	0.062
R	−0.017	0.032	0.007	0.064	−0.024	0.065
S	−0.003	0.029	−0.061	0.041	−0.093**	0.043
TNG*ME	−0.046	0.049			−0.117*	0.064
TNG*LA	−0.060	0.055			−0.146**	0.073
TNG*B			0.068	0.118	0.148	0.119
TNG*C			0.043	0.112	0.138	0.120
TNG*D			0.170*	0.089	0.231**	0.094
TNG*E			−0.155*	0.092	−0.075	0.104
TNG*F			−0.172	0.116	−0.040	0.126
TNG*G			−0.079	0.138	0.046	0.145
TNG*H			0.001	0.102	0.110	0.111
TNG*I			0.040	0.090	0.107	0.094
TNG*J			−0.014	0.183	0.062	0.183
TNG*L			0.143	0.122	0.244*	0.130
TNG*N			0.426***	0.092	0.531***	0.108
TNG*P			−0.131	0.154	−0.089	0.148
TNG*Q			0.023	0.125	0.098	0.125
TNG*R			−0.065	0.123	0.008	0.128
TNG*S			0.144	0.100	0.232**	0.106
No. obs.	6734		6734		6734	
R^2	0.262		0.286		0.294	
Heteroscedasticity	1484.7 [0.000]		890.8 [0.000]		936.6 [0.00]	
Normality	247.7 [0.000]		281.0 [0.000]		255.4 [0.000]	

(continued)

Table 4 (continued)

Variable	Model (Almazan and Molina 2005) (size interactions)		Model (Baltagi 2008) (industry interactions)		Model (Banque de France 2019) (both interactions)	
	Estimate	Std. error	Estimate	Std. error	Estimate	Std. error
AIC	−9901.8		−10095.5		−10162.1	
Hausman test	114.6 [0.000]		142.7 [0.000]		154.8 [0.000]	
Joint significance of interactions						
Size	−1.310 [0.191]				−2.162 [0.031]	
Industry			0.833 [0.405]		2.088 [0.037]	

Notes: (1) $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, (2) White's test for heteroscedasticity, (3) Doornik–Hansen test for normality of residuals, (4) Interpretation of parameters in relation to section A and small firms

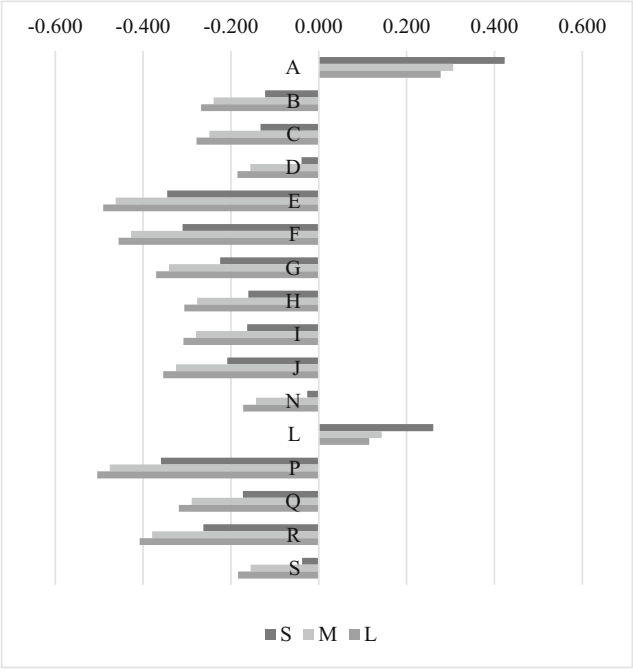

Fig. 1 The impact of asset tangibility on total debt across industries and size groups. Note: the bars represent sums of parameters from the model with industry and size interactions. Source: own study

5 Conclusions

Generally, the study highlights the importance of the relation between corporate material and financial decisions, reflected in asset structure and capital structure, respectively. Contrary to the TOT expectations, as well as denying the maturity matching principle, the relation between asset tangibility and debt level proved

mainly negative, which is in line with the findings by Daskalakis and Psillaki (2008), or Pepur et al. (2016), but opposing the evidence reported by Degryse et al. (2012). The main conclusion corresponds to the view that a higher share of long-term fixed assets, meaning lower elasticity and therefore higher operational risk, tends to be compensated by lower leverage-induced financial risk. This suggests the occurrence of a trade-off between the activity-related risk level and the risk resulting from indebtedness.

However, findings provide evidence that the relationship in question varies depending on the indirect factors. The direction of the relation between asset tangibility and capital structure depends significantly on the industrial classification of firms, and to a lesser extent on their size. This provides support for hypothesis (2), concerning the relevance of the industry effect for the examined asset tangibility–capital structure relation, and only weak support for hypothesis (1), which assumes the importance of the firm size effect in this area. Daskalakis et al. (2014) report similar conclusions on the size effect in capital structure: while the firm size does affect how much debt a firm will use, it does not influence the relationship between the other factors and debt usage.

The reported prevalence of the industry effect over the firm size effect in the assets–capital structure relation indicates the likely truthfulness of hypothesis (3), according to which the industry specifics is more important than the firm size effect in the relation between corporate material and financial decisions.

The impact of the above findings on theory is therefore such that the competing capital structure theories should not be treated as universal or comprehensive concepts. Rather, their applicability, interpreted as the ability to explain corporate behaviour, may differ depending on a number of indirect circumstances, many of which certainly yet to be identified.

As for the limitations of the study, the sample covering only 12 EU countries certainly does not meet the requirement for generalization of the research results, probably not even within the EU area, whose various regions are far from homogeneity in terms of economy. Therefore, extending the database with harmonized and comparable financial information would create opportunities for a more complete analysis and understanding of the phenomena in question. Nevertheless, the study offers framework for further investigation of the indirect effects in capital structure, e.g. by considering international cross-sections and (or) debt maturity. It might be also worthwhile to determine whether and how the regularities within the area of corporate material and (or) financial decisions are affected by the financial crisis.

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Technology Level and Financial Constraints of Public Listed Companies

Katarzyna Prędkiewicz, Paweł Prędkiewicz, and Marek Pauka

1 Introduction

The role of corporate innovation for economic growth is undoubtful. With varying influences depending on the country's economic development and its phase of the economic cycle, innovation accounts for approximately 50% of a country's total GDP growth (OECD 2015).

From a theoretical point of view, the asymmetry of information, problems at the principal-agent interface, and the phenomenon of moral hazard and inverse selection are the reason for various disturbances in the debt and equity financing market. These phenomenons may transfer into problems with obtaining external financing (financial constraints) at the level of individual enterprises.

That is why governments improve access to capital for innovative and high-technology companies to support them by direct (e.g., grants) and indirect (e.g., tax incentives) instruments and developing the financial system, among other things, the stock exchange market.

Theoretical models support the hypothesis that the development of a capital market should lower capital costs for innovative companies and ease access to funds (Brown et al. 2009). However, there is no consensus in the literature about whether the stock exchange market can conclusively solve financial constraints for innovative companies. For example, Brown et al. (2009) proved that despite the development of the US capital market, the companies may still have a problem with financing R&D projects. Other authors concluded that companies in the USA, which undertake R&D projects are not financially constrained, whereas those in Europe still are (Cincera and Ravet 2010).

K. Prędkiewicz (✉) · P. Prędkiewicz · M. Pauka
Wroclaw University of Economics and Business, Wrocław, Poland
e-mail: katarzyna.predkiewicz@ue.wroc.pl

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We want to contribute to previous studies and analyze whether one of the best-developed stock exchange markets in Central and East Europe (Poland) alleviates financial constraints for high-technology companies. Based on the Warsaw Stock Market (Poland) data, we will check whether high-technology companies are financially constrained compared to low and not technological firms.

2 Literature Review

The returns on innovative activities are uncertain and make innovation riskier to finance (Hall 2002; Mazzucato 2013; Coad et al. 2016). Companies that undertake highly risky projects have an informational advantage over external agents who may not be able to assess a firm's quality based on their innovative activity (Stiglitz and Weiss 1981; Carpenter and Petersen 2002; de Rassenfosse et al. 2011). High asymmetry of information causes investors or suppliers of external capital to have difficulty distinguishing good projects from bad ones. To assess a project in an early stage of technological development, skilled experts are necessary what can occur problem for banks (Ueda 2004). Additionally, innovative projects are typically long-term with uncertain outcomes and challenging to predict revenue (Brown et al. 2012). Moreover, the knowledge asset created during the innovation process could not be used in an easy way as collateral because they are intangible (however, there is a possibility of IP-backed debt). Also, most R&D investments are human expenses (Hall 2010).

Problem with access to capital (financial constraints) may force innovative firms to rely on internally generated funds. However, it is only possible for older companies, which have established a stream of revenue and cash flow from earlier closed projects yet. According to Kaplan and Zingales, "*Firm is considered more financially constrained as the wedge between its internal and external cost of funds increases*" (Kaplan and Zingales 1997). Tirole indicated that financial constraints are caused by the disorders in the supply of external capital, and the mean reason is information asymmetry between an investor and a firm (Tirole 2006). Hall provides three main reasons for financial constraints: (1) information asymmetry (2) moral hazard problem (3) tax reasons, which lead to changes in preferences between internal and external capital (Hall 2010). When a company is financially constrained, it cannot undertake part or all of its investments because of problems with capital access. Nonoptimal investments of individual companies lead to also to nonoptimal development of the economy.

The key queries in literature are whether companies undertaking investments (innovative, but also ordinary) are financially (liquidity) constrained. This question is followed by next, how to measure financial constraints. Because the supply of capital is not easy to capture by econometric methods, measuring them is a big empirical challenge. The indirect approach is based on the investment equation. The companies are considered financially constrained when investments are sensitive to cash-flow changes, assuming that cash-flow represents internal capital's arability.

When the company invests only in response to cash-flow fluctuations, it cannot gain external capital at a lower cost than a marginal return from the project. The early research focused on ordinary (non-R&D) investments, e.g., works of Fazzari et al. (1988), which were, however, criticized by Kaplan and Zingales (1997). In regards to investment in R&D, pioneer research was initiated by Hall (1992), Himmelberg and Petersen (1994), and are continued contemporary inter alia in works of Cincera and Ravet (2010), Czarnitzki and Hottenrott (2011), Lööf and Nabavi (2016).

The results of previous studies confirmed that innovative and high-technology companies behave dissimilarly compared to non-innovative, low-technology firms. They rely mainly on equity finance rather than debt.

For example, Brown et al. (2009) note that in high-tech companies, there is a specific financing hierarchy—R&D projects are financed first from internal equity (cash flow) and then from external (share issue). However, this hierarchy does not apply to investments in fixed assets that provide the possibility of securing a debt. Based on empirical research, the authors stated that young high-tech companies are financially limited in terms of financing R&D projects, but mature (operating on the market for more than 15 years) are not. They have proven that in the case of investment in innovation, an equally important source of financing as cash flow is external capital obtained from the issue of shares. It follows that enterprises operating on market-oriented financial markets are more likely to implement R&D projects than those operating on banking-oriented markets.

Also, Casson et al. (2008) conclude that the "probability of issuing new equity rises monotonically with R&D intensity, while the use of debt finance starts to decline eventually as R&D intensity increases." Similarly, Aghion et al. (2004) noticed that "firms that report positive but low R&D use more debt finance than firms that report no R&D, but the use of debt finance falls with R&D intensity among those firms that report R&D", moreover "firms that report R&D are more likely to raise funds by issuing shares than firms that report no R&D, and this probability increases with R&D intensity." It also confirms that large and highly innovative companies behave differently to non-innovative ones. Schäfer et al. (2004), based on a sample of German high-tech companies, conclude that the probability that a young high-tech company "receives equity financing is an increasing function of the financial risk".

The research confirmed that companies implementing R&D projects operating in emerging markets, like Poland, are financially constrained (Nehrebecka and Białek-Jaworska 2015). A higher self-financing capacity (internal financing) favors the development of research and development activities. Enterprises that maintain a higher level of savings finance R&D investments to a greater extent with their funds. They are less dependent on external debt financing sources (credit, loans, and debt securities).

In turn, Bah and Dumontier (2001) confirmed that a lower level of financial leverage characterizes enterprises in the USA, Great Britain, and Japan with high R&D spending. Similarly, Friend and Lang (1988) and Hall (2010) confirmed a clear negative correlation between the intensity of R&D expenditure and financial

leverage in American enterprises. Hall et al. (2007) had the same conclusions observing European enterprises.

The results of so far conducted studies confirmed that more innovative and high-technology companies rely mainly on equity finance rather than debt compared to non-innovative, low-technology firms. It means that the stock exchange may be crucial for the development of innovative companies. Brown et al. (2009) confirmed that with the development of the US capital market, the financial constraints for investments in fixed assets have disappeared; however, they are persisted for R&D projects. Simultaneously, the number of enterprises with negative cash flows was growing. For them, after exhausting internal cash flow, the main source of financing is equity obtained from the issuing of the shares. Brown et al. (2009) also observed that American manufacturing companies significantly changed their investment structure with time. In typical production companies, the share of investments in fixed assets decreased and increased in R&D projects. Thus, although, according to the authors, financial constraints in the US for projects in fixed assets have practically disappeared; however, they are still present for total corporate investment.

Opposite conclusions formulated Cincera and Ravet (2010). They analyzed financial constraints for R&D projects, both in the USA and Europe in the period 2000–2007 and concluded that all companies undertaking R&D projects were financially constrained. However, they analyzed subsamples separately for USA and Europe, and it occurred that only European companies were financially constrained. In contrast, those in the USA had no problem with capital access. However, it should be stressed that the research sample covered huge companies (median of employees was 6000).

However, according to most studies, a market-oriented financial system has not entirely solved the problem of financial constraints. Innovative, high-technology companies undertaking R&D projects may have problems with capital access, even in countries with well-developed capital markets (Brown et al. 2009).

3 Data and Methodology

In this study, we used indirect methods of measuring financial constraints based on the investment equation. This method assumes that financially constrained enterprises invest only when internal capital (cash flow) increases. Then cash flow represents the availability of internal capital.

The general reduced-form of investment equations that we employed in our studies is following (Fazzari et al. 1988):

$$(I/K)_{it} = f(X/K)_{it} + g(CF/K)_{it} + u_{it}$$

where:

- I_{it} represents an investment in plant and equipment for firm *i* during period *t* or R&D expenditure*;*
- X represents a vector of variables, possibly including lagged values, that have been emphasized as determinants of investment from a variety of theoretical perspectives;
- CF (firm's internal cash flow) and it represents the potential sensitivity of investment to fluctuations in available internal finance after investment opportunities are controlled for through the variables in X; the function g depends on the firm's internal cash flow;
- K is the beginning of period capital stock;
- u_{it} is an error term.

The statistically significant coefficient for variable CF/K will confirm that the investment is undertaken when the operating cash flow is available, which means that the company is financially constrained.

The above presented basic model was developed in further studies, then we took into account improvements and suggestions formulated by other researchers.

In most studies, investments in fixed assets or operational cash flow were calculated based on the balance sheet (Fazzari et al. 1988; Hall 2010).

Lewellen and Lewellen (2016) compared the CF determined according to the traditional methodology (net profit plus depreciation) with the CF based on additional information obtained from the cash flow statement. They concluded that simplified CF is a distorted measure, especially after 1990, due to the growing importance of the profit's non-cash position. A similar remark applies to investments, which can be determined based on fixed assets changes from the balance sheet or all capital expenditure from the cash flow statement. According to the authors, data from the cash flow statement allows for the correct financial constraints measurement. Our research took into account the above suggestions—operational cash flow and capital expenditure were directly derived from the cash flow statement.

The access to information on R&D expenditure is limited and not available in Polish enterprises' financial statements. In this situation, the sensitivity of investments in tangible fixed assets to a change in cash-flow was analyzed in previous studies (Scellato 2007; Ughetto 2008), assuming that investments in innovations are partially included in the value of tangible fixed assets.

In the investment model, the company's development prospects are controlled to separate the influence on investment decisions of the company's management expectation regarding the future demand for products from decisions related to increasing investments in response to changes in available internal funds (CF). In the literature, various proposals can be found—sales revenues (Fazzari et al. 1988; Kaplan and Zingales 1997; Harhoff 1998; Ughetto 2008), revenues growth rate (Konings et al. 2003), as well as Tobin's Q-index (Kaplan and Zingales 1997; Audretsch and Elston 2002; Carpenter and Petersen 2002; Wagenvoort 2003). We adopted the value of sales revenues for the control of investment opportunities,

referring to the principle that the demand for capital (investments) results from the level or change in the company's sales.

Apart from the classic variables in the investment models, the cash holdings, debt, and the possibility of new shares are often considered.

In addition to the currently generated operational cash flow, enterprises may also "accumulate" cash from previous periods, especially if they perceive themselves as financially constrained. Cash holdings can provide a kind of "financial pillow" that reduces the investment's sensitivity to CF changes. Therefore, a positive relationship between the measures of financial liquidity and undertaken investments should be expected. The more financially constrained company, the stronger the relationship is (according to Fazzari et al.). The high cost of external capital prompts the need to raise funds to mitigate the impact of cash-flow "shocks" on the company's investments. Brown et al. (2012) paid attention to the need to control the investment-CF model's savings level. They proved that without the control of smoothing out expenditures from the kept funds and the possibility of issuing shares, it is impossible to confirm predicted by theoretical models the relationship between CF sensitivity and R&D expenditures. Our model assumes that the level of savings from the previous period will affect the current investments; therefore, we included as a control variable the last cash period holding.

In our model, we also assumed the need to control the debt level. According to Scellato (2007), this variable should reflect the restriction in access to a new debt due to the previously identified high debt level. Also, Brown et al. (2009) used the variable relating to the rising of new long-term interest debt, i.e., change in debt. The debt role turned out to be different for investment in fixed assets and investment in R&D projects. In the first case, the debt is essential.

In contrast, in the second case (investment in innovation), debt plays a less critical role. The possibility of obtaining capital from the issue of the new shares may be crucial. In our research, we control the debt level in the period preceding the investment (t-1). Firms with higher debt levels will find it more challenging to undertake new investments. However, we do not control the possibility of issuing new shares (this will be future research).

As a standard, the variables in investment models are scaled. However, there is no agreement in the literature on the methodology. It is often the value of capital at the beginning of the period (in t-1). We assumed for all variables scaling the total assets at the beginning of the period.

To summarize, we used in our study the following model. Expectations about future demand changes are controlled by revenues with additional control variables in the field of cash holding and the possibility of obtaining debt:

$$\frac{I_{i,t}}{K_{i,t-1}} = \beta_1(S_{i,t}/K_{i,t-1}) + \beta_2(CFO_{i,t}/K_{i,t-1}) + \beta_3(CASH_{i,t-1}/K_{i,t-1}) + \beta_4(D_{i,t-1}/K_{i,t-1}) + d_t + \alpha_i + v_{i,t}$$

where:

- $I_{i,t}$—represents all investment of firm i during period t—we used capital expenditure from cash flow statement,
- $S_{i,t}$—operating revenues (control of companies expectations about future demand changes),
- $CFO_{i,t}$—operational cash flow for firm i during period t (cash flow statement),
- $CASH_{i,t-1}$—Cash and cash equivalent (control of companies' savings),
- $D_{i,t-1}$—interest debt (long-term debts and short-term loans),
- $K_{i,t-1}$—is the total assets at the beginning of period t.

We have collected a sample of companies publicity traded in Poland on the Warsaw Stock Exchange from 2004 to 2018 (334 companies). We gathered their financial statements from the EMIS database—the financial reports covered the time from the initial public offering to 2018. The correctness of data was verified based on their financial statements on companies' websites or the National Court Register.

We used the Eurostat indicators on the High-tech industry and Knowledge-intensive services (Annex 3—High-tech aggregation by NACE Rev. 2).[1] The manufacturing companies were qualified based on NACE code as high-technology, medium high-technology, medium-low-technology, and low-technology and others that have not been qualified for any groups. We aggregated them into two groups: high-tech (we included companies-technology, medium high-technology, medium-low-technology) and low-tech (low-technology, not qualified to any group—not-technology). The sample structure is presented in Table 1.

Data were cleaned—the abnormal and outstanding data were excluded from the sample. Every observation which got variable outside the range: Q1–3*(Q3-Q1); Q3 + 3 * (Q3-Q1) was removed from the sample.

The means of standardized capital expenditure is higher for HT companies (Table 2). When we compare the mean of standardized operating cash flow, we noticed that the value is positive both for HT and LT firms, but it is a bit higher for HT companies. HT firms in line with expectations and previous studies have lower debt. Cash holding is also lower in HT compared to peers. All descriptive statistics are presented in Table 2.

We used panel models with fixed effects and random effects, but Hausman test showed that fixed-effects model was more efficient in all cases.

4 Results

To answer our research question, we have executed two models for panel data with fixed-effects. The first model is calculated for HT companies and the second for LT.

Based on the first model (Table 3) we can conclude that HT companies invest in fixed assets in response to changes in operating cash flow (p-value < 0.0001), which

[1] https://ec.europa.eu/eurostat/cache/metadata/en/htec_esms.htm.

Table 1 Sample structure

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
HT	3	12	17	38	45	50	54	62	65	72	81	87	89	90	85
LT	16	29	46	79	98	107	130	150	164	177	191	208	221	229	227

Note: *HT* high-tech companies, *LT* low-tech companies

Table 2 Descriptive statistics

	I	S	CFO	DEBT	CASH
HT mean	0.0517	1.2820	0.0637	0.1583	0.0763
LT mean	0.0451	1.0588	0.0543	0.1992	0.0894
HT S. dev.	0.0516	0.8870	0.0927	0.1513	0.0903
LT S. dev.	0.0557	0.9521	0.1092	0.1901	0.0963

Table 3 Investment models

	High technology	Low technology
	Coefficient (std. error)	Coefficient (std. error)
Const	0.0197 (0.0106)*	0.0252 (0.0049)***
S	0.0118 (0.0057)**	0.0128 (0.0038)***
CFO	0.0936 (0.0316)***	0.0144 (0.0175)
DEBT	−0.0576 (0.0214)***	−0.0394 (0.0088)***
CASH	0.1423 (0.0367)***	0.0659 (0.0171)***

Note: S—operating revenues; CFO—operational cash flow, DEBT—interest debt (long-term debts and short-term loans), CASH—Cash and cash equivalent; *p-value < 0.10, **p-value < 0.05, ***p-value < 0.01

supports the hypothesis that this group of companies is financially constrained. Also, the previous year's cash holding is crucial for investments of HT companies. Investments are undertaken in response to current operating cash flow, but also prior savings impact the capital expenditure level. Cash-holdings then affect the investment –HT firms invest when they have enough financial resources (savings). Statistically significant is the debt level. However, there is the opposite relation between capital expenditure and debt. A high debt level in the previous year limits investments in fixed assets. It means that not only operational cash flow plays an important role for investments, but also access to debt.

Based on the second model (Table 3), we concluded that LT companies do not invest in fixed assets in response to changes in operating cash flow. The coefficient for variable CFO (operational cash flow) is not statistically significant. It means that this group is not financially constrained. However, similarly to HT companies, there is a negative relationship between debt level and investment in LT firms, but weakest compared to HT companies. The level of cash holding positively impacts the expenditure level in LT companies; however, also the previous savings are less critical than for HT firms. Every variable (except S) t-Welch test confirmed significant differences between HT and LT companies' coefficients.

We run some robustness checks and divided our sample into subgroups using size as the criterion (Table 4). If company sales were in the upper 50% of sample distribution for the given year, it was treated as a BIG company otherwise SMALL. We used every year subsampling (the company could move between BIG/SMALL subgroups as time goes by) [method A] and a single subsampling approach, where companies were divided based on the criterion of the majority of every year subsampling [method B]. Both methods gave similar results.

Table 4 Investment model—size subsamples [method A]

	BIG High technology	BIG Low technology	SMALL High technology	SMALL Low technology
	Coeff. (std. error)	Coeff. (std. error)	Coeff. (std. error)	Coeff. (std. error)
Const	0.02686 (0.01531) *	0.02956 (0.00864) ***	0.00492 (0.01450)	0.02552 (0.00566) ***
S	0.01004 (0.00519) *	0.01426 (0.00494) ***	0.01452 (0.01085)	0.00797 (0.00568)
CFO	0.12844 (0.03903) ***	−0.00066 (0.02230)	0.04131 (0.05067)	0.02749 (0.02477)
DEBT	−0.04493 (0.02481)*	−0.05374 (0.01450) ***	−0.05430 (0.04551)	−0.04317 (0.01241) ***
CASH	0.16782 (0.05893) ***	0.06792 (0.02847) **	0.12604 (0.04495) ***	0.06818 (0.02197) ***

Note: S—operating revenues, CFO—operational cash flow, DEBT—interest debt (long-term debts and short-term loans), CASH—Cash and cash equivalent; *p-value < 0.10, **p-value < 0.05, ***p-value < 0.01

The robustness check (Table 4) confirms that only big high-technology companies are financially constrained, whereas small firms are not. We think that the result can be linked with the size of risk equity capital available for all companies on the capital market. The demand for equity capital for risky projects exceeds supply on the less developed capital market, like Poland. Then only the demand of smaller companies may be fulfilled. Investors should invest their money in a few projects (companies) undertaking risky projects than in one big high-technology company because they can diversify their capital. This phenomenon requires a more in-depth analysis in future studies. However, the low technology companies, both small and big, are not financially constrained, which is in line with our main findings.

5 Discussion and Conclusion

In this paper, we verified whether the Warsaw Stock Exchange (Poland) is an effective means of alleviating financial constraints for high technology companies. Based on the literature review, we supposed that the high-technology enterprises, compared to low-technology firms, may be still financially constrained. It follows from the literature review that for innovative companies and high technology firms equity market is crucial. The high-technology firms have a specific financing hierarchy—new projects (especially R&D) are financed first from internal equity (cash flow) and then from external capital. However, not debt, but equity is firstly preferred—opposite to classic pecking order theory. That is why the development of the equity market should be a priority for governments. Although even well-developed market-oriented financial systems (e.g., USA) have not entirely solved financial constraints—even if financial constraints for investments in fixed assets

partially disappeared, they still present for innovative investment. To answer our research question, we used an indirect measure of financial constraints—the investment equation. The method assumes that when companies invest in reaction to operational cash-flow changes, which represent internal capital—the company has a problem with capital access, then is financially constrained. We executed models for fixed assets—measuring them by capital expenditure from the cash flow statement. We controlled future demand by the level of revenues, previous year level of leverage, and past cash-holding. Two models—for high-technology and low-technology companies were executed. Panel models with fixed effects were used.

The statistically significant coefficient for variable CF confirmed that the HT companies undertake investments when the operating cash flow is available. It means that this group is financially constrained. Simultaneously, for LT coefficient for the same variable (CF) was statistically insignificant. We have a basis for concluding that LT public companies had no problem financing their investments in fixed assets (then are not financially constrained). When we came to the control variable—cash-holding—the models confirmed that previous savings are significant for HT and LT companies but more critical for HT firms. The results may also be an indication that the HT firms are financially constrained.

Summarizing, based on our results, we can conclude that the stock market in emerging markets, like Poland, has not entirely solved the problem of capital access for innovative, high-technology firms. However, it plays a role in the case of non-technology companies. Our studies then contribute to previous research because they extend the research area to the emerging markets. Moreover, we analyzed financial constraints based on the newest data from IPO date to 2018 for the Warsaw Stock Exchange data. The literature confirms that financial constraints may change over time (Brown et al. 2009). Especially development on the financial market may change the situation of innovative firms and measuring them, by methods we used, help to answer the question of whether changes are going in the right direction.

However, our studies have limitations. We could not execute the model for investment in R&D because such data are not available in Polish enterprises' financial statements. Also, our criteria for dividing companies into high-technology and low-technology firms is based on NACE codes. It would be better to collect more information about companies' activities and define the measure of technology level and analyzed companies' innovativeness.

Our research has implications for future studies. The models may be extended by additional control variables—especially referring to new shares issuing. According to previous studies, this variable should also be controlled in the investment model (Brown et al. 2012). Moreover, it would also be interesting to analyze how specific improvements implemented on the stock exchange market changed the financial constraints over time.

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Part IV
Personal Finance

Differences in Use of Credit Products Between the Old and New Member States of the European Union

Agnieszka Huterska

1 Introduction

Financial behaviour of consumers are related not only to the amount of earned income (Potocki 2018), but result primarily from financial literacy, which includes financial knowledge, behaviour and attitude (OECD 2016: 8). Financial knowledge alone is not sufficient to make rational financial decisions. The consumer's ability to use knowledge in the effective management of financial resources is necessary in order to ensure financial well-being (OICU-IOSCO 2014: 5–6; NFCS 2015:1). Therefore, financial literacy, i.e., a combination of knowledge, attitudes and behavior related to financial decisions made, leads to the financial well-being of households (Musiał and Świecka 2016; Lusardi and Mitchell 2011; Maciejasz-Świątkiewicz 2015). Financial literacy is crucial not only in terms of involving as many consumers as possible in using basic banking products. It allows a rational selection of products offered by financial institutions. Furthermore, the relationship between the use of financial products and financial literacy is two-way. Less interest shown in using financial products in some EU countries proves weaker financial literacy among their inhabitants. However, the lack or very limited use of financial products makes it difficult for such communities to practically develop financial literacy through their personal experiences. Simpson and Buckland (2009), Lusardi and Mitchell (2006), Lusardi et al. (2010) among others, indicated the links between financial literacy, and financial exclusion and credit constraint in their research. The conducted research (Musiał and Świecka 2016; OECD 2016: 8; Frączek et al. 2017) indicates a low level of financial knowledge among young people. This is an extremely worrying phenomenon because decisions made in

A. Huterska (✉)
Nicolaus Copernicus University in Toruń, Toruń, Poland
e-mail: Agnieszka.Huterska@umk.pl

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young adulthood at the beginning of professional activity, often affect the financial situation in later life, including the risk of a debt spiral.

Adequate financial knowledge of young people affects not only the rational management of current income, but also the awareness of the need to accumulate savings throughout the entire period of professional activity, which is the subject of research by Lusardi and Mitchell (2011). This is important when there is a need to collect funds outside of mandatory retirement systems in order to have sufficient funds after retirement. Particular attention should be paid to young adults and their financial education. As indicated (Friedline and Rauktis 2014), young people 'may be the front lines of financial inclusion'. Financial inclusion in young adulthood is more likely. However, reckless use of credit products may lead to excessive indebtedness in young adulthood and result in financial exclusion or remaining outside mainstream banking. This threat, resulting from excessive indebtedness of young people, is presented also in works by Williams and Oumlil (2015).

Numerous works, e.g., Demirguc-Kunt et al. (2015), Frączek (2017), Huterski et al. (2020), Korzeniowska and Huterska (2020), indicate the existence of a strong spatial differentiation of financial inclusion and the popularity of using specific financial products. The results of the research conducted by Lusardi (2015) showed, however, no correlation between the country's GDP and the results of the test on the knowledge and financial skills of young people. The level of financial skills depends not only on the type and manner of transferring knowledge to young people through formal education systems, which varies between countries. Banks, financial institutions and various types of organizations, both governmental and non-governmental, operating in individual countries also play an important role in providing information about the benefits of using specific financial products and the related risks. The influence of the peer group on young people also plays an extremely important role. Taking into account the diversity of the European Union member states not only in terms of education systems, but above all the experiences of individual societies in taking advantage of the opportunities offered by the market economy.

The research objective of the study was to assess the specificity of disproportions in the use of loan products by young people aged 15–24 in the old and new European Union countries.

In the article, the following research hypothesis was formulated:

The differences in the level of financial exclusion of young people in the scope of using credit products among new and old member states of the European Union cannot be found.

The analyses conducted constitute an introduction to a broader study on the indebtedness of young people in the European Union member states, and the diversity of this phenomenon, while taking into account the level of financial knowledge of young people.

2 Data and Research Methods

The study analysed the degree of use by people aged 15–24 of banking products such as a credit card and a loan in a financial institution. The analysis used data obtained from the Global Findex Database (The World Bank 2017b), which contains the results of a survey conducted among households in 2017. The data collected in the Global Findex database are drawn from survey data covering almost 150,000 people in 144 economies—representing more than 97% of the world's population. The data used in the article come from a survey conducted in 2017 by Gallup Inc. According to 2017 Global Findex Survey Methodology, they carried out surveys of approximately 1000 people in each of the member states of European Union,[1] using randomly selected, nationally representative samples. The target population was the entire civilian, noninstitutionalized population aged 15 and above. The interviews were conducted by means of landline and mobile telephones*, face to face conversations** and only with mobile telephones*** (The World Bank 2017a).

Statistical analysis of data on the degree of use of the financial products in question was applied as a research method.

A preliminary analysis of the relationship between the shares of respondents using specific types of financial services was also carried out. For the dependency between having a credit card in and borrowing from a financial institution, Pearson correlation coefficients were calculated and their significance was checked using t-statistics (Sobczyk 1997, p. 253; Piłatowska 2006, p. 103; Kufel 2013):

In the European Union countries (EU_ALL) there is a moderate, positive correlation (0.4320) between the share of credit card holders and the share of borrowing in a financial institution.[2] On the correlations the t-statistics prove that calculated correlation for variables are statistically significant (i.e., the null hypothesis about the irrelevance of the correlation coefficient at the significance level of $a = 0.05$ is rejected, $|t| = 2.442 > t_{\alpha,s} = 2.056$, where $\alpha = 0.05$, $s = 26$.).

Taking into account the above dependencies, the further part of the paper presents the differentiation of share of consumers' own credit card and loan in a financial institution in the old European Union member states compared to the new.

[1] Austria* May 30–Jun 28, Belgium* Jul 11–Sep 18, Bulgaria** May 11–Jun 26; Croatia** May 23–Jul 9, Cyprus Apr 27–Jun 20, Czech Republic** Apr 4–Jul 11, Denmark May 5–May 30, Estonia** Jun 15–Jul 15, Finland*** Apr 26–May 30, France * Apr 19–May 18, Germany* Apr 19–May 18, Greece** May 20–Jun 16, Hungary** May 14–Jun 21, Ireland* Mar 14–Apr 10, Italy* Jan 30–Feb 23, Latvia** Jun 5–Jul 27, Lithuania** Jul 17–Aug 6, Luxembourg* Apr 19–May 18, Malta* Mar 17–Apr 15, Netherlands* Jul 11–Sep 1, Poland** Aug 12–Sep 25, Portugal* Mar 27–May 3, Romania ** Apr 12–Jun 15, Slovak Republic** May 12–Jun 6, Slovenia* Mar 3–Apr 5, Spain* Jan 30–Feb 23, Sweden* May 3 May 30, United Kingdom* Mar 14–Apr 10.

[2] Correlation coefficients between credit card ownership and borrowed in financial institution, calculated using the observations 1–28, 5% critical value (two-tailed) = 0. 0217.

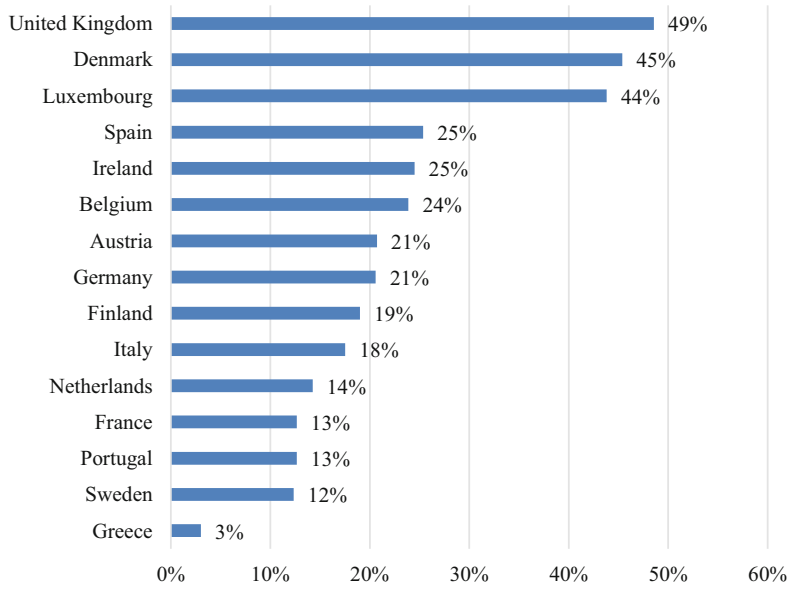


Fig. 1 Credit card ownership by young adults in the old European Union countries

3 Credit Card Ownership

In both groups there were countries where only about 3% of respondents declared that they had credit cards. The highest proportion of respondents with a credit card (48.57%) was in Great Britain (see Fig. 1), which until 2020 had belonged to the old EU countries. The percentage of credit card holders in Denmark and Luxembourg, belonging to the group of old member states of the European Union, and Malta (see Fig. 2), which has been a member of the European Union since 2004, was at a similar level. Greece was the country of the old European Union in which the number of young adult people declaring owning a credit card was the smallest (3.03%). Also, Sweden (12.36%), Portugal (12.65%), France (12.66%) and the Netherlands (14.25%) were among the countries from the old EU with the number of people using this financial product considerably below the median.

In the new member states of the European Union, only in Malta the percentage of young adults owning a credit card (41.91%) was similar to the percentage of people possessing this product in Denmark or Luxemburg (see Figs. 1 and 2). In Bulgaria, Poland, Hungary and Romania the percentage did not exceed 5%.

Despite similar minimum and maximum values in both groups, the median in the EU_old group (22.60%) was twice as high as the median in the new EU countries group. On the one hand, this proves that the new EU countries belong to the countries where the popularity of credit cards among young people is very low. On the other hand, however, this group includes countries where young people use this product to a similar degree as in the old EU countries.

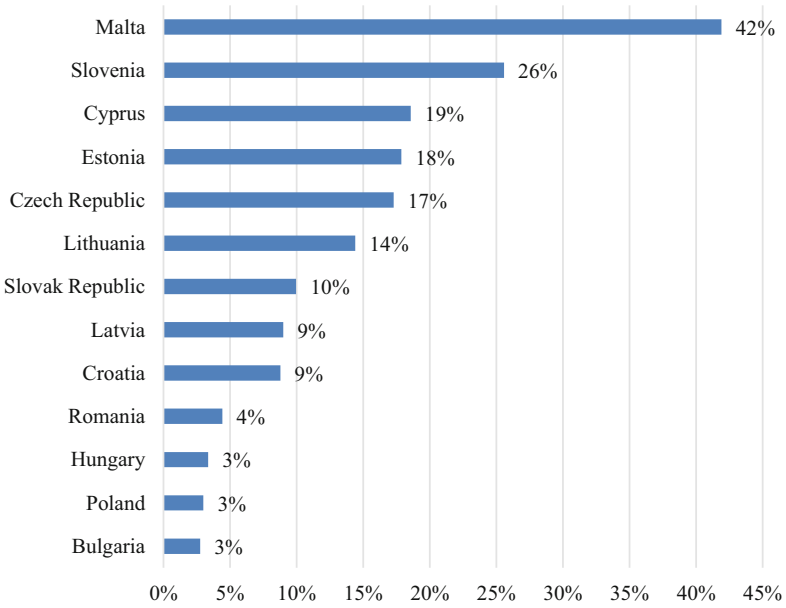


Fig. 2 Credit card ownership by young adults in the new European Union countries

The much lower popularity of credit cards (The median = 20.6% for EU_old and 10.0% for EU_new) when compared to accounts in financial institutions (The median = 92.6% for EU_old and 62.6% for EU_new) among people aged 15–24 results, on the one hand, from the natural income limitations for this age category, and, on the other hand, from the existence of alternative methods of satisfying the needs of short-term increase in available funds (see Table 1).

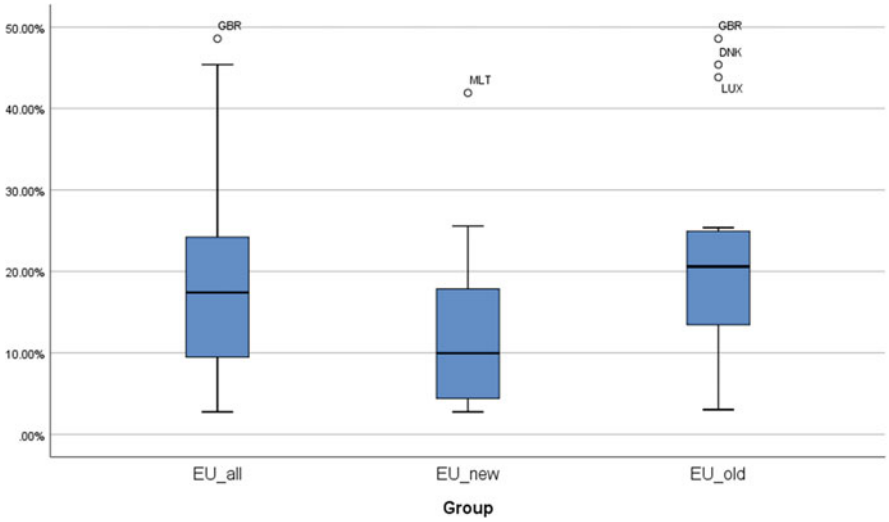
In the first case, one should take into account the limited creditworthiness of the majority of young people due to the lack or limitation of personal permanent sources of income. In the second case, the option of obtaining a current account credit facility and using it with a debit card may affect the reduction of interest in credit cards. In some countries, this may also be the result of the high popularity of easy, though costly, indebtedness in non-bank loan companies, which, unlike banks, do not use extensive creditworthiness assessment procedures (payday loans, e.g., the United Kingdom, where the authorities recognized such debts among young people as a serious problem—Rowlingson et al. 2016).

It is also important that the card owner pays fees and commissions to the financial institution that provides the service.

Factors affecting the popularity of having credit cards among young people are certainly even more complex and varied, as evidenced by the lack of a clear geographic (north-south) or income (rich-poor) pattern in the distribution of credit card popularity among countries, as in the case of accounts and debit cards. For example, Slovenia, a post-socialist country from the EU_new group of countries, has a share of credit card holders of almost 26%, while in the EU_old group in Greece

Table 1 Statistics for credit card ownership (%)

Group	n	Sd	25%	Me	75%	min	max	Skew	kurtosis	Se
EU_new	13	13.6	4.4	10.0	17.9	2.8	41.9	1.4	2.5	11.1
EU_old	15	23.0	13.5	20.6	24.9	3.0	48.6	0.9	0.1	13.3
EU_ALL	28	18.6	9.5	17.4	24.2	2.8	48.6	1.0	0.4	13.0



Source: the author's own calculations based on data from The World Bank (2017b)

this share is 3%, in Sweden it is just over 12%, similar to Portugal and France. Even in the Czech Republic, another post-socialist country in the EU_new group, the share of credit cards is over 17% despite the fact that it is a country with extremely low popularity of having accounts in financial institutions and debit cards among young people. At the same time, in neighbouring Poland (also a post-socialist EU_new country), this share is the same as in Greece, i.e., 3%.

4 Taking Loans from a Bank or Other Formal Financial Institution

While the possibility of getting into debt due to having a credit card was personalized in the Findex survey, in the case of other forms of borrowing any money by respondents, both indebtedness incurred individually and jointly with another person were taken into account. Here we focus on borrowing from a bank or another type of formal financial institution. Data on borrowing from family, relatives, or friends or

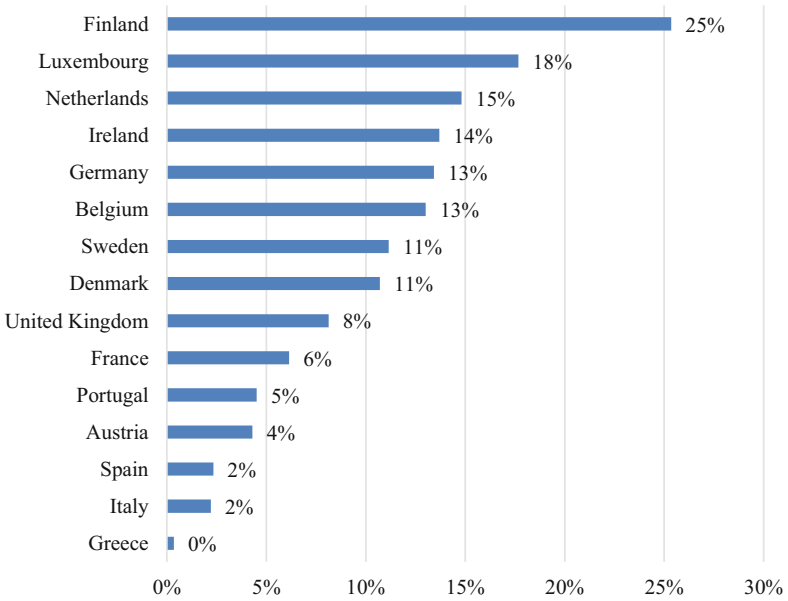


Fig. 3 Borrowing from financial institution by young adults in the old European Union countries

from an informal savings group/club as alternative sources of additional funds are interesting material for comparison, however, it is beyond the scope of this article.

In the old EU, Finland was the country in which the most young adults had a debt in a financial institution (%). However, in Portugal, Austria, Spain, Italy and Greece the percentage did not exceed 5% (see Fig. 3).

The percentage of young adults with a debt in a financial institution in the group of the new members of the European Union does not exceed 11%. The highest percentage can be seen in Lithuania and Malta, the lowest in Latvia, Hungary, Cyprus and Bulgaria (see Fig. 4).

Borrowing from a credit institution is even less popular among young people than having a credit card. There were countries within the analysed groups where less than 1% of young people used a bank loan or a loan from a financial institution. The exceptions are the new EU countries, where the lowest share was over 2% in Latvia. In this group, the median was also at the level of 8.8%, while in the country with the highest use of loan products, i.e., Lithuania, this share was 10.3%, which is significantly below the highest values in the old EU (see Table 2).

A significant element that hinders inference on the basis of data on the popularity of loans among the young is the differentiation of the percentage of students (tertiary level education) in relation to people in the typical study age range between the countries surveyed. According to the data of the UNESCO Institute for Statistics (for 2017–2018), tertiary school enrolment in Central Europe and the Baltics is 62%, in the European Union 69%, in the OECD member countries 74%, and in all high income countries it is 75%. However, within the European Union, there is a

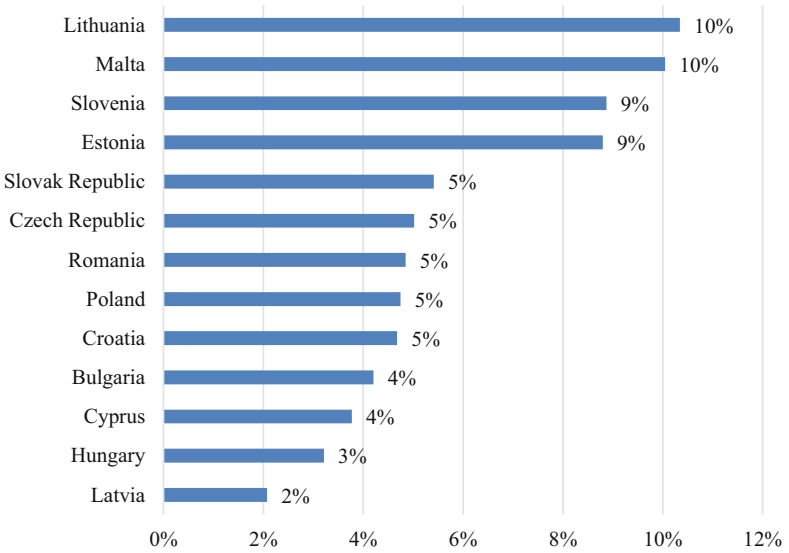


Fig. 4 Borrowing from financial institution by young adults in the new European Union countries

significant variation, from 47% in Slovakia, 88% in Latvia in the EU_new countries group, and from 60% in the United Kingdom to 89% in Spain in the EU_old group. We omit Luxembourg (19%), due to the specificity of this small country, and Greece (137%), due to the specific use of higher education to combat unemployment in the conditions of the economic crisis.

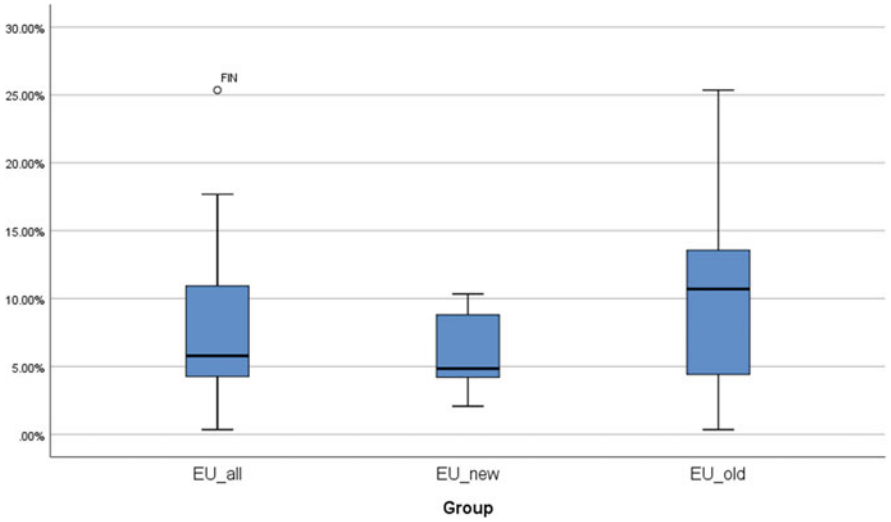
Data on the popularity of loans from financial institutions among adolescents aged 15–24 are not accurate enough to distinguish having a student loan from other types of loans, and also from ordinary consumer loans. This means that the correct interpretation of data would require not only knowledge of the participation of students in this age group, but also of the financial student support systems in individual countries. The availability of preferential loans for students may in practice be used to a different extent by young people from different countries, due to the different structure and competitiveness of scholarship systems.

The differences in the level of life and financial independence of young people in individual countries should also be considered, which may result from both economic and cultural background, as well as from differences in the functioning of banking systems in individual countries. All these factors require taking a cautious approach when looking for certain regularities in the differences in the popularity of borrowing from financial institutions by young people from different countries.

As mentioned above, credit facilities may take the form of an acceptable overdraft in the current personal account or in the limits assigned to credit cards, which naturally competes with typical loans up to a certain amount. Also, access to payday

Table 2 Statistics for money borrowed from the bank or other formal financial institution (%)

Group	n	Sd	25%	Me	75%	min	max	Skew	kurtosis	Se
EU_new	13	5.9	4.2	4.9	8.8	2.1	10.3	0.6	−1.0	2.7
EU_old	15	9.9	4.4	10.7	13.6	0.4	25.4	0.6	0.3	6.8
EU_ALL	28	8.0	4.3	5.8	10.9	0.4	25.4	1.2	2.0	5.6



Source: the author's own calculations based on data from The World Bank (2017b)

loans from institutions that are not banks or other formal financial institutions, such as pawnshops and many online loan companies, can have a similar effect.

5 Discussion and Conclusions

Several important conclusions of a different nature follow from the above considerations. The new member states of the European Union (EU_new) as a group show a lower degree of inclusion in financial services among young people aged 15–24 in terms of credit cards and loans in a financial institution compared to the group of countries that belonged to the EU already before May 2004 (EU_old). However, the EU_new group turns out to be highly diversified and this is not only due to the fact that Malta and Cyprus are the only countries in this group that have not gone through the era of real socialism. High levels of inclusion in financial services, as evidenced not only by the percentage of people who have an account, but also by those who use other financial products and services, including loans, are present in Slovenia and

Estonia and the distance between them and the weakest EU_new countries in this area, i.e., Bulgaria, Croatia, and Romania, is significant.

Among the countries of the EU_old group, attention should be paid to the low level of having a credit card and a loan in a financial institution in southern European countries, i.e., Greece, Italy, and Spain, compared to northern countries such as the Netherlands, Finland, Denmark, and Sweden. However, the disproportions among the EU_old countries are not as strong as among the EU_new countries. The exception is Greece, which clearly stands out from other EU_old countries and has a banking services level comparable to that of Bulgaria or Romania.

The above comments indicate that although the differences in the wealth of the EU_old and EU_new countries may partly explain the differences in the degree of use of credit products by young people in these countries; however, this link is not clear. The examples of Slovenia, Estonia, and Latvia indicate that it is possible to promote the use of banks and other formal financial institutions among young people effectively also in relatively less wealthy countries.

Careless usage of credit products can lead to the situation in which young people at an early stage of the working life incur debts, which will in the future prevent them from using any credit offer of banks. In Poland, according to the data presented by BIG InfoMonitor and Biuro Informacji Kredytowej (BIK), the credits granted to the 18–24 age group amount to 1.3% of the value and 4% of the number of all active credits. It is also significant that consumer credits constitute the share of almost 70% (cash loans—40.7% and instalment loans—24.8%), overdraft limits amount to 20.9%, credit card debts amount to 12.2% and mortgage loans to as little as 1%. Reckless expenditure, living beyond means or unexpected spending with no savings lead to the fact that one out of every 20 people aged 18–24 experiences financial difficulties (BIG InfoMonitor 2019; Busines Insider Polaska 2019). Moreover, people in the 18–24 age group constitute 1.5% of unreliable debtors in Poland (BIG InfoMonitor 2020). Having an account, which is the first step to financial inclusion, creates an opportunity for young people to develop proper financial habits, the ability to rationally manage their budget and to collect savings. This is extremely important in a situation where young people show a need for credit products later in their lives. However, only skillful use of this group of products, with an appropriate level of financial literacy covering not only knowledge, but also financial habits, can prevent young people from falling into a spiral of debt in the future.

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Diversified Risky Financial Assets in Portfolios of Risk-Averse Households: What Determines Their Occurrence?

Katarzyna Kochaniak and Paweł Ulman

1 Introduction

Financial risk tolerance is a behavioural finance term which can be defined as the maximum amount of uncertainty that someone is willing to accept when making a financial decision (Grable and Joo 2004) or the willingness to engage in a financial behaviour in which the outcomes are uncertain with a possible identifiable loss (Irwin 1993). It can be analysed within two approaches—subjective (based on individuals' self-assessments of risk attitudes) and objective (related to individuals' actual financial risk-taking). According to the so-far literature, perceptions of own risk tolerance determine investment choices and thus the composition of portfolios. However, the measurement of financial risk tolerance based on the above approaches does not always lead to consistent results. In such cases, under- or overexposure to financial risk can be concluded (Marinelli et al. 2017).

The overexposure to financial risk can be assumed especially regarding households that declare unwillingness to take any risk (i.e., risk aversion) but participate in risky assets. In the euro area countries, this phenomenon is not commonly observed; however, in Belgium, Cyprus, Finland, France, Germany, Ireland, Luxembourg, Malta, and Spain it may affect from 10% to 35% of risk-averse households (Kochaniak and Ulman 2020). According to the microdata from the Eurosystem's Household Finance and Consumption Survey (HFCS), it is mostly due to their investments in one type of risky assets. Diversified risky parts of portfolios can be recognised more often in risk-averse households residing in Belgium, Finland, France, Germany, and Spain.

K. Kochaniak (✉) · P. Ulman
Cracow University of Economics, Kraków, Poland
e-mail: katarzyna.kochaniak@uek.krakow.pl; pawel.ulman@uek.krakow.pl

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It should be noted that financial risk tolerance in both approaches became invoked in the EU regulations—the MiFID II (Directive 2014/65/EU) and MiFIR (Commission Delegated Regulation 2017/565), which promote the rules of 'suitability', 'know your client' and 'know your product'. They require practitioners to provide individuals and households only with products meeting their investment objectives and preferences. Thus, the provisioning of retail clients who declare risk aversion with risky financial assets became legally prohibited.

Our study is based on microdata derived from the second wave of the Eurosystem's Household Finance and Consumption Survey. It focuses on households declaring unwillingness to take any financial risk (that can be named subjectively risk-averse) and residing in Belgium, Finland, France, Germany and Spain. Because part of them indeed participate in risky financial assets, we aim to identify socio-demographics and socio-economics, which are decisive for their propensity to diversify these items in portfolios. This paper seeks to answer the following research questions related to the households in question:

1. Which characteristics are conducive to their participation in diversified types of risky assets?
2. Which characteristics foster their consistent behaviour on the financial market, i.e., preventing them from investments in risky assets?

Thus, based on socio-demographics and socio-economics, we aim to describe two separate profiles of households that declare risk aversion—with a tendency to the diversification of risky financial asset and with a tendency to remain free from risks.

Our study extends the existing research line of inquiry regarding the subjective and objective risk tolerance, in relation to households declaring risk aversion. It fills the gap in the so-far literature, providing knowledge about their characteristics that favour holdings of diversified risky financial assets, despite beliefs in own unwillingness to take any risk, as well as fostering limitation of their portfolios solely to riskless components.

The results of our study may have implications for both practice and policy. The findings can be noteworthy for the EU financial entities obliged to fulfil the MiFID II and MiFIR especially when they offer financial assets to households declaring risk aversion due to their vulnerability to wrong decisions. A more profound diversification of risky assets in such a household may signal its inability to assess own risk attitude. Furthermore, it may signal the need to re-examine its objectives and preferences by a professional prior to offering retail financial products or services. Our findings may also be useful for financial entities operating cross-border since we find the differences in domestic profiles of households affected by the conflict between their perceived risk attitude and composition of financial asset portfolios.

The policy implications refer to consumer protection since a significant part of the risk-averse households makes financial decisions on their own (EC 2012). The prevalence of households with a gap between subjective and objective financial risk tolerance in a population, which signals their overexposure to financial risks, may lead to negative social consequences, especially under stress on the financial market.

The remainder of the paper is as follows: Section 2 contains an overview of the subject literature, Sect. 3 presents the method and data applied. Section 4 contains the results of empirical analysis. Section 5 provides conclusions.

2 Related Literature

The attitude towards risk and actual risk-taking are discussed in the so-far literature, however, more often concerning specified sub-groups of individuals or households (Marinelli et al. 2017; Moreschi 2005) than countries' populations (Martin 2011; Warneryd 1996). It should be noted that the so-called subjective and objective financial risk tolerance is analysed with the use of various measures that have their own strong and weak sides.

Subjective risk tolerance is often discussed with the use of the single question self-classification method, which is valued for its simplicity and easy collection of information required. It consists of the question about own risk attitude and proposed answers—from the willingness to take substantial risks to the risk-aversion. This method is often applied by researchers and practitioners (Marinelli et al. 2017; Grable 2016; Hanna et al. 2008; Roszkowski and Grable 2005; Chang et al. 2004; Grable and Lytton 2001; Schooley and Worden 1996) and adopted in national surveys, such as, for instance, the Eurosystem's Household Finance and Consumption Survey or the US Survey of Consumer Finances. However, it is not free from weaknesses such as ambiguous wording of 'substantial', 'above average' and 'average', which respondents may interpret differently (Kimbal et al. 2007). Moreover, the lack of 'willingness to take less-than-average financial risk' among proposed responses may be a potential cause of too often declarations of risk aversion (Schooley and Worden 1996). Assessments of subjective risk attitudes in economic behaviour are also based on the choices between lotteries, but they suffer from non-homogeneous outcomes. Due to this, verbal descriptions of situations are implemented, with different options to choose (Warneryd 1996). However, they may give rise to associations that obscure the measure of a respondent's subjective risk attitude.

Objective risk tolerance relates to actual investment behaviour and is measured on the basis of the riskiness of financial asset portfolios. It is often described by the ratio of a respondent's risky assets to his or her wealth, but also by a degree of the diversification of the risky part of a portfolio. However, both measures' weak side is limited control over contextual variables related to liquidity needs or financial constraints of a respondent and market expectations, influencing behaviour beyond risk tolerance (Nosic and Weber 2007). Warneryd (1996) finds the first measure useful only if applied to respondents with high incomes and risky assets in portfolios, while the latter recognises as universal and informing about the risk-taking-progression. In his opinion, the simplest behavioural measure of a portfolio's riskiness is that a household holds risky assets. Limitations of the ratio of risky assets to wealth as a measure of risk tolerance are also discussed by Hanna et al. (2001) who

emphasise its unusefulness regarding individuals or households that do not participate in any financial asset.

The aforementioned weaknesses of subjective and objective risk tolerance measures should be kept in mind when applied in research studies as a proxy for true risk tolerance of individuals or households. They may lead to equivocal results obtained within both approaches, not necessarily signifying the underexposure or overexposure to financial risks. It should be noted that the so-far literature identifies gaps between subjective and objective financial risk tolerance; however, to a limited extent regarding households we focus on—risk-averse but risk-taking.

Due to the aim of our study, it is essential to know which socio-demographics and socio-economics can be concluded as decisive for subjective and objective financial risk tolerance. The literature provides vast evidence in this regard. A respondent's age is found to negatively influence risk tolerance (Bucciol and Miniaci 2010; Sahm 2007; Yao et al. 2005; Coleman 2003; Bakshi and Chen 1994). It is explained by the fact that young investors have more time to recover from losses. However, the relationship between age and risk tolerance may not be linear. The same direction of impact is recognised for household size (Calvet and Sodini 2014; Yao and Curl 2011). Larger households tend to be more conservative in their risk attitudes since their size negatively influences the wealth per capita and positively the committed expenditure-to-wealth ratio. Moreover, they are more exposed to the risk of members' random needs (Calvet and Sodini 2014; Yao and Curl 2011). Among the determinants positively influencing risk tolerance, there is a level of education completed (Gilliam et al. 2008; Chang et al. 2004; Grable 2000), as well as wealth and incomes, including their levels and sources (Gibson et al. 2013; Bucciol and Miniaci 2010; Deaves et al. 2007; Chang et al. 2004; Grable and Joo 2004; Hallahan et al. 2004; Grable 2000). More formal education is concluded to make an assessment of risk-return trade-offs easier (Gilliam et al. 2008; Chang et al. 2004; Grable 2000). Considerable wealth or incomes allow overcoming market requirements, including entry costs (e.g., advising fees) and minimum value of investments (Vissing-Jorgensen 2002; Haliassos and Bertaut 1995). The gender of a responding person is recognised significant as well since males are found more risk-tolerant than females (Weller et al. 2010; Chang et al. 2004; Slovic 2004; Weber et al. 2002; Grable 2000; Jianakoplos and Bernasek 1998). The respondent's status on the labour market also matters, and the self-employed are recognised more willing to be exposed to risks (Alessie et al. 2002; Stewart and Roth 2001). Hallahan et al. (2004) and Yao and Hanna (2005) find the marital status significant and conclude greater risk-tolerance of singles than couples. The limited willingness of couples to take risks may be supported by similar reasons to those discussed regarding large households. It should be noted that selected studies provide opposite findings or do not recognise the above characteristics as statistically significant (Calvet and Sodini 2014; Bucciol and Miniaci 2010; Deaves et al. 2007; Grable 2000).

A description of risk-averse retail investors who hold risky financial assets in portfolios is presented in brief in the study of Marinelli et al. (2017). It is based on the characteristics selected from the above ones, such as high income and lack of dependant children, but also on financial literacy, and less cautious economic

behaviour. However, these outcomes refer to a non-representative group of respondents in question. Our study is based on data related to the populations of selected euro area countries. It supplements our previous research profiling households in question and identifying the causes of their overexposure to financial risks (Kochaniak and Ulman 2020) since it discusses the phenomenon of their holdings of diversified risky assets. To some extent, our study recalls Warneryd's (1996). Both are cross-sectional and based on nationally representative data. Moreover, both use information about the numbers of risky asset types in portfolios as a proxy of actual risk-taking of households. According to Warneryd (1996), this measure is correlated with households' subjective risk attitudes. However, both studies differ in terms of their aims and methods, as well as the targeted group of households which in Warneryd's research consists of respondents of all possible ranges of subjective and objective risk tolerance.

3 Method and Data

We conduct a cross-sectional study in which we analyse the phenomenon of the diversification of risky financial assets in the portfolios of households declaring risk aversion.

The study applies the Poisson regression model, in which the dependent variable Y is a count variable with a conditional Poisson distribution in relation to household characteristics (Hilbe 2014). This means that for each household with specific characteristics, the distribution is different. It can be seen in diverse values of the λ distribution parameter for individual households. Regarding this, the parameter λ_i (for the i-th household) should be a function of the vector of characteristics (x_i). Since in the Poisson regression model this function should take non-negative values, we apply its exponential form described as:

$$\lambda_i = e^{x_i'\beta}, \tag{1}$$

Thus, the Poisson regression model with parameter estimates based on the Maximum Likelihood Estimation (MLE) can be presented as follows:

$$lnE(y_i|x_i) = ln\,\lambda_i = x_i'\beta. \tag{2}$$

It should be noted that the variance and expected value in the Poisson distribution are equal. If the value of variance is higher, the overdispersion may occur and lead to a kind of heteroscedasticity. In such a case, an appropriate assessment of standard errors should be ensured, or a negative binomial distribution applied for the count variable (Winkelmann 2008).

In our study, the dependent variable (2) refers to the number of risky financial asset types in the portfolio of a household that declares risk aversion. It takes values from 0 to 4.

Based on the so-far literature, we propose a set of independent variables recognised as statistically significant for the formation of subjective and objective risk tolerance of a household. This set refers to the following socio-demographics and socio-economics:

1. Quintile class of total gross income of a household, at a country level (dummies): *TGI_1Q*—the first (reference variable), *TGI_2Q* – the second quantile, *TGI_3Q*—the third quantile, *TGI_4Q* – the fourth quantile, *TGI_5Q*—the fifth quantile
2. Type of income of a household (dummies): *I_Empl*—employee income, *I_SEmpl*—self-employment income, *I_Pens*—income from pensions, *I_STrans*—regular social transfers (except pensions)
3. Number of adult members of a household (discrete variable): *N_Adult*
4. Number of dependant children in a household (discrete variable): *N_Child*
5. Education level of the responding person (dummies): *E_1L*—primary and lower (reference variable), *E_2L1S*—lower secondary, *E_2L2S*—upper secondary, *E_3L*—tertiary
6. Marital status of the responding person (dummies): *MS_S* (reference variable)—single (never married); *MS_M&CU*—married and in a consensual union on a legal basis, *MS_Wid*—widowed, *MS_Div*—divorced
7. Age of the responding person (dummies): $A < 25$ (reference variable), *A_25-39*, *A_40-54*, *A_55+*
8. Gender of the responding person (a dummy): *Gender*—1 if male.

We apply household-level data derived from the second wave of the Eurosystem's Household Finance and Consumption Survey (ECB 2016), which provides information about the distribution of households' socio-demographics and socio-economics in 20 euro area countries. However, due to the aim of this study, we focus solely on populations in which the phenomenon of risky asset diversification can be recognised—of relatively large fractions of risk-averse households with two or more types of risky financial assets in portfolios. At the threshold of 3%, the following countries are recognised as being in the interest of the study: Belgium, Finland, France, Germany, and Spain. Within this subset, the fractions mentioned vary from 3% to 14% (Table 1). It is worth adding that in 10 out of 20 euro area countries participating in the HFCS, which are Austria, Cyprus, Estonia, Greece, Ireland, Italy, Latvia, Portugal, Slovenia, and Slovakia, the problem analysed almost does not exist.

The total number of households considered in our study is 25,829, while regarding individual countries it ranges from 1617 (in Belgium) to 9266 (in France).

In the HFCS database, the subjective risk attitude of a household is recognised on the basis of the single question self-classification method, which boils down to asking 'Which of the following statements comes closest to describing the amount of financial risk that you (and your husband/wife/partner) are willing to take when

Table 1 Number of households declaring risk aversion and holding 0–4 types of risky financial assets in portfolios in selected euro area countries

No. of types of risky financial assets	Belgium	Finland	France	Germany	Spain	Group
0	1329	4084	7225	2253	3609	18,500
1	244	2161	1538	356	954	5253
2	43	866	470	120	295	1794
3	1	163	33	19	59	275
4	0	2	0	0	5	7
Total of households	1617	7276	9266	2748	4922	25,829

you save or make investments?' This method limits possible responses to the following: (1) Take substantial financial risks expecting to earn substantial returns; (2) Take above average financial risks expecting to earn above average returns; (3) Take average financial risks expecting to earn average returns; (4) Not willing to take any financial risk. Since we are solely interested in households with subjective risk aversion, we focus our study on respondents indicating the last answer.

Apart from the declared risk aversion, we are interested in households' financial assets. Part of them hold portfolios, in which risky assets of different types can be identified. Thus, for each risk-averse household, we count the following types of financial assets in the case of which the loss of the capital invested is possible:

1. Mutual fund units
2. Bonds, except state and other general government ones
3. Publicly traded shares
4. Other equities related to non-self-employment not publicly traded businesses.

4 Results

The Poisson regression provides us with useful results for discussing the propensity of households with subjective risk aversion to hold diverse types of risky assets, both for individual countries as well as for the entire group of these countries. The results allow distinguishing both profiles being the subject of our interest—involved in different types of risky assets and consistent, i.e., avoiding risky financial assets.

Most of the parameter estimates of Poisson models for the countries and the group are statistically significant at 0.1 or less (Table 2). It can be concluded on the basis of the standard Wald test. The lowest number of independent variables with statistically significant parameter estimates concerns Germany. However, the Likelihood Ratio test proves that all models applied in the study contribute significant information to explaining the variability of the dependent variable. It is worth adding that the problem of overdispersion is recognised solely in the model for Germany, for which we apply negative binomial distribution. Despite this, the differences between

Table 2 Results obtained from the Poisson regression model (dependent variable: the number of types of risky financial assets held by a household declaring risk aversion)

Variable	Belgium	Finland	France	Germany	Spain	Group
Intercept	−3.8467	−2.5706	−4.0300	−3.6429	−3.0541	−3.1843
TGI_2Q	0.7733	0.3389	0.6030	–	0.4574	0.4611
TGI_3Q	0.9718	0.6295	1.0198	0.4361	0.8700	0.8192
TGI_4Q	1.5212	0.8786	1.5483	0.8766	1.1261	1.1433
TGI_5Q	1.7230	1.0974	2.2804	1.5336	1.7058	1.5349
N_Adult	−0.4032	0.1363	−0.1296	−0.3920	0.1330	−0.1005
N_Child	−0.1702	–	0.0455*	–	–	–
Educ_2L1S	0.4794*	0.7318	0.4471	–	0.4639	0.9236
Educ_2L2S	0.5112	0.7300	0.4336	1.2930	0.7231	0.7886
Educ_3L	0.6626	0.9125	0.7711	1.5866	1.0721	1.0670
I_Empl	–	−0.0897	−0.0998*	–	−0.4174	–
I_SEmpl	–	0.2756	–	–	–	0.3766
I_Pens	0.5393	0.1715	–	0.2794	–	0.3026
I_STrans	0.2982	−0.0932	−0.1120	–	−0.1891	0.0582
MS_M&CU	0.3351	–	–	–	−0.2434	−0.0990
MS_Wid	–	–	–	–	−0.2298	−0.1765
MS_Div	−0.5446	−0.1028	–	−0.6669	−0.4495	−0.2850
A_25–39	–	–	0.6795*	–	–	–
A_40–54	0.8822	0.1517	0.8686	0.5552	0.6294	0.2276
A_55+	1.0601	0.3527	0.8881	0.7068	1.1414	0.4905
Gender	–	–	0.1330	–	–	–

Note: (−) refers to a significance level above 0.1; (*) denotes significance at the level of 0.051–0.1; in the remaining cases, the *p*-value did not exceed 0.05

the individual parameters estimates in the Poisson and negative binomial distributions do not differ significantly and do not affect the merit conclusions.

The outcomes obtained from the model for the group of countries allowed us to conclude about the significance of selected characteristics of risk-averse households for the formation of the number of risky asset types they hold. The propensity to diversify risky parts of portfolios is found to be increasing along with increases in the levels of their incomes, and education level and age (aged 40 and over) of responding persons (Table 2). More risky asset types can be expected in households receiving incomes from selected sources, mostly self-employment and pensions, ceteris paribus. Additionally, they are recognised among relatively small households, particularly of the singles, if we measure their size by the number of adult members.

Opposite to the above, the propensity to make investment choices adequate to declared risk aversion can be recognised mostly among large, low-income households of relatively young (up to 39 years of age) and poorly educated responding persons, also divorced or widowed ones.

It should be noted that the statistical significance of characteristics such as the number of dependants or the gender of a responding person is not confirmed at the

group level. Also, we cannot conclude about the peculiar investment behaviour of risk-averse households living on incomes from employment.

The statistically significant characteristics mentioned above also emerged as significant for the analysed propensity at the country level. In each of the countries, the propensity to hold diverse types of risky assets increases along with increases in incomes of risk-averse households, ceteris paribus. However, in Germany, more types of risky assets in portfolios can be identified only within a higher range of this characteristic (at least assigned to the third quintile class of total gross income).

Regarding the types of incomes, their significance for the analysed phenomenon is not so clear cut. In Finland, more types of risky asset can be recognised in households with incomes from self-employment and pensions, in Belgium among living on pensions and regular social transfers, while in Germany solely among living on pensions, ceteris paribus.

In selected countries, a greater propensity to hold diversified risky assets is conditioned by a higher level of education completed by a responding person. In Belgium and Spain, the strength of the impact of this characteristic increases within its full range—from primary and lower up to tertiary. However, in all of the countries analysed, the most diversified financial risky assets should be expected among respondents who graduated from tertiary education, ceteris paribus.

The analysed propensity remains under the influence of the age of responding persons as well. In France, the impact of this characteristic strengthens along with its increase from the lowest to the highest range. In the remaining countries, its growing influence is confirmed starting from the age of 40, ceteris paribus.

The significance of household size for the analysed phenomenon turned out to be equivocal, and dependent on whether it is described by the number of adult members or children. Moreover, regardless of how this characteristic is defined, it is recognised as a stimulant in selected countries, while in the others as a destimulant. In Spain and Finland, more types of risky assets should be expected in subjectively risk-averse households with more adults, while in Belgium, Germany, and France with their lower numbers. Regarding the number of dependant children, its positive impact on the discussed propensity is recognised in France, but negative in Belgium.

In all countries, except France, selected marital status types allow us to expect more types of risky assets, ceteris paribus. This refers to singles in Spain, couples (married and in a consensual union) in Belgium, while in Germany and Finland regarding singles, couples, and widowed. Moreover, in France, greater diversification of risky assets should be observed among risk-averse households represented by males.

Out of all considered socio-demographics and socio-economics, we can also indicate the ones favouring the adequacy of investment behaviours of the households that declare unwillingness to take the risk. They are in line with the conclusions based on the model for the entire group of countries. The consistency between what household members think and what they actually do should be expected mostly among living on low incomes (assigned to the lowest range), as well as represented by young, poorly educated and divorced persons. It can also be recognised among relatively small households (regarding the number of adult members) in Finland and

Spain, but large ones in Belgium, France and Germany. Moreover, lower propensity to hold diversified risky assets is recognised in French households without dependants and Belgian ones with their large numbers, ceteris paribus. In Finland, France, and Spain, we can conclude about the tendency to riskless investment behaviour of the households living on incomes from employment and regular social transfers. Additionally, in France, less interest in risky assets is found in households represented by females.

The Likelihood Ratio test showed that all models contribute significant information to explaining the variability of the dependent variable.

5 Conclusions

According to the results obtained, the propensity to hold diversified types of risky assets can be recognised in selected euro area countries, among subjectively risk-averse households of particular socio-demographics and socio-economics.

It characterises mostly the wealthiest ones (with incomes from the largest range), represented by well-educated persons aged 40+. Moreover, in most countries, this phenomenon refers to households with responding persons of marital status other than divorced. The significance of the remaining characteristics, such as, for instance, the size of a household, sources of incomes, and gender of the responding person is confirmed only at the domestic level, and their direction of impact may differ.

The opposite conclusions can be drawn about households whose behaviour on the financial market is consistent with their declared risk aversion, i.e., avoiding risky assets. Such an attitude is more evident among households with lower incomes and represented by poorly educated and relatively young persons. However, in selected countries, the significant impact of the size of a household and source of incomes (mostly from employment and regular social transfers) can be recognised, as well as the responding persons' marital status of being divorced.

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Financial Behavior: Preliminary Survey Results

Kutlu Ergün

1 Introduction

Financial literacy includes three essential components: financial knowledge, financial attitude and financial behavior. Perhaps financial behavior is the most important factor which formulates the financial literacy of an individual. According to Xiao (2008), to develop a behavior change focused educational program, researchers of consumer finance need to better understand how behaviors are formed and why and how to help consumers change undesirable financial behaviors and develop positive financial behaviors. On the other hand, psychological economists highlight the importance of considering psychological antecedents to explain financial behavior (Ning and Baker 2016). Apart from keeping abreast of latest technological innovations, enhancing overall financial literacy is essential factor for individuals' well-being. Financial literacy and technological literacy are important resources that low-income people need to exit poverty (Servon and Kastner 2008). Therefore, in addition to having good financial knowledge, especially level of positive financial behaviors should be increased in order to increase the level of financial literacy.

Financial literacy includes a number of behaviors that can enhance financial well-being. One of these important behaviors is saving. Active savers exhibit a behavior supporting their budgeting behavior. People who build savings are also likely to be more resilient to financial shocks and better able to meet financial goals. Also budgeting is a valuable tool for money management and a component of financial literacy (OECD 2016).

According to Wagner and Walstad (2019), financial behaviors are defined as short-term if they involve a money or credit management task. The four short-term

K. Ergün (✉)
Balikesir University, Balikesir, Turkey
e-mail: kutlu.ergun@balikesir.edu.tr

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financial behaviors cover expenses and paying all bills each month, managing checking account, paying off credit card balances in full each month; and, making monthly mortgage payments on time. However, if we consider long-term financial behaviors, we can include more behaviors which are impact of positive financial behaviors of individuals. This study included more short-term and long-term financial behaviors: spending according to personal budget, saving regularly, saving emergency and long-term, and paying bills on time, having monthly budget plan and comparison shop. Showing positive behavior on these components positively affects the financial literacy. However, overconfidence and optimism are especially important factors negatively effecting favorable financial behaviors, and it has negative impact on financial literacy. Behavioral studies showed that unrealistic optimism was associated with less prudent financial behaviors, such as short planning horizons and saving less (Collins and Gjertson 2013). Therefore, financial education, especially for young individuals, is required to enhance positive financial behavior and overall financial literacy. Financial education is also essential for the average family trying to decide how to balance its budget, buy a home, fund the children's education and ensure an income when the parents retire (OECD 2006). Well-designed and well-executed financial education initiatives can have an effect (Hastings et al. 2013).

This paper shows *the preliminary results* of a study carried out among Italian and Turkish university students. After the introduction which is the first section, the methodology is the second section which explains methods of the study. Third section is the section of results which summarize the survey results. Conclusions summarize the main findings of the research.

2 Literature Review

Consumers' behavior is important factor in shaping their financial situation and well-being as well as having impact on the level of financial literacy. On the other hand, some types of behavior such as failing to actively save money, putting off bills payment, failing to plan future expenditures or choosing financial products without shopping around, may impact negatively on an individual's financial situation and well-being (OECD 2020). Desirable financial behaviors and overall financial literacy depend on socio-demographic and socio-economic characteristics. Xiao et al. (2015) suggest that older consumers have higher level financial capability than younger consumers. The finding show that age is an important determinant for financial capability. Rostamkalaei and Riding (2020) examined the financial knowledge and financial practices among immigrants and Canadian-born individuals. They showed that immigrants had lower financial knowledge and financial behavior score (having retirement account and saving for long-term) than Canadian-born individuals. They also demonstrated that individuals who are not native English and French had lower level of financial knowledge. Individuals who speak an official language were relatively more likely to have retirement plan and check their credit reports.

Mahendru et al. (2020) explored the antecedents of financial well-being, such as financial knowledge, objective and subjective financial situation and personality traits. The results of their study revealed that the attainment of financial well-being is characterized by the fulfillment of present and future commitments, feeling of financial security; freedom of choice; and improved quality of life.

Financial attitudes, financial literacy and behavioral control play an essential role in explaining responsible financial consumption behavior (Barbić et al. 2019). Financial knowledge is known to have a significant effect on financial decisions such as saving for retirement. Therefore financial knowledge and saving behavior could contribute to the household saving behavior (Kim and Yuh 2018). Since financial literacy includes financial knowledge, financial behavior and financial attitude, in particular increasing financial knowledge can positively affect financial behavior, leading to improving financial literacy. Woodyard, Robb, Babiarz and Jung (2017) found that having a higher level of financial knowledge is more likely to be associated with positive financial behavior. Both objective knowledge and subjective knowledge displayed consistent associations with the reported behaviors.

Financial education can contribute to a positive change in financial behavior and overall financial literacy. Financial education has the potential to help people make more informed financial decisions and change financial behavior. Also it has stronger and more positive impact on the long-term financial goals (Wagner and Walstad 2019). If individuals have a positive perception to achieve their long-term financial goals, they display positive financial behaviors. This increases saving tendency to both in the short-term and in the long-term.

3 Methodology

For the purpose of this study, It was used a financial behavior survey which was open to all voluntary participants on social media. The survey created by the author comprised of socio-demographic variables including gender, monthly income, working experience and pre-knowledge on financial finance. To reach the financial behavior score, total 10 questions were included in the survey. Important elements of financial behaviors such as saving regularly and for emergency, budgeting, comparing products when shopping and paying bills on time were included to measure the financial behavior score of university students participated in this study.

To collect data, the link of the survey was shared on social media in Italy and Turkey. It was reached totally 455 responses. Only 394 complete survey questionnaires from Italy and Turkey were included in the study. The study consisted of 170 Italian and 224 Turkish students. Financial behavior score calculated from close-ended statements related to spending, saving, budgeting, shopping and controlling expenditure. Maximum possible score was 10. The Independent Samples t-test was used to analyze whether there were any statistically significant differences between each groups' independent variables. Following statements were included in the survey questionnaire: *"I spend according to my personal budget", "I have*

enough saving", I pay my bills on time", "I have a monthly budget plan", "I save for emergency situations", "I have written budget plan", "I have enough money for each month", I compare product when shopping", "I save regularly for long-term", and "I have enough money for unpredictability".

4 Results

Table 1 displays sample characteristics of students from Italy and Turkey including 170 participants from Italy (43.1%) and 224 participants from Turkey (56.9%). The majority of the students were female (Italy, 57.6%; Turkey, 54.5%). For both countries, more than 50% of students' monthly income was under 300 Euros. Italian students had more working experience (58.8%) than Turkish students (36.2%). The percentage of Italian students was higher than Turkish students in terms of having pre-knowledge on personal finance (51.8%, 33.5% respectively).

Table 2 shows positive answers to the survey questions. Out of the maximum behavior score of 10, on average students from Italy and Turkey scored about 5.43 across the whole sample. The highest behavior score were achieved by Turkish students (5.72), Italy (5.04). For both countries, the vast majority of students indicated that they paid their bills on time (Italy, 77.6%; Turkey, 87.5%). Both Italian and Turkish students had a low percentage of having written budget plan comparing to positive answers to other survey questions measuring financial behaviors. While 79.5% of Turkish students compare shops while purchasing product, 63.5% of Italian students make comparison between shops.

Table 1 Sample characteristics

	Italy		Turkey	
Variable	Frequency	Percentage	Frequency	Percentage
Gender				
Male	72	42.4	102	45.0
Female	98	57.6	122	54.5
Monthly income				
Lower than €300	90	52.9	140	62.5
Higher than €300	80	47.1	84	37.5
Working experience				
Yes	100	58.8	81	36.2
No	70	41.2	143	63.8
Pre-knowledge on personal finance				
Yes	88	51.8	75	33.5
No	82	48.2	149	66.5
Nationality				
Total	170	43.1	224	56.9

Table 2 Descriptive statics for survey questions

		Italy		Turkey	
	Question	Frequency	%	Frequency	%
Q1	Responsible spending	112	65.9	145	64.7
Q2	Enough saving	92	54.1	142	63.4
Q3	Paying bills on time	132	*77.6*	196	*87.5*
Q4	Monthly budget plan	74	43.5	142	63.4
Q5	Saving for emergency	104	61.2	127	56.7
Q6	Written budget plan	56	*32.9*	81	*36.2*
Q7	Enough money for each month	96	56.5	171	76.3
Q8	Comparison shop	108	63.5	178	79.5
Q9	Saving regularly	90	52.9	82	36.6
Q10	Having money for unpredictability	98	57.6	145	67.7
	Countries total	170	50.4	224	57.2

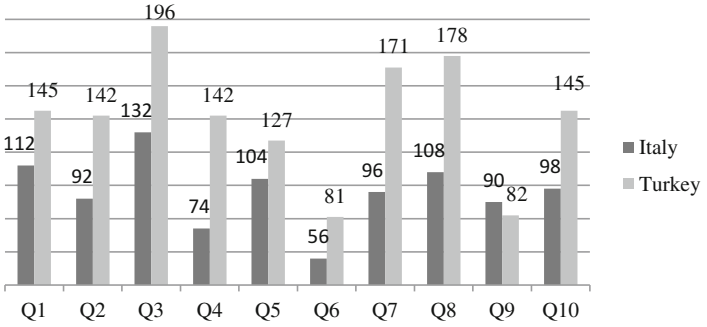

Fig. 1 Positive responds to survey questions

Table 3 Independent samples t-test comparing nationalities' financial behavior scores

Group	*N*	*M*	*SD*	*t*	*p*
Italy	170	5.04	2.28	3.04	0.002
Turkey	224	5.72	2.10		

Figure 1 shows the link between nationalities and positive responds to survey questions. Response from Turkish students to Q3 (paying bills on time) is significantly more positive than others. Q8 (comparison shop) is also more clear positive response for Turkish students. Positive response to Q6 (written budget plan) question is the lowest for both university students. Although all positive responses of Turkish students are higher than Italian students, Italian students have more positive answers regarding saving regularly.

Table 3 represents the t test result in terms of financial behavior scores of Italian and Turkish participants. The independent variable, financial behavior scores ranged from 1 to 10 with a mean of 5.72 and a standard deviation of 2.10 for Turkish participants. Italian participants' consumer behavior score ranged from 1 to 10 with a

Table 4 Independent samples t-test comparing financial behavior scores for Italian students

Groups	*N*	*M*	*SD*	*t*	*p*
Gender					
Male	72	5. 27	2. 75	1. 12	0.261
Female	98	4. 87	1. 86		
Monthly income					
Lower than €300	90	4. 35	2. 20	−4. 40	0.000
Higher than €300	80	5. 82	2. 13		
Working experience					
Yes	100	5. 58	2. 54	3. 77	0.000
No	70	4. 28	1. 77		
Pre-knowledge on personal finance					
Yes	88	5. 65	2. 15	3. 75	0.000
No	82	4. 39	2. 25		

Table 5 Independent samples t-test comparing financial behavior scores for Turkish students

Groups	*N*	*M*	*SD*	*t*	*p*
Gender					
Male	102	5.60	2.14	−0.75	0.454
Female	122	5.81	2.07		
Monthly income					
Lower than €300	140	5.49	2.02	−2.13	0.034
Higher than €300	84	6.10	2.18		
Working experience					
Yes	81	6.14	2.09	2.29	0.023
No	143	5.48	2.07		
Pre-knowledge on personal finance					
Yes	75	6.05	1.99	1.67	0.096
No	149	5.55	2.14		

mean of 5.04 and a standard deviation of 2.28. To make a comparison between the differences of means among nationality group based on overall demographic conditions and consumer behaviors, Independent Samples t-test was performed. It was indicated that there was a significant difference between Italian and Turkish participants ($t = 3.04$, $p < 0.05$). Turkish participants had higher financial behavior score than Italian participants.

Table 4 shows the t-test results of Italian students. There was no significant relationship between male and female students ($t = 1.12$, $p > 0.05$). There was a statistically significant relationship in terms of monthly income, working experience and pre-knowledge on personal finance ($t = -4.40$, $p < 0.01$; $t = 3.77$, $p < 0.01$; $t = 3.75$, $p < 0.01$ respectively).

Table 5 shows the t-test results of Italian students. There was no significant relationship between male and female students ($t = -0.75$, $p > 0.05$). There was a statistically significant relationship in terms of monthly income, working experience

Table 6 Independent samples t-test comparing nationalities scores each variable

Groups		*N*	*M*	*SD*	*t*	*p*
Gender						
Male	Italy	72	5.27	2.75	0.88	0.376
	Turkey	102	5.60	2.14		
Female	Italy	98	4.87	1.86	3.50	0.001
	Turkey	122	5.81	2.07		
Monthly income						
Lower than €300	Italy	90	4.34	2.20	4.01	0.000
	Turkey	140	5.49	2.02		
Higher than €300	Italy	80	5.82	2.13	0.83	0.404
	Turkey	84	6.10	2.18		
Working experience						
Yes	Italy	100	5.58	2.54	1.65	0.100
	Turkey	81	6.14	2.09		
No	Italy	70	4.28	1.77	4.13	0.000
	Turkey	143	5.48	2.07		
Pre-knowledge on personal finance						
Yes	Italy	88	5.65	2.15	1.20	0.231
	Turkey	75	6.05	1.99		
No	Italy	82	4.39	2.25	3.88	0.000
	Turkey	149	5.55	2.14		

and pre-knowledge on personal finance ($t = -2.13$, $p < 0.05$; $t = 2.99$, $p < 0.05$; $t = 1.67$, $p < 0.10$ respectively).

Table 6 represents the comparison of the t-test results among Italian and Turkish students. There was no significant relationship between male students among Italian and Turkish participants ($t = 0.88$, $p > 0.05$). However, there was a statistically significant relationship between female students ($t = 3.50$, $p < 0.05$). Female students from Turkey had higher financial behavior score than female from Italy (Turkey: $M = 5.81$, $SD = 2.07$; Italy: $M = 4.87$, $SD = 1.86$). There was no statistically significant relationship between Turkish and Italian students in terms of higher income category in the group of monthly income ($t = 0.83$, $p > 0.05$). On the other hand, there was a statistically significant relationship between Italian and Turkish students among students with income level lower than €300 ($t = 4.01$, $p < 0.05$). Students with low income level from Turkey had higher financial behavior score than Italian students (Turkey: $M = 5.49$, $SD = 2.02$; Italy: $M = 4.34$, $SD = 2.20$). There was also statistically significant relationship between Italian and Turkish students in terms of the variables including "working experience and pre-knowledge on personal finance". Turkish students who had no working experience and no pre-knowledge on personal finance had higher financial behavior score than Italian students who had no working experience and no pre-knowledge on personal finance [no working experience: (Turkey: $M = 5.48$, $SD = 2.07$; Italy

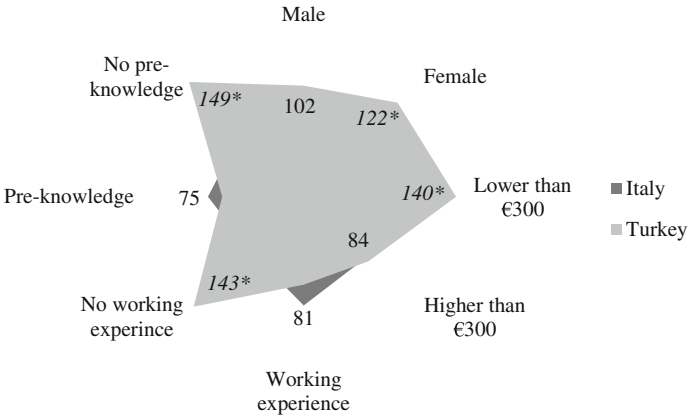

Fig. 2 Significance levels of natalities' financial behavior scores

M = 4.28, SD = 1.77); no pre-knowledge on personal finance: (Turkey: M = 5.55, SD = 2.14, Italy: M = 4.39, SD = 2.25)].

Figure 2 represents the significance levels of nationalities' financial behavior scores. Almost all independent variables' scores for Turkish participants are higher than the scores for Italian participants. The scores with asterisks show the significant variables including "being female", "having no pre-knowledge on personal finance", having no working experience", "having the income level lower than €300". Italian participants have higher scores only for the independent variables of "pre-knowledge on personal finance" and "having working experience". Both variables are not statistically significant.

Increasing positive financial behavior does not produce the same result in both countries. Lack of knowledge and working experience, and lower income may result in more negative consequences for Italian individuals. On the other hand, it can be concluded that the increase in income, working experience and financial knowledge has more positive impact on Italian individuals. This may be due to differences in the providing of financial knowledge in both countries. A study conducted by Henager and Mauldin (2015) showed that perceived financial knowledge was a strong indicator of saving behavior. They suggested that saving behavior may increase confidence or confidence increases saving behavior even though there was no causality. Planning also found to be significantly related to the decision to save regularly. On the other hand, overall financial literacy can also have positive effect on saving behavior because financial literacy because increased financial literacy means an increase in positive financial behavior and attitude. Murendo and Mutsonziwa (2017) analyzed the determinants of financial literacy and its effect on individual's savings decisions in Zimbabwe. They showed that financial literacy has a positive impact on saving behavior of individuals living in both rural and urban areas. Key element of increasing long-term saving is improving positive financial behavior, leading to enhanced financial literacy.

5 Discussion

Turkish students achieved higher financial behavior score (5. 72 out of a possible 10) than Italian students (5.04 out of a possible 10). According to OECD/INFE 2020 International Survey of Adult Financial Literacy (OECD 2020), Italy had the lowest financial behavior score (4.2 out of a possible 9) across the sampled 26 OECD countries. On the other hand, according to OECD/INFE International Survey of Adult Financial Literacy Competencies (OECD 2016), Turkey achieved 4.8 financial behavior score (out of a possible 9), which is higher than the score of Italian participants' score in 2020 OECD survey. Thus the result of this study is similar to OECD/INFE 2016 and 2017 survey results. The striking result of all the studies on financial literacy (financial knowledge, financial behavior and financial attitudes) is that the level of financial behavior is almost always lower than the level of financial knowledge. It takes a long time for financial knowledge to turn into positive financial behavior.

Many studies have shown that there is a gender gap in financial literacy. The financial literacy level of male is higher than female. Gender gap focuses on traditional socioeconomic factors and cultural differences to explain the differences in financial literacy between men and women. However, such factors can only partially explain the gender gap (Arellano et al. 2018). Women are marginally more likely to give incorrect responses than men, but they are even *more* likely to give *don't know* (DK) responses relative to men (Chen and Garand 2018). This study found that there was no association between Italian and Turkish male students in terms of positive financial behavior. However, Turkish female students had higher level of financial behavior than Italian female students. On the other hand, there was no statistically significant association between Turkish and Italian students in terms of higher income category. Higher household income is consistently associated with higher scores on financial knowledge and financial capability including attitudes and behavior (Robson and Peetz 2020). In this study, there was a significant association among students with lower-income category. Low-income Turkish students had higher financial behavior than Italian students in low-income. Although studies have found that high income level is a positive determinant of financial literacy and financial behavior, there are also differences in terms of the effect of low income.

Personal finance skills are essential factors affecting individuals' positive financial behaviors. Positive financial behavior increases as individual financial capabilities increase. The study concluded that there was also significant association in terms of having working experience and pre-knowledge on personal finance. Turkish students with no working experience and no pre-knowledge on personal finance had higher level of financial behavior than Italian students who had no working experience and no pre-knowledge on personal finance.

6 Conclusions

The most important effect of positive financial behavior is on long-term saving behavior. Positive financial behaviors make spending behaviors more responsible. The purpose of this study was to examine the relationship between financial behavior and socio-demographic variables among Italian and Turkish students. It was concluded that Turkish students had higher financial behavior score than Italian students. Higher income, having working experience and pre-knowledge on personal finance was found as determinants to have higher financial behavior scores for both Italian and Turkish students. When Italian and Turkish students were compared, different results were reached. Turkish students who were female, having low income, no working experience and no pre-knowledge on personal finance had had higher level of financial behavior scores. Increasing income, having working experience and increasing knowledge on financial finance do not lead to positive changes in the financial behavior of Turkish participants. Gender, high income, having working experience and pre-knowledge on personal finance did not play a determinative role in comparing Italian and Turkish students. The result of this survey may provide valuable information to improve positive financial behaviors of university students. Providing financial education can increase the level of favorable financial behavior. If future research is included more variables and participants it may be reached some different and fruitful results.

7 Limitations

The study included 394 students from Italy and Turkey. The results cannot be generalized since there were small amount of participant in the survey. If the number of the participant of this survey were, different results could be reached. It would be better to take this into account in future studies. Adding some other socio-demographic and socio-economic variables to the survey can produce useful results. Although the study has some limitations, it offers useful results in terms of evaluating financial behaviors.

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