ISSN 2392-1641
e-ISSN 2450-0097

Economics and Business Review

Volume 10 (1) 2024

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Poznań University of Economics and Business Press

Paper based publication

https://doi.org/10.18559/ebr.2024.1

ISSN 2392-1641
e-ISSN 2450-0097

POZNAŃ UNIVERSITY OF ECONOMICS AND BUSINESS PRESS
ul. Powstańców Wielkopolskich 16, 61-895 Poznań, Poland
phone +48 61 854 31 54, +48 61 854 31 55
https://wydawnictwo.ue.poznan.pl, e-mail: wydawnictwo@ue.poznan.pl
postal address: al. Niepodległości 10, 61-875 Poznań, Poland

Printed and bound in Poland by:
Poznań University of Economics and Business Print Shop

Circulation: 80 copies

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Economics and Business Review

Volume 10 (1) 2024

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sciendo Economics and Business Review Vol. 10 (1), 2024: 3–5
https://www.ebr.edu.pl https://doi.org/10.18559/ebr.2024.1.1261

Editorial introduction

It may seem that there is nothing special in the way people use money; they have been using it for many centuries. Yet recent technological changes, external shocks, growing welfare and also advancements in the field of economics have changed the way the financial markets behave and the way they are described. The current issue of *Economics and Business Review* reflects that trend, because it focuses heavily on financial topics. It consists of eight articles written by nineteen authors who work in Croatia, North Macedonia, Poland, Spain, the United Arab Emirates, the United Kingdom, the USA, and Vietnam. The authors use quantitative and qualitative methods to answer their research questions, which hopefully would be of interest not only to researchers but also to practitioners and policymakers.

The opening article **Some implications of behavioral finance for international monetary analysis**, by Thomas D. Willett, provides a thoughtful perspective on behavioural finance in an international context. It aims to explore insights from behavioural finance for international monetary and financial analysis, focusing on capital flows, sudden stops, currency regimes and the effectiveness of interventions in the foreign exchange markets, or the discipline impact of international financial markets on domestic monetary and fiscal policies. The author highlights the coexistence of behavioural finance and traditional finance theories, such as the Efficient Market Hypothesis. The paper also stresses that the diverse range of hypotheses within behavioural finance reflects the complexity of human behaviour and allows for a more comprehensive exploration of the factors influencing market performance. Consequently, the author argues for a contingent and nuanced approach to analysing international monetary issues.

The second article, entitled **Google Search intensity and stock returns in frontier markets: Evidence from the Vietnamese market**, is written by Dang Thi Viet Duc, Nguyen Thu Hoai, Van Phuoc Nguyen, Dang Phong Nguyen, Nguyen Huong Anh and Ho Hong Hai. It investigates investor attention's impact on stock trading by modelling the relationship between Google Search intensity and stock return in the Vietnamese capital market. The authors apply an approach based on the Fama-French three-factor model. The study confirms the price pressure hypothesis and attention theory that Google Search intensity affects stock returns positively. This relationship is more robust when individual investors enter the market. The paper argues, however, that the impact of Google Search intensity on stock price is in general short-term.

Francisco Javier Jorcano Fernández, Miguel Ángel Echarte Fernández and Sergio Luis Náñez Alonso in their article entitled **The asset-backing risk of stablecoin trading: The case of Tether** extend the understanding of risks in the cryptocurrency market. This is of special importance nowadays, as the size of the market for digital assets is rapidly expanding. The article analyses the asset-backing risk of stablecoins using Tether—the token with the largest market capitalisation and daily trading volume—as a case study. The article points out issues related to transparency and liquidity of Tether's reserves. The authors argue that there is a need for more detailed accounting and auditing regulations that apply to stablecoins in order to foster greater confidence among stablecoin users.

The fourth article, written by Anna Iwona Piotrowska, is entitled **Determinants of consumer adoption of biometric technologies in mobile financial applications**. As the title suggests, it aims to identify what factors incline customers of banks and FinTechs to use biometric tools to access their financial services. The results are based on a novel survey conducted among a representative set of Polish residents. The study confirms that younger and better-educated customers are more willing to use biometric tools, but also reveals that the COVID-19 pandemic has strongly accelerated the adoption of biometric solutions in financial services. Interestingly, it also indicates that awareness of the threat to customers' privacy is growing hand in hand with respondents' willingness to use new technological advancements in financial services.

The subsequent article, entitled **Central bank communication in unconventional times: Some evidence from a textual analysis of the National Bank of Poland communication during the COVID-crisis**, is written by Lada Voloshchenko-Holda and Paweł Niedziółka. The study uses qualitative methods to determine what message about monetary policy objectives was conveyed by the central bank in Poland one year after the outbreak of the COVID-19 pandemic. The study finds that during this uneasy period for monetary policy the National Bank of Poland communicated inconsistently with the public. It is conjectured that this inconsistency led to greater persistence of inflation in Poland in subsequent quarters.

The article on **Corporate governance and risk management: An evaluation of board responsibilities in western and Islamic banks** by Bchr Alatassi and Rekha Pillai explores the popular topic of board's responsibilities in the relatively unexplored environment of Islamic banks. This group of banks differs significantly from their Western counterparts, not only in the set of risks they are exposed to but also in the way they are supervised. The study evaluated risk management guidelines in the corporate governance codes of the United Kingdom, Germany, Saudi Arabia, and Malaysia. The results reveal that boards are ultimately responsible for the risk management, regardless of the governance structure, in both Islamic and Western banks.

Silver entrepreneurship: A golden opportunity for ageing society is the title of the article authored by Ivana Barković Bojanić, Aleksandar Erceg, and Jovanka Damoska Sekuloska. The paper provides a review of silver entrepreneurship, both from theoretical and empirical viewpoints. Silver entrepreneurship is defined in different ways in the literature, and the review aims to bring together these various strands of research. It also presents selected policies and strategies that can help reinforce that type of entrepreneurship. Due to the probable growing role of the silver economy in the foreseeable future, the study has significant practical value.

The closing article of the current issue, entitled **Assessing the long-term asymmetric relationship between energy consumption and CO_2 emissions: Evidence from the Visegrad Group countries**, is authored by Błażej Suproń. This study investigates the impact of renewable and non-renewable energy usage, along with economic growth, on carbon dioxide emissions in the Visegrad countries. The analysis employs a panel asymmetric regression based on data from 1991 to 2021. The study corroborates the results of other authors by showing that a rise in renewable energy consumption has a direct and proportional negative impact on CO_2 levels, while a decrease in non-renewable energy consumption brings about a significant decrease in CO_2 emissions in the long run. Interestingly, GDP was found to have an asymmetric effect on CO_2, where a decrease in GDP induces a greater decrease in emissions than an increase in GDP.

Michał Pilc
Konrad Sobański
Lead Editors

sciendo Economics and Business Review https://www.ebr.edu.pl Vol. 10 (1), 2024: 7–29 https://doi.org/10.18559/ebr.2024.1.1193

Some implications of behavioral finance for international monetary analysis

Thomas D. Willett[1]

Abstract

This paper discusses some of the important insights from behavioral finance for international monetary and financial analysis. A broad approach to behavioral finance is advocated which includes analysis of the effects of uncertainty, perverse incentives, and complexity economics as well as the cognitive biases focused on in the initial contributions to behavioral finance. It offers reasons why capital mobility is often not perfect and expectations are sometimes not rational. Correctly interpreted it is not a wholesale attack on efficient market theory but rather argues that markets can behave differently at different times, being efficient sometimes and subject to destabilize or insufficiently stabilizing speculation at others and focuses on the conditions that make different types of behavior more likely. It helps provide insights into issues such as currency crisis, the effects of official intervention in foreign exchange markets, the international monetary trilemma, capital flow surges and reversals, the discipline effects of fixed exchange rates and international financial markets and why uncovered interest rate parity often does not hold.

Keywords

- behavioral finance
- capital flows
- efficient markets
- international monetary analysis
- open-economy macroeconomics

JEL codes: E7, F3, G4

Article received 10 January 2024, accepted 5 March 2024.

Suggested citation: Willett, Th. D. (2024). Some implications of behavioral finance for international monetary analysis. *Economics and Business Review*, *10*(1), 7–29. https://doi.org/10.18559/ebr.2024.1.1193

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This paper is dedicated to the memories of my coauthors and friends Richard Sweeney and Clas Wihlborg who were closely associated with this journal. It is based on a talk given to the Claremont Institute for Economic Policy Research's research workshop in international money and finance. I appreciate valuable suggestions from the members of the workshop, especially Graham Bird, Levan Efremidze, Ozan Sula, and Horst Brezinski, Ken Reinhert, Kishen Rajan, Konrad Sobanski, and Ed Tower, and Debra Claypool and Dan Zhang for research assistance.

Introduction

Behavioral finance has become an important topic of research and analysis over recent decades.

However, its applications have been predominately to domestic financial issues. While there have been some important applications to international monetary analysis these have been much fewer.

The purpose of this paper is to sketch out some of the important insights from behavioral economics and finance for international monetary analysis. The focus will be particularly on applications to international capital flows.[2] Differing assumptions about the behavior of international capital flows have important implications for open economy macroeconomic analysis. These include such traditional topics as the effects of fixed versus flexible exchange rates on the strength of monetary and fiscal policies, the international transmission of disturbances, the international monetary trilemma, the effectiveness of sterilized intervention in the foreign exchange markets, the discipline effects of international financial markets over domestic monetary and fiscal policies, and the international contagion effects of crises as well as the more recent topic of capital flow surges and sudden stops.

The paper is organized as follows. We begin with a discussion of the nature of behavioral finance in Section 1. We argue that the behavioral approach is best broadly conceived to include a wide range of analysis that goes beyond simple optimizing models such as efficient market theory. These include not only behavioral biases such as were the focus of the earliest behavioral finance contributions, but the roles of factors such as complexity theory, mental models or narratives, perverse incentives, and the distinction between risk and uncertainty. It is stressed that these approaches should be seen as complements to efficient market theory, not complete substitutes as has been sometimes argued. Many potential cognitive biases have been identified. Section 2

[2] While not discussed in detail in this paper it also has important implications for the behavior of foreign exchange markets and macroeconomics. See, e.g., De Grauwe and Grimaldi (2006) and De Grauwe and Ji (2019).

discusses some of these that I have found to be most useful in my own research on international monetary issues as well as some of the other types of broader behavioral analysis. Section 3 considers in more detail implications for capital flows and international policy analysis. The last Section concludes.

1. What is behavioral finance?

A word about behavioral finance. As Illiashenko (2017) has argued "there is no simple answer to what behavioral finance actually is. There are many ways to define the field and its boundaries" (p. 29). Some of its more extreme advocates have viewed behavioral economics and finance as a replacement for the traditional assumptions made by economists of maximizing behavior and efficient markets and see the two approaches as battling one another.[3] A typical definition, especially in some of the earlier literature, was that behavioral economics and finance is based on the assumption of irrationality in place of the traditional rationality. A more reasonable view which has been adopted by many of the advocates of behavioral finance is the need for contingent analysis under which markets may behave differently in different situations and the need to analyse the conditions under which they are likely to behave in different ways. Such broader views have sometimes been described as analysis based on imperfect human behavior under realistic assumptions about limited information and mental abilities.

While much of the early discussion of behavioral economics and finance drew on the distinction between rational and irrational behavior, I believe that much of this debate has been of limited usefulness because once one moves beyond simple cases such as are often set up in laboratory experiments clear distinctions can often become difficult to make. For example, as Kay and King (2020) argue, the use of simple rules of thumb or heuristics that would clearly be irrational in a world of full information may prove to be quite sensible in a world of uncertainty. Thus, the use of narratives to aid decision-making can be quite rational, but it can make a considerable difference whether these narratives are roughly correct or false. And under uncertainty it is a judgment call whether some narratives that turn out to be wrong were rational to adopt under radical uncertainty. While attempting to make such distinctions can be intellectually interesting, from a practical standpoint this is much less important than attempting to discover under what types of circumstances different types of behavior are likely to occur and what are the effects of such behavior.

[3] For a more detailed discussion of behavioral finance see Willett (2022) and the extensive references cited there. That paper also covers the complementary areas of complexity economics and eco physics. Behavioral and neuro economics and finance often draws hypotheses from cognitive psychology and neuroscience. See also Barberis and Thaler (2002) and Bhoj (2019).

Rationality-irrationality should not be seen as an either-or concept. While we can identify extreme cases or clear rationality of irrationality there is a substantial gray area in between. As Steven Pinker (2021) argues, "(…) rationality is not a power that an agent either has or doesn't have" (p. 6). How should we define rationality? Pinker explains "As with most words in common use, no definition can stipulate its meaning exactly" (p. 36). In terms of applied analysis, we can focus on tendencies without having to label them as rational or irrational. One suspects that a major reason this issue has assumed such importance for many economists is that rationality has often been considered a fundamental aspect of economics. This need not be the case, however.

In financial markets this broad view of the behavioral approach does not reject the value of the Efficient Market Hypothesis (EMH) but views it as an important special case and analyses reasons why markets sometimes behave in ways that deviate from it. For example, Andrew Lo in his book on the adaptive markets (2019) describes efficient market theory as being not so much wrong as incomplete.

In my broad conception of the behavioral approach, it includes all of the factors that may lead to inefficient economic and financial outcomes. These include quite rational behavior under perverse incentive structures such as can be generated by factors like moral hazard and principal-agent problems, imperfect information and limited abilities to process information, as well as cognitive biases such as overconfidence and confirmation bias. It also draws on analysis from agent-based models, complexity theory and evolutionary analysis.[4]

Just as it is difficult to define the boundaries of behavioral finance it is difficult to draw a definitive history of its evolution. Some scholars have attempted to describe this evolution into different phases, but I have found this to be of limited usefulness and will not engage in such an exercise here. However, a few words of history are in order. The narrow version of modern behavioral finance is generally considered to have started with the contributions of Kahneman and Treversky and Thaler in the late 1970s and early 1980s, but aspects of the broader approach can be associated earlier with analysis of the implications of limited information with contributions such as Herbert Simon's concept of bounded rationality and Frank Knight's (1921) distinction between risk and uncertainty.[5]

In terms of macroeconomics and finance we have Keynes' argument in The General Theory that for "human decision-making affecting the future we cannot depend on strict mathematical expectation, since the basis for making such calculations does not exist. We calculate (…) where we can, but often falling back for our motives on whims, or sentiment, or chance" (p. 156, cited

[4] See, e.g., the analysis and references in Beinhocker (2007) and Bookstaber (2017).

[5] This distinction is particularly emphasized in the recent book by Kay and King. On the development of behavioral economics and finance see Thaler (2015).

in Russell, 1998). Also interesting is Keynes rejection of wild irrationality, "We should not assume that everything depends on waves of irrational psychology."[6]

It is easy to understand why behavioral finance initially attracted considerable resistance from mainstream finance experts. (It still does from some.) Efficient market theory provides a powerful approach to the behavior of financial markets and has made many important contributions to financial analysis, for example, emphasizing that markets are typically forward looking rather than responding only to current or past developments as was commonly assumed in much Keynesian analysis at one time. It provides the important insight that markets are likely to behave differently to news that is anticipated than to news that is unanticipated. Efficient market theory has contributed to the reconceptualization of the foreign exchange markets as having important elements of financial markets not just goods markets, and undermined the idea of a static Phillips Curve and replaced it with the expectations augmented Phillis Curve which made an important improvement to standard Keynesian macroeconomic theory. It would be foolish to abandon the important insights that efficient market theory has provided.

Besides the important aspects of behavior that it helps to explain, it provides an intellectually satisfying unified framework for analysis. One suspects that this intellectual attraction was one of the important reasons why many economists were quite hesitant to give it up. This hesitancy was reinforced by those behavioral economists who tended to put the debate in either-or terms and viewed their work as a wholesale attack on the rationality assumption. To those who believed that the rationality assumption was the fundamental keystone to all of economics, this was an attack to be strongly resisted. However, with hindsight we can see that this was a false characterization of the issue. The real question is when to use efficient market assumptions and when to make other ones.

Modern behavioral finance began with efforts to explain financial behavior which was not consistent with standard efficient market theory. For example, stock markets were found to display much more volatility than could be explained by variability in earnings and there were numerous ways to follow statistical rules that would make above average returns, a fact inconsistent with the view that markets made use of all available information.[7] While such facts became clear their interpretation was not. They clearly falsified some aspects of

[6] Unfortunately, this aspect of Keynes was left out of the famous ISLM version of Keynesian economics that became standard. Since the Global Financial Crisis this aspect of Keynes has begun to attract more attention, as has the work of Hyman Minsky (1975) and (1986) with his argument that stability generates instability. For an insightful analysis of the distinction between Keynesian economics and the economics of Keynes see Leijonfufhyud (1968).

[7] Of course, one could almost always hunt long enough to find rules that would have made profits. The key question is whether there are rules that will earn profits in future periods, i.e. out of sample.

simple efficient market theory based on risk neutrality, but such findings might still with consistent with risk averse efficient markets with risk premia For example, in the early studies of the behavior of foreign exchange markets after the breakdown of the Bretton Woods pegged exchange rate regime a number of us found that statistical rules could provide above average returns, but while some of us interpreted these as showing that in its early days the foreign exchange markets were not fully efficient, others who were committed to the EMH interpreted the evidence as showing that there had been time varying risk premia.

While many of the applications of behavioral finance have been quite *ad hoc* there has been a substantial maturing of analysis in recent years. One of the standard defenses of efficient markets theory used to be that there are almost an infinite number of ways to be irrational so that the recognition that people may sometimes be irrational cannot give a useful guide to supplementing the EMH. A major strength of recent behavioral analysis is that it draws on cognitive and neuroscience to consider particular ways in which human biases and cognitive limitations in decision making may lead at times to inefficient behavior. This narrows down substantially the number of hypotheses which should be major candidates to include in financial analysis. This process is still in a relatively early stage so there is much analysis to be done to discover which of the different biases are most important under various circumstances. And, of course, some biases may reinforce each other, for example, in generating follow the leader behavior. Such analysis presents an exciting agenda for research.

Two different versions of the EMH should be distinguished. One is that markets set roughly the "right", i.e. fundamental equilibrium, price and is a very strong conclusion. The second interpretation is that it is impossible for agents, or more reasonably very difficult, for agents to consistently beat the market. While the first conclusion implies the second, the second conclusion does not imply the first. Thus, as Malkiel (2023) has emphasized, the second interpretation of the EMH is consistent with the existence of bubbles in asset markets.

Some argue that a serious weakness of behavioral finance is that it lacks the sort of a unified theoretical framework provided by efficient market theory. This is quite understandable from an esthetic point of view but from the point of view of positive analysis it can be viewed as a major strength. We should remember that mainstream economics itself contains many different models, for example, monetarist versus Keynesian versus new classical macro models and a variety of models of exchange rate determination and formation of expectations in the foreign exchange market. Indeed, a key aspect of good-applied analysis is to know which models to apply to different situations. For example, monetarist models have a comparative analysis for longer run analysis while Keynesian models work much better for short term than long term analysis. James Tobin has referred to this as regime shifts.

Despite its advances a critic might describe behavioral finance as concluding that anything can happen, not a very useful conclusion. This has a certain

degree of truth. For example, there are behavioral hypotheses that conclude that markets will under react to news and others that they will overreact. This is not helpful for predictions, but it does have an important negative type of value in terms of arguing that we should not assume that markets will always respond optimally to news.

It is often as important to know what you don't know as what you do know. Thinking that you have knowledge which is false can lead to major disasters.[8] Indeed, this was one of the major causes of the Global Financial Crisis where many decision markets had excessive faith in the precision of financial engineering to give precise estimates of risk, whereas Kay and King (2020) have convincingly argued there was considerable uncertainty.[9] As a result, many financial institutions and investors took on much more risk than they realized and suffered huge losses as well as inflicting enormous pain on the rest of the economy.

As will be discussed below many of the behavioral hypotheses reinforce rather than contradict each other in terms of their predictions. We can most usefully think of behavioral finance and behavioral economics in general as providing a set of plausible hypotheses about various types of influences that may lead to nonoptimal behavior. A huge number of possible biases have been identified.

Different papers have identified small numbers of biases as being among the most important, but these lists often do not agree. A sample of some of the possible biases most frequently mentioned include Ambiguity aversion, Anchoring, Availability, Cognitive dissonance, Confirmation, Familiarity, Framing, FOMO (fear of missing out), Herd mentality, Hindsight, Hubris, Loss aversion, Mental accounting, Myopia, Overconfidence, Prospect Theory. Regret Theory, Short time horizons and Wishful thinking. Thus, an important task for researchers is to try to identify which types are most important when analysing different issues.

A list of the many potential biases can make one extremely pessimistic about human beings. However, this need not be the case. A number of these traits were evolutionarily efficient in previous settings but are not so in many modern circumstances. In terms of standard evolutionary models these new environments have not been around long enough for some of these counterproductive traits to have been bred away. Such unhelpful traits can often be

[8] Ed Tower called my attention to the quote from Mark Twain "It ain't what you don't know that gets ylo into trouble. It's what you know for sure that just ain't so."

[9] For a discussion some of the false mental models or views that contributed to the US subprime and global financial crises such as the belief that housing prices never fall in aggregate see Willett (2012). Other important causes include the failure to recognize sufficiently systemic risks and how interconnected the financial system had become. Many of the risk management techniques adopted were quite efficient in spreading the risks of shocks to particular institutions but not for system wide shocks.

overcome, however. Many of our inefficient biases come from instincts from the parts of our brains that evolved early on, what are sometimes called our lizard brains. More recent biological evolution in our brains has given us the power to often override these instincts or gut reactions. This is emphasized in Kahneman's bestseller*, Thinking fast and slow* (2011). Our rational thinking can often override our initial irrational (or less than fully rational) instincts and they can be trained to do this more effectively. Our brains have evolved to a point that we have the capacity to learn at a speed that far exceeds the operation of biological evolution. Andrew Lo uses this concept as the subtitle of his recent book, *Adaptive markets: Financial evolution at the speed of thought* (2019). Of course, some humans learn faster than others. And some may not learn at all. It is not clear to what extent behavioral analysis in its current stage allows agents to systematically beat the market but it is clear that counteracting some of these tendencies can be a substantial help in not losing so much relative to the market, for example, by reducing overtrading and making more use of index funds.

What will make behavioral finance most useful for practical purposes is when it can go beyond a checklist of possibilities and develop contingent analysis of the types of circumstances under which different behavioral hypotheses are more likely to be important. Progress is already being made in this task, but we have much further to go. Such contingent analysis can give rise to predictions that can be confirmed or falsified with empirical evidence, the hallmark of science. As will be discussed in Section 3 the international monetary area presents a number of cases where there is empirical support for some of the important predictions that can be derived from behavioral finance hypotheses.

2. Some of the important hypotheses from behavioral analysis for applications to international monetary analysis

As noted above there are many, many hypotheses that have been developed from behavioral science. Here I will briefly review a few of the ones that I have found particularly important for my work on international. monetary issues. Let us begin with a discussion of important preconditions for contingent behavioral finance.

Behavioral biases and limitations tend to be following to most prevalent in circumstances of considerable complexity and uncertainty. Thus, I view behavioral finance and the uncertainty analysis present by Kay and King as

complements rather than competitive approaches.[10] Biases often tend to be much less important in stable environments where there have been many repetitions of events and quick feed-backs, and thus opportunities to lean from experience. This is a key component of Andrew Lo's (2019) adaptive market hypothesis where markets converge toward efficiency[11] over time in stable environments and is consistent with concepts of evolutionary efficiency that occur over long time periods. Lo suggests that it would be useful if economics was based more on biology that physics.[12]

An important aspect of the extent of learning is whether there is fairly quick and unambiguous feedback on the consequences of actions. Where the consequences occur only well into the future, and it is difficult to see whether-or-not they were based on correct information and models or narratives, little learning may take place. Likewise with complex outcomes such as crises there are typically a number of interacting causes. While there may be agreement on the checklist, there is often considerable disagreement on the interpretations of which are most important. Thus, quite different lessons may be taken from a particular crisis. This problem is compounded by the behavioral tendency for people to conflate their objective views of developments with their normative views of what they would like to see. A complementary tendency (confirmation bias) is to count heavily evidence that is consistent with prior views while ignoring or heavily discounting evidence that conflicts. Such tendencies can lead to ignoring warning signs of impending crises and the lessons that should be taken away from developments. There is also the tendency to learn much less from the mistakes of others than from our own. For example, the Asian crisis offered important lessons that were largely ignored in the advanced economies, e.g., that low inflation is not always sufficient to avoid bubbles in asset markets.

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[10] In places Kay and King give the impression that they see their uncertainty analysis as an alternative to behavioral economics and finance. Several other authors have done the same with their contributions relative to their descriptions of behavioral finance. They often present cogent critiques of particular examples of behavioral economics and finance, but I do not see these as reasons to abandon the broad approach. Generalizing these critiques may reflect an understandable tendency for those presenting new approaches to emphasize the differences rather than complementarities with other approaches. However, Bookstaber (2017) surely goes too far however when in his book advocating an agent-based modeling approach that mainstream economics has nothing useful to say about crises.

[11] See also Gennaioli and Shleifer's (2018) hypothesis of diagnostic expectations.

[12] Economics is sometimes charged with suffering from physics envy, meaning that more value is placed on mathematical models than on empirical studies even if the models don't fit the data. Some economists seem to have the idea that studies are more scientific if they are based on mathematical models, but the true hallmarks of science are the discovery and explanation of empirical facts. In this process mathematical models can be extremely useful, but they are not always necessary, and in some cases, can be seriously misleading.

One problem that can make efficient learning more difficult is that environments can sometimes shift swiftly. There is an important adage which holds that disequilibria can go on for much longer than one would think and then can collapse much faster than one would think.

Other behavioral hypothesis can interact with those just mentioned. One is the tendency to have excessively high rates of time preference, i.e. short time horizons, that result in ignoring or discounting heavily effects that will occur well into the future. This reinforces the rational incentives such as concerns with reelection where the public has short time horizons These can generate time inconsistency problems where there are important differences between the time patterns of the costs and benefits of actions. This results in tendencies to adopt policies with quick payoffs and defer ones where the costs tend to come first. The political business cycle with its tendency to adopt expansionary policies before elections with the good effects of expanding growth and employment coming predominantly before the election and most of the costs in terms of rising inflation coming after is one of the most well-known examples. Another is the tendency for governments to delay needed balance of payments adjustments promptly enough to avoid currency crises.[13]

A complementary type of behavior is myopia, the tendency to forget or too heavily discount the effects of events that occurred in the past. Memories can be short. Previous crises are often forgotten fairly rapidly by investors and financial institutions. Failure to sufficiently heed the lessons of past crises are often important contributors to future crises. This is especially true when there are long periods of stability between crises. This gives rise to the adage that crises breed in the benign periods that precede them as a result of short memories and complacency setting in. This is a major theme of Minsky (1986). In the short run the feedback to excessive speculation and loose lending standards can be positive, leading in some cases to credit boom and asset bubbles.[14] This has been termed "recency" by Bernstein (2023).

Such considerations made an important contribution to the Global Financial Crisis where the weights put into many of the risk models were based only on fairly short time periods dominated by the benign environments of the previous decade or two (the great moderation). This type of problems is particularly likely for institutions where there is fairly rapid turnover of personnel. Younger individuals typically often have little sense of history. This applies not only to

[13] See Bird and Willett (2008).

[14] Excessive rates of credit creation typically encourage more risky borrowing and investing which make losses and the outbreak of a crisis more likely. It also contributes to high leverage which can make the effects of a crisis much worse once it breaks out. For example, a major reason that the effects of the bursting of the dot.com bubble in the US were much milder than the bursting of the housing bubble was that leverage from the baking system was much greater in the second case.

teenagers but also to many professionals. There also seems to be a tendency to learn much more from one's own mistakes than from those of others.

And as noted above even in the longer run the lessons taken away from crises may differ a great deal to different agents. For example, while there is fairly general agreement about the causes of the global financial crisis there is still considerable disagreement about the relative importance of different contributing factors. Many on the left put heavy weight on financial deregulation while on the right emphasis is often placed on government programs to expand home ownership for lower income individuals.[15] These considerations suggest that the speeds and extents of learning many differ greatly from one area to another, and also of course from one agent to another depending in part on to what extent the agents are open minded.[16]

While rules of thumb and narratives can be efficient in situations of limited information and considerable uncertainty, this is not the case with all of them. Information gathering is often costly and there is no clear way to judge if agents have invested an efficient amount of effort in learning.[17] However, there are clearly cases where most people would judge that people have adopted narratives and mental models that are clearly wrong. Rather than spending time trying to judge whether the adoption of such narratives reflects irrationality or ex ante efficient decisions that turn to be wrong ex post some economists have made what I believe is a very useful suggestion to not try to solve this issue and focus instead on whether the narratives are useful or not in achieving one's objectives. This is a more operational question. Even here, however, it is important in judging the usefulness of particular assumptions in models to try to distinguish between cases of narratives that are fundamentally wrong and those that are merely incomplete.

From the standpoint of positive analysis in many cases it is important to try to discover what mental models are motivating various important actors.[18] The traditional assumptions of much of older economic analysis as well as many versions of the more recent new classical macroeconomics that assumes that everyone knows the correct model is clearly a serious limitation for many types of questions. For example, this is likely to be useful in understanding

[15] For analysis of the crisis see, e.g., Davies (2010) who identifies over 20 causes of the crisis that have been suggested in the literature. A valuable review of a number of books on the crisis is given in Lo (2012).

[16] Of course, most of us are more minded on some things than on others.

[17] Like rationality there are many cases which are clear cut and many which are not. Given the limitations of human brains ignorance with respect to particular issues is often quite rational. The concept of rational ignorance, e.g., plays an important role in public choice analysis, helping to explain the extent of trade protectionism and why voters often do not catch on to political business cycles.

[18] I use mental models, narratives and stories interchangeably. For recent discussion of the importance of narratives and mental models see Shiller (2019) and Willett (2012).

different policy positions and attempting to judge whether substantial asset price increases are bubbles. For the latter evaluating the correctness of popular views may be quite helpful.[19]

Another important bias is the tendency of people to believe what they would like to believe, i.e. to conflate normative with positive analysis. Learning that one's views are incorrect is usually not pleasant. This helps contribute to the problem of confirmation bias, the tendency to pay more attention to evidence that is consistent with prior beliefs than to ones that contradict them. Hubris and the tendencies of a majority of people to believe that they are above average in a wide variety of skills can also lead individuals to discount the views of those who disagree with them.[20] Such factors lead to a tendency toward wishful thinking that things are as we would like them to be. Some of this tendency can be explained by what the psychologists call efforts to avoid the cognitive dissonance generated when events occur that are different than agents would like them to be such as situations where the situation actually requires tradeoffs to be made between objectives. Such disutility is avoided by ignoring inconvenient evidence.

A major example of this involves the tendency of many conservatives to embrace extreme forms of supply side economics.[21] Conservatives generally prefer low taxes and fiscal prudence. Standard economics argues that under most circumstances if one wishes to reduce fiscal deficits, cutting government expenditure and/or raising taxes is necessary. While many conservatives in this situation would typically prefer is to cut expenditures but this may not be politically feasible. In such cases the conservatives would be faced with making a choice among competing objectives, a situation that generates disutility. How to make this conflict disappear? The answer is to assume that cutting taxes will increase rather than reduce government revenues because the

[19] Of course, there may be a number of different views which fall within a range of plausibility so there are limits to what can be done with this type of analysis. We should try to guard against the problem that we may think that our preferred view is the only plausible one. Still reasonable people may agree that some views are outside plausibility, especially when they are based on assumptions that are clearly factually incorrect such as the belief that Donald Trump actually won the last US presidential election.

[20] In behavioral economic and finance the focus is on biases which many but generally not all people tend to have, i.e. they are propositions which may hold on average. We all know people who underestimate their abilities, but numerous studies have found that over estimation generally dominates. Identification of such possible biases may still be useful even if they don't consistently dominate outcomes since they can point to possibilities to look for. Knowledge of such biases can also help individuals try to reduce them. For example, it is not yet clear how useful behavioral finance is in allowing investors to beat the market, but it can definitely help individuals try to correct habits such as overtrading which tend to yield below market returns.

[21] All mainstream economists believe that supply side behavior is important although such considerations did not play an important role in traditional Keynesian economics.

reduction in disincentives to work will generate so much increase in output that the tax cuts can more than pay for themselves. As is shown by the Laffer curve analysis this is a theoretical possibility that can occur in cases of very high tax rates. However, almost all the empirical evidence suggested that income tax rates in the US at that time were not that high and the Reagan tax cuts failed to pay for themselves.

However, this has not kept later conservatives from repeating these arguments, with former President Donald Trump a prime example.[22] The effort to pursue such Laffer curve type fiscal policy led to a major financial and currency crisis in the United Kingdom in 2022. The newly elected government of Prime Minister Liz Truss proposed tax cuts in the face of large fiscal deficits. The market did not share the view that these tax cuts would reduce the deficit and major financial and currency crise quickly followed. Indeed, the opposition generated by this proposal was so strong that the Prime Minister felt forced to resign after less than two months in office.[23]

Another important type of potential bias is the human tendency to follow the herd. In earlier eras this was likely very adaptive behavior. In primitive times when others in your group began to run it was wise to follow suit even if you had not seen a danger, it was likely that some of your group had. And the cost of running unnecessarily was low relative to not running when there was a lion in the bush. The result could be fatal.

As noted above, one of the implications of evolutionary analysis is that modern financial markets provide a quite different environment from those that faced humankind over most of its history. Thus, some behavior that was evolutionary adaptive for a long time may have become maladaptive in the current environment and has contributed to a tendency for financial markets to display herd behavior which pushes price movements too far.[24] Recent analysis has emphasized that herding can also apply to the narratives adopted by market participants.

The result of such tendencies is for financial markets to sometimes suffer from the types of herding behavior which generate excessive price movements such as in bubbles and crashes. Such behaviors are reinforced by two other important factors. One is the tendency to assume that the developments of the recent past will always continue into the future. Despite the

[22] See, e.g., Bird (2018).

[23] Another example of the adoption of faulty mental models leading to crises was the belief by Turkish President Recep Erdoğan's that against all evidence high interest rates cause increased inflation. His insistence that the central bank keep interest rates well below the rates of inflation over a period of years led to capital flight and repeated currency crises and inflation rates that eventually rose above 70 %. Finally in 2023 after his reelection Erdoğan finally relented and allowed the central bank to raise interest rates substantially.

[24] Of course, herding can be quite rational in terms of following the actions of those who you believe have better information than you.

warnings by financial companies that past returns are not a guarantee of future behavior it is well documented that for many investors past behavior is often projected into future expectations. In cases of limited information such behavior can be rational, but behavioral finance suggests that it often goes beyond what is rational.

Such behavior can be reinforced by the 'kernel-of-truth" phenomena. Most bubbles begin with developments that justify substantial increases in prices or in capital flows. The problem is that such initially rational behavior can begin to feed on itself for the reasons just discussed and this can lead to excessive price movements and surges in capital flows that end in disruptions.[25] With respect to capital flow surges the initiating event is often the election of a new government that is committed to more orthodox economic policies.

Such excessive movements are consistent with the classic argument against efficient markets, that people tend to swing between mania and depression. This is certainly true for those with the misfortune of being bipolar and there are examples of bubbles and crashes that have been characterized as resulting from the madness of crowds However, with respect to financial behavior such episodes are fairly rare events.[26] More common is the widespread acceptance of false narratives such as 'This time it's different', which have been called the four most dangerous words in investing.

There is also the tendency of people to react to good news by becoming more optimistic and to bad news by being more pessimistic. A major additional contributor to crashes and contagion is when developments force market participants to finally recognize that the narratives that had motivated their recent behavior were false. Such broken mental models and recognition by agents that they had not really understood the situation will typically lead to major increases in risk aversion that are not necessarily irrational. Such tendencies can of course contribute to stronger swings in asset prices and capital flows.[27] As will be discussed in the following section such reactions are often a major cause of contagion.

A focus on narratives and mental models points to the likelihood that these will differ across different agents. While there has been some mainstream eco-

[25] For an application of behavioral finance to help explain capital flow surges and reversals see Efremidze, Rutledge et al. (2016). For empirical analysis of the patterns of surges and reversals and sudden stops see Efremidze, Kim et al. (2017) and references cited there. For further analysis of these issues see Bird (2018).

[26] See the analysis and references in Bernstein (2021) and Menschell (2002). There is of course also the wisdom of crowds. One of the important factors that distinguishes these are whether decisions are being made largely independently opposed to being swept up in crowd psychology.

[27] I should note that some of the empirical proxies for market sentiments are sometimes treated as if they reflect just swings in psychological optimism and pessimism, but they are in fact generally measures of outlooks which can combine elements of both rational expectations and behavioral factors.

nomic analysis based on heterogeneous expectations, most macroeconomic and currency crisis models are based on unified actor models where differences in expectations are not considered. This assumption is typically needed for mathematical tractability and does not keep them from being useful, but if only these models were followed some important phenomena would be missed. For example, in the standard currency crises models a switch on expectations from optimistic to pessimistic occurs at a particular point in time resulting in calm in the foreign exchange markets turning into a sudden crisis. This does sometimes occur such as the example of the UK in 2022 mentioned above[28]. But frequently speculative pressures build up more gradually over time. This can be explained by different agents having different expectations about future shocks, their effects, and what policies governments will adopt. Over time more and more market participants may switch to seeing higher probabilities of a crisis and so capital outflows may continue to mount for a considerable period of time.

We know from the analysis of complex systems and far from equilibrium behavior that at times small events can have important non-linear effects with huge consequences. An example is that in a tightly coupled system such as a rocket the failure of a small component can bring destructive system failure.[29] This was the case with the crash of the *Challenger* mission in 1986 where the malfunction of a small connector component led to an explosion of the rocket and resulted in the death of all those abroad.

When such systems, which can include financial sectors, enter far from equilibrium states a small adverse development can sometimes lead to a system crash that is vastly disproportionate to the magnitude of the event. Where systems are close to equilibrium, the effects of shocks tend to be linear, as is predicted from standard efficient market theory. However, when systems enter critical stages tipping points may be reached. An initial example given of this property is when adding one more grain of sand leads to a land slide. In asset bubbles markets may become so overvalued that a small spark can lead to a sudden collapse.[30]

An important example from international monetary analysis can be illustrated by the popular currency crisis models. In the first-generation models there is a fundamental disequilibrium, often assumed to be due to large fiscal deficits that the government does not have the political strength to correct. In such cases a currency crisis in inevitable and the only question is when it

[28] Another example of a quick swift in expectations was the market reaction to the Russian legislature's failure to pass the fiscal legislation that had been agree by the government with the IMF as a condition for a large IMF loan.

[29] Bookstaber (2007, 2017) gives nice treatments of this issue.

[30] Of course, not all bubbles end in crashes. Some deflate slowly. This is another example of how markets can behave differently in different situations, one of the most important conclusions from behavioral analysis.

will occur. In such models, fundamentals are either good or bad. The second-generation models add a third state where the fundamentals or neither so bad that a crisis is inevitable or so good that there is no risk of one. In this third, intermediate state, a country is in a vulnerable zone where a crisis is not inevitable and with good luck will not occur but with bad luck some adverse event, not necessarily a huge one, can set off a self-fulfilling speculative attack. In such cases officials often argue that this type of nonlinear response is evidence that the attack is caused by destabilizing speculation. And this would be true if the balance of payments was close to equilibrium, but could reflect quit rational expectations when the country was in a vulnerable zone.

The factors discussed above have focused on various behavioral biases. It is important to remember that the other key aspect of behavioral finance is that there are limits to arbitrage that can keep stabilizing speculation from fully offsetting the effects of destabilizing speculators on prices. It seems likely that these failures will be even stronger in the case of capital flows since there is less of a mechanism for stabilizing capital flows to offset the effects of destabilizing flows. For international monetary analysis these considerations have the important implications that capital mobility may often not be perfect, i.e. there are limits to international arbitrage.

3. Some implications for capital flows and international monetary analysis

As noted in the introduction some of the most important implications of behavioral finance for international monetary analysis concern the nature and behavior of international capital flows. One is based on limits to arbitrage and helps to explain why, even in the absence of capital controls, international capital mobility is often much lower than the perfect capital mobility that is assumed in many of the currently most popular open economy macro models. Therefore, uncovered interest rate parity does not always hold.[31]

As has been famously analysed in Mundell-Fleming models of open economies the degree of capital mobility will affect the strengths of monetary and fiscal policies under fixed and flexible exchange rates. Another implication is that expectations in the foreign exchange market can deviate from both the static expectations assumed in the initial Mundell-Fleming models and the rational expectations assumed in many of the recent models.

[31] Another possible reason is due to risk premia although there has been limited success in finding useful empirical proxies for such risk premia. There would be no risk premia even in the face of considerable uncertainty if market actors were risk neutral.

A key point is that expectations formation may be quite different under different circumstances. This applies also to the degree of capital mobility and the thickness of financial markets. As a result, sterilized exchange market intervention may be effective under some circumstances and not others. Under conditions of a great deal of uncertainty foreign exchange markets may become quite thin. In such cases the possibility of mispriced exchange rates may come in the form of capital outflows combined with of an insufficiency of stabilizing speculative, not only from destabilizing speculation. In such cases the short run equilibrium price in the foreign exchange market could fall well below the long run equilibrium price. While this would offer scope for speculative profits great uncertainty might lead rational speculators to not take advantage of this opportunity This may have been part of the explanation for the large exchange rate depreciations which followed the abandonments of pegged exchange rates during the Asia crisis in 1997–1998. In such cases of thin markets official intervention can be effective although effectiveness is likely to depend on the credibility of the government and central bank.

On the other hand, when governments are trying to maintain a pegged exchange rate which is clearly substantially overvalued the supply of funds economic agents wish to move out of the country is likely to be quite elastic. In such cases efforts to use sterilized intervention to maintain the peg are unlikely to be successful. This implies that the traditional debate about whether sterilized intervention is effective or not is seriously mis-specified. The issue should be reframed as under what conditions can sterilized intervention be effective and under what conditions will it not.

The fact that capital mobility will often be far from perfect, even if high, has important implications for the international monetary trilemma which states that at any one time a country cannot have all three of a fixed exchange rate, no controls, and an independent monetary policy. It is often not recognized that this trilemma need hold in the short run only under conditions of close to perfect capital mobility. With a lower degree of capital mobility sterilized intervention can allow a country to operate outside of the trilemma constraint set in the short run and have some degree of monetary independence even with a credibly fixed exchange rate and no capital controls.[32] There is some evidence that this situation may hold even for a small open economy with well-developed financial markets such as Hong Kong (see Xue & Willett, 2024).

While such ability offers the benefit of being able to operate outside of the trilemma constraints in the short run it also carries a potential danger. Officials seeing what they would like to see and engaging in wishful thinking may be too optimistic that current payments deficits are temporary and thus do not require undertaking costly adjustment polices to correct the deficit when in fact they face a fundamental disequilibrium. The desire to delay ad-

[32] For further analysis see Willett and Bird (forthcoming).

justments is increased under uncertainty where officials may see the choice as being between the certain costs of adjustment in the present versus the uncertain benefits of possibly avoiding a crisis in the future. In Kahneman and Tversky's terminology this could be explained as a framing effect where officials become risk takers when facing certain short-term costs versus a smaller chance of facing huge costs in the future.

Political economy incentives such as those which can generate political business cycles can reinforce this tendency to delay needed adjustments for too long. Such tendencies to delay need adjustments is one of the primary causes of currency crises.[33]

Two further areas of important applications of behavioral finance concern the discipline effects of financial markets and contagion generated by crises. There is a popular view, which I once held, that financial markets provide strong discipline over national monetary and fiscal policies. However, this requires two conditions to be met—that financial markets quickly signal increasingly dangerous policies and that policy officials respond to these signals. With rational expectations the first condition should generally hold. However, we have observed many cases where such early warning signals have not been provided by financial markets. Important examples include the Asian crisis of 1997–1998, the Argentine crisis of 2000–2001, and the recent Greek crisis.

In a Mundell-Fleming model with static expectations high capital mobility can help finance fiscal deficits and thus reduce their impacts on interest rates. As a result, the Mundell-Fleming models imply that while the adoption of fixed exchange rates would provide discipline over monetary it would do the opposite for fiscal policy. Argentina in the late 1990s provides an example. These models also imply that with high capital mobility and a fixed exchange rate a fiscal expansion can undermine the effects of an independent central bank. The resulting capital inflows would generate corresponding monetary expansion despite any efforts by the central bank at monetary tightening.[34]

Why do markets often fail to give strong signals until it is too late? One standard explanation is moral hazard coming from being too big or connected to fail or being geopolitically important.

But that is not the only factor. While it has been argued that the bailouts of Mexico in its 1995 crisis were a cause of the excessive capital flows into Asia and the failure of governments to follow appropriate policies this seems doubtful given the economic pain that was still generated in Mexico despite the bailouts and the large losses suffered by many investors.

There are other important types of moral hazard, however. In the case of the Asian crisis, one was the connected lending which took place in a number

[33] For further discussions of the tendencies to delay needed adjustments see Amri and Willett (2017), Bird and Willett (2008) and Walter and Willett (2012).

[34] For further analysis of such discipline issues see Willett, Chiu et al. (2014).

of the countries where it was often assumed that there was an implicit government guarantee of the politically important financial institutions. The second was the widespread belief that while small depreciations of the currencies might take place, several of the countries had adopted de facto crawling pegs, governments would not allow large depreciations. This led many institutions to fail to cover their international borrowings. These unhedged positions led to a massive rush to cover after the large depreciation of the Thai currency.

Faulty narratives or mental models often also play an important role. In the case of the Asian crisis many investors focused mainly on the countries strong domestic economic fundamentals and failed to consider sufficiently their weak international economic positions and the problems in their financial sectors.

It is a common view that with respect to contagion from crises that it is during the contagion stage that markets deviate the most from efficiency, being dominated by excessive fear and pessimism. The Asian crisis is a prominent example. However, I have argued that the most important market failure occurred before the crisis where excessive capital surges helped set up the preconditions for the crisis. By generating risky financial positions, the previous capital inflows magnified the rational incentives to reduce or hedge such positions once the crisis began. Willett, Nitithanprapas et al. (2005). These actions resulted in large capital outflows. Undoubtedly some of the contagion was due to excessive swings in mood toward excessive pessimism. But much of the panic was quite rational. Agents discovered that reality was quite different from what they had thought it was and that they had taken on much more risk than they had expected. Indeed, it seems likely that contagion will generally contain both rational and irrational behavior.[35]

The outbreak of the Thai crisis served as what is often referred to as a wake-up call resulting from the discovery that agents had been operating on the basis of faulty narratives or mental models.[36] The Thai crisis led investors and borrowers in other Asian countries to quite rationally reevaluate their financial positions and in a number of the countries there were enough similarities to the Thai case to generate rational panics. In many cases closer examinations led to discoveries that financial positions were much riskier than they had appeared from less thorough investigations. The Greek crisis led to a similar wake-up call within the eurozone with much, but likely not all, of the resulting contagion being quite rational.[37] The criticisms that the contagion was unjustified in the Asian case were often based on the same types of narratives which focused on the strong macroeconomic fundamentals. They paid

[35] In the case of the Greek crisis see Bird et al. (2017).

[36] Faulty mental models such as that in aggregate house prices never fall and that the complex products generated by financial engineering were quite safe also played a major role in the generation of the global financial crisis. See, e.g., Willett (2012).

[37] See the analysis and references in Bird, Du et al. (2017).

insufficient attention to the financial sectors which had become substantially overextended both domestically and internationally.

These crises in Asia and Greece, like the earlier Mexican crisis, are classic cases of capital flow surges and sudden stops or reversals.[38] As is typical with asset bubbles, the initial capital flows were quite rational responses to improved conditions in these countries. In the cases of Mexico and Asia this was caused by important economic policy reforms and for Greece it was entry into the euro zone. As with asset bubbles the problem was that the capital inflows were carried too far. There can be little question that the excessive inflows were not based purely on the judgments of many investors independently arrived at. Herding behavior was undoubtedly a major cause. It is important to recognize that this herding was not due just to following what others were doing. The spread of common narratives, which proved to be ultimately faulty, was a major factor.

Conclusions

Behavioral finance is an exciting new area of research. While some experts have viewed this enterprise as a wholesale attack on efficient market theory this is not a helpful way to conceive of it. It should be viewed as a complement rather that substitute for efficient market theory. It is also not a single theory but a range of hypotheses all of which are wrong in terms of explaining everything, but which often can be quite useful in explaining some things. This applies as well to the broader range of analysis that goes beyond simple optimization models and consider factors such as the roles of uncertainty, narratives, and complexity economics.

While to date most of the applications of behavioral finance have been to domestic financial markets it is also important for the behavior of international capital flows and the behavior of international financial markets including the foreign exchange markets. As illustrated in this paper these in turn can have important implications for countries monetary and fiscal as well as exchange rate policies.

While the focus in this paper has been on the behavior of economic agents the behavioral approach also has important implications for the political economy analysis of policymaking. And again, it should be seen as a complement

[38] For recent treatments of capital flow surges and reversals see the analysis and references in Efremidze, Rutledge et al. (2016) and Efremidze, Kim et al. (2017). For a discussion of the similarities between the causes of asset bubbles and crashes and capital flow surges and reversals see Efremidze, Rutledge et al. (2016).

rather than a substitute for efficiency analysis. Great gains have been made in applying economic analysis to political questions. This was the prime objective of public choice theory, and it has been extremely successful. There are many areas however where such simple optimizing analysis can be usefully supplemented by behavioral analysis. For example, time inconsistency analysis provides an important explanation for why governments often delay adjustments for too long with the result that crises breakout. It seems very likely that this problem is much worse under conditions of greater uncertainty and that wishful thinking also often contributes, to delaying needed but costly adjustments as does confirmation bias which results in ignoring or heavily discounting information that conflicts with one's preferred narratives or mental models.

Some economists have been distressed by behavioral finance because it leads to a range of theories or hypotheses rather than a single elegant theory. But in truth markets do not always behave in the same manner. Thus, in my view the lack of a single unifying theory in behavioral finance as there is in efficient market theory is actually a strength reflecting the fact that the financial world is in practice much more complex that assumed by efficient market theory.

Of course, this is in one way distressing but in another it is exciting. Behavioral finance is in its infancy and we have much to learn about which hypotheses, including efficient market theory, have more explanatory power under what conditions. This gives us a rich agenda for research.

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sciendo Economics and Business Review https://www.ebr.edu.pl Vol. 10 (1), 2024: 30–56 https://doi.org/10.18559/ebr.2024.1.778

Google Search intensity and stock returns in frontier markets: Evidence from the Vietnamese market[1]

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Abstract

The study investigates the impact of investor attention on stock trading by modeling the relationship between Google Search intensity and stock return with stocks listed in frontier markets in Vietnam from October 2016 to October 2021. The study has three findings. First, the study confirms the price pressure hypothesis and attention theory that Google Search intensity positively affects stock returns. Second, this study indicates that the impact of Google Search intensity on stock price is short-term. The positive effect is within the week of searching and reverses the following week, although the reverse force is not strong. Third, the relationship is more robust during COVID-19 than in the pre-pandemic period, suggesting that after a shock, more new

Keywords

- investor attention
- search intensity
- Google Search
- stock returns
- frontier markets
- Vietnam
- COVID-19

[1] This is the extended version of Khanh, T. Q., Hoai, N. T., Duc, D. T. V., & Nguyen, D. P. (2022, November 24–26). *Effects of investor via Internet search intensity on stock market: Evidence in Vietnam market*. International Symposium on Sustainable Development in Transition Economies, Hanoi, Vietnam.

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individual investors enter the market, the impact of GSVI on stock return is more substantial.

JEL codes: D53, G1, G4

Article received 23 August 2023, accepted 15 February 2024.

Funding: This research was funded by the Posts and Telecommunications Institute of Technology, Vietnam.

Suggested citation: Duc, D. T. V., Hoai, N. T., Nguyen, V. P., Nguyen, D. P., Anh, N. H., & Hai, H. H. (2024). Google Search intensity and stock returns in frontier markets: Evidence from the Vietnamese market. *Economics and Business Review*, *10*(1), 30–56. https://doi.org/10.18559/ebr.2024.1.778

Introduction

The efficient market hypothesis (EMH) formulated by Fama (1970) holds that stocks are always traded at their fair value on exchanges. Therefore, investors cannot outperform the market through fundamental or technical analysis methods. Although the EMH is the cornerstone of modern financial theory, it is still the subject of many questions and controversies. The EMH assumes that all investors perceive all available information similarly. However, Merton (1987) argued that investor recognition was essential in pricing and determining stock liquidity. The reason was that potential investors must recognise the company before becoming familiar with it and ultimately making investment decisions. Using various methods to analyse and value stocks, each investor would judge a stock's growth potential differently. Thus, the same stock was not perceived in the same way by different investors. On the other hand, according to the EMH, a stock valuation and analysis system was available to all investors, and their access to the system must be equal. However, there are always significant disparities between institutional and individual investors in the ability to access, collect, synthesize, and analyse information. Barber and Odean (2007) stated that individual investors would inevitably buy stocks that attracted their attention due to their financial and time constraints. The statement is called attention theory (AT). Individual investors' buying decisions led to temporary fluctuations in stock returns. However, their attention did not affect selling decisions because they could only sell what they had.

Because attention cannot be measured, choosing an appropriate proxy for it is challenging for researchers. Today, as the Internet becomes ubiqui-

tous and easily accessible, individual investors express their interest in a particular stock by using search engines or referencing online forums. When investors are interested in a particular stock, they tend to seek information about that stock to a greater extent. This means that search volume can be used as a direct proxy for investor attention. This proxy is used in many studies, such as those by Da et al. (2011), Siganos (2013), Aouadi et al. (2013), Bijl et al. (2016), Takeda and Wakao (2014), Kim et al. (2019), Perlin et al. (2017), Smales (2021), Costola et al. (2021). Although these authors use different keywords, they conclude that the Google Search Volume Index (GSVI) is a suitable tool to test the relationship between the attention of investors and financial markets.

Several studies on the relationship between investor attention expressed through GSVI and the stock market were conducted for single markets (Ekinci & Bulut, 2021; C. Nguyen et al., 2020; Swamy & Munusamy, 2019) or expanded to an international level (Akarsu & Süer, 2021; Chen, 2017; Tantaopas et al., 2016). However, there are still three research gaps that need filling.

First, the studies mentioned above focus on advanced and emerging financial markets rather than frontier markets. Frontier markets are less established than emerging markets. In frontier markets, information transparency and the effectiveness of regulations are lower (Vo & Phan, 2019). Frontier markets have few large companies, and foreign investor activity is significantly restricted. Thus, most investors are domestic individuals. Because these investors lack access to complex and professional information sources, they rely on available and free information sources like Google. Therefore, studying the relationship between GSVI and stock market volatility in these frontier countries will be significantly meaningful.

Second, studies on the relationship between investor attention and price movements in frontier markets have not reached a consensus of conclusions. For example, both C. P. Nguyen et al. (2019) and C. Nguyen et al. (2020) use data from the Vietnamese market to find the relationship between GSVI and stock return. However, while C. Nguyen et al. (2020) concluded a positive relationship between these two variables, C. P. Nguyen et al. (2019) proved the relationship in the opposite direction. Another study by Osarumwense (2020) shows that investor attention does not impact stock returns in the Nigerian market. Therefore, more research should be conducted for frontier markets to provide further evidence about the relationship between search intensity and stock prices and to point out the reasons for different study results.

Vietnam can be a typical frontier market in which to study the impact of investor attention through GSVI on the stock price. According to the State Security Commission of Vietnam, the proportion of individual investors in Vietnam is 99.4% (State Security Commission of Vietnam, 2022). By 2022, the percentage of the population using the Internet in Vietnam is 77.38%

(Statista, 2023), and Google is the most popular search engine, accounting for 91.8% market share (Statcounter, 2022). Because individual investors lack the knowledge and financial capability to gather information, they often refer to their friends or Google Search engines to make decisions.

Third, studies on the impact of GSVI and the stock market have not mentioned the difference between market conditions, especially during the COVID-19 pandemic. "During COVID-19" refers to the two years after the COVID-19 breakout in Vietnam. Negatively affected by the COVID-19 pandemic, many Vietnamese businesses had to reduce the scale of their operations or go bankrupt. According to the General Statistics Office of Vietnam, 19,800 enterprises had to withdraw from the market in 2021, an increase of 17.8% compared to 2020 (Vy Vy, 2021). A similar situation emerges worldwide and predicts a decline on stock markets. However, unexpectedly, Vietnam's stock market grew strongly. On the Ho Chi Minh City Stock Exchange, during COVID-19, the number of individual accounts increased by 2.26% a month, and the trading volume was VND 17,472 billion/month, while in the pre-COVID-19 period, these figures were only 0.92% and 3,988 billion VND/month, respectively (State Securities Commission of Vietnam, 2022). Search frequency for stocks also increased, showing that Vietnamese investors pay more attention to the stock market and consider it a promising new investment channel. Changes in market conditions provide a natural context for testing and analysing the rigor of the relationship between GSVI and stock returns. Khanh et al. (2022) investigate the effects of investor behavior via Internet search intensity on the Vietnam stock market. Using the date when the first case of COVID-19 was discovered in Vietnam, this study moved one step further to divide the data into two research periods: before and during COVID-19.

In summary, this study aims to test the investor recognition hypothesis of Merton (1987) and the investor attention theory of Barber and Odean (2007) in the case of a frontier market. Furthermore, the authors seek to establish the various effects of investors' attention on stock returns in different market conditions, specifically before and during the COVID-19 pandemic. Lastly, the research aims to propose essential implications for businesses and investors in the Vietnamese market and other frontier stock markets. In addition to corporate factors, investors can consider GSVI as an indicator to support their stock investment decisions.

After the Introduction, the rest of the paper is organized as follows: A review of the theories and empirical studies is presented in Section 1. Section 2 provides details of the models and datasets. Section 3 discusses the study's results, and the last Section comprises the conclusion and implications.

1. Literature review

Both Merton's investor recognition hypothesis (1987) and Barber and Odean's investor attention theory (2007) acknowledge the existence of the "investor attention" factor but disagree on the effect of this factor on stock returns. Merton (1987) argues that gathering information about stocks requires many resources, so investors will save these resources by tracking only certain stocks. Investors will not buy stocks they do not follow, even if they attract their attention. In contrast, Barber and Odean (2007) argue that investors tend to buy stocks that attract their attention because they face significant challenges in evaluating stocks when deciding to buy. Increased investor attention creates greater buying pressure, causing stock prices and yields to rise but decline afterwards. This argument presented by Barber and Odean (2007) is relevant to individual investors because they tend to access freely available information sources. Attention has little effect on selling because individual investors can only sell available stocks.

Much research has been done to find empirical evidence for these two hypotheses. Because attention cannot be measured, choosing an appropriate representative is challenging for researchers. In the past, indirect measures have been used. The researchers used advertising costs (Grullon et al., 2004; Vorkink et al., 2010), frequency of company reports (Peress, 2008; Rao et al., 2010), and trade volume (Gervais et al., 2001), and profitability (Loh, 2010). However, these proxies have limitations because investors may not notice them (Bank et al., 2011).

Black (1986) stated that noise traders trade on noise signals like information. EMH confirmed no correlation among noise traders because transactions based on noise signals are random, and they will cancel each other out. However, if many investors act on the same signal, there will be a correlation between them, which can be called herd instinct. Herding is the tendency for independent dealers to buy or sell the same security over a period of time. Herding exists among individual investors because they rely on the same signal (Shleifer & Summers, 1990). They are also more sensitive to new trends in their investment decisions (Long et al., 1990). Along with the development of the Internet, online search engines appeared and quickly became effective assistants for individual investors in finding information about stocks they were interested in. When investors utilize the same sources of information, there could be a correlation among them.

The more attention investors pay to a particular stock, the more information investors want to collect to make investment decisions. Therefore, Internet search intensity is used by many scholars as a direct proxy for investor attention in their research. A few scholars use search volume of web browsers—Baidu (Shen et al., 2017; Zhang et al., 2013) or Yahoo (Lawrence et al., 2016;

Mangold et al., 2005). However, most other studies use GSVI as a proxy for investor attention, since this is the world's most popular search engine. Baidu and Yahoo have only small global market shares, 0.5% and 1.1%, respectively, while the share of Google is 92.8% (Statcounter, 2023).

Pioneering studies have been conducted in the context of developed stock markets, but scholars are yet to draw consistent conclusions about how GSVI correlates with the stock market. Many scholars use US market data to assert that search frequency has a positive relationship with stock returns (Da et al., 2011; Joseph et al., 2011; Vlastakis & Markellos, 2012). Research by Bank et al. (2011) for the German market, Takeda and Wakao (2014) for the Japanese market, and Aouadi et al. (2013) for the French market also obtained similar results. Not only stock returns but also stock trading volume increases as the search frequency for stocks increases (Preis et al., 2010; Vlastakis & Markellos, 2012). These conclusions generally support the investor attention hypothesis developed by Barber and Odean (2007). However, other studies reveal contrasting results. Kim et al. (2019) assert that although GSVI can help predict increases in volatility and trading volume of stocks, it cannot help predict future returns on the Norwegian market. Bijl et al. (2016) assert that investor attention harms US stock returns. Using Korean market data, Pyo's research (2017) also shows that investor attention lowers KOSPI returns. Perlin et al. (2017) researched four developed countries, namely the US, UK, Australia, and Canada, and used keywords related to the stock market, in general, such as "stocks," "finance," and "market". They found that the search volume of some keywords was negatively correlated with the overall market return.

Other studies devoted to emerging markets have also reached mixed conclusions. Investor attention positively affects the growth of stock returns in markets such as Malaysia and Indonesia (C. P. Nguyen et al., 2019) and Turkey (Ekinci & Bulut, 2021). In contrast, scholars argue that the more attention an investor pays to a security, the less likely it is that its returns will increase. This was found in Swamy and Munusamy's (2019) study for the Indian market, research by C. P. Nguyen et al. (2019) in the case of the Philippines and Thailand, and by Shen et al. (2017) for the Chinese market.

Instead of just focusing on a few specific markets, some other researchers have expanded their research scope to an international scale, with their aim being to establish the factors that affect the relationship between investor attention and stock returns. Akarsu and Süer (2021) researched 31 markets and found that investor attention is more significant in individualist countries, countries with a psychological avoidance of instability, and developed countries. Tantaopas et al. (2016) examined the impact of investor attention on returns in 10 Asia-Pacific countries. They found that, in most cases, investor attention does not affect indices of return, volatility, or volume but does predict returns because attention will lead to more explicit information-based decisions. Chen (2017) conducted a comprehensive study of 67 countries and

concluded that investor attention has a significantly negative effect on stock returns. It is worth noting that this study adds the emotional variable of the market and confirms that more positive market sentiment will make investors pay more attention and vice versa. These findings by Chen (2017) confirm Merton's investor perception hypothesis. Studying various US, European, and emerging markets, Duz Tan and Tas (2021) assert that social media sentiment can help investors build their investment strategies. On the other hand, positive sentiment on Twitter is more evident in small and emerging market companies, which is consistent with the literature that small companies are challenging to value, and emerging market companies have a high level of information asymmetry.

Some other researchers are interested in examining market volatility when a powerful force, such as a pandemic or war, occurs. The study by Kropiński and Anholcer (2022) uses keywords related to uncertainty about Polish economic policy and divides the research data into two periods before and after COVID-19. This study's results show that an increased empirical relationship was confirmed between 12 EPU-related terms and market changes in the second period compared to six terms in the pre-COVID period. The study by Gheorghe and Panazan (2023) aims to quantify the volatility caused by the military conflict between Russia and Ukraine by analysing stock market indices across 40 countries. The results demonstrate that conflict shocks affect stock markets globally. The implications of these findings are significant for investors, decision-makers, portfolio managers, investment funds, and central banks.

Only a few studies have been done on frontier markets. A study by Osarumwense using Nigerian data (2020) concluded that GSVI is not a driving factor for stock price movements and has no interaction with earnings, volume, and volatility when determining price dynamics. Studies by C. Nguyen et al. (2020) and C. P. Nguyen et al. (2019) classified Vietnam as an emerging market, although MSCI (2022) classified Vietnam as a frontier market. Conclusions about the effect of investor attention on stock returns in the Vietnam market differ between the two groups of authors. While C. P. Nguyen et al. (2019) suggested that the higher the search frequency, the lower the stock return, C. Nguyen et al. (2020) obtained the opposite result. The multinational studies by Akarsu and Süer (2021) and Chen (2017) also refer to frontier markets but only analyse at the market level, not at the stock level. On the other hand, rather than delve into the differences between markets, these studies aim to understand the influence of non-economic factors such as emotions and culture on the relationship between investors' attention and the stock market.

According to the market classification framework of MSCI (2022), in emerging markets, the ease of capital inflows and outflows and the effectiveness of the operational framework are significant. Meanwhile, in the frontier markets, the level to which these criteria are fulfilled is only partial or very modest. On the other hand, the quantified requirements for the number and size of

large companies in these two market groups are also significantly different. Accordingly, in the frontier markets, there are not many large companies, and the activities of foreign institutional investors are limited, leading to the vast majority of investors being individuals. Google Search further proves its role in helping investors find information. In other words, the Vietnamese market provides an ideal context to test the investor attention hypothesis of Barber and Odean (2007).

The emergence and outbreak of the COVID-19 pandemic seriously affected global socio-economic activities. New market conditions were established and these attracted the attention of many scholars. Many authors have explored the extent of the pandemic's impact on different business sectors. Ding et al. (2020) investigated the daily closing prices of 1,567 stocks listed on NASDAQ and classified these companies into 37 sectors and found that GSVI has a positive correlation with the stock price of the group with a high level of digital conversion stock price but has a negative impact on the stock price of the group with medium and low digital conversion. Lee (2020) also divided the sample into 11 industries and found that the stock index of the IT and healthcare sectors increased, while the overall market index of the S&P500 and the stock index of the remaining industries decreased during the COVID-19 period.

Although most studies agree that a higher GSVI makes the market more volatile, the conclusion about the correlation between GSVI and stock prices and returns during the COVID-19 pandemic is different. A positive relationship is found in Japan and Singapore (Vasileiou, 2021). The negative effect on stock returns can be found in the studies by Shear et al. (2021), Smales (2021), Chundakkadan and Nedumparambil (2022), and Costola et al. (2021). Smales (2021) further argues that individual investors are not looking for information about potential stocks to buy, as argued by Barber and Odean (2007), but are looking for answers to attitudes about the economy and Financial and Economic Attitudes Revealed by Search (FEARS) of households as suggested by Da et al. (2011). Costola et al. (2021) found no relationship between investor attention to the pandemic and the volatility of the French and British stock markets. However, they also find interesting evidence in the Italian situation, where the country's GSVI serves as a precursor and helps to explain yield fluctuations in other countries. Furthermore, the impact of GSVI was also more robust, corresponding to the different periods of the blockade in Italy. Studies have focused on the impact of GSVI on the stock market during the COVID-19 outbreak; however, no studies compare this impact before and during COVID-19 to see how this impact changes as market conditions change.

2. Model specification and data

2.1. Model specification

The study builds a model of the influence of GSVI on stock prices based on the Fama-French three-factor model (FF3FM). Studies such as those by Fang et al. (2017), C. Nguyen et al. (2020), and Khoa and Huynh (2023) proved the higher validity of FF3FM for the Vietnamese stock market compared to other similar models such as CAPM and CF4 (Carhart Four Factor Model).

This paper carries out two types of analysis after statistics analysis. First, the aim is to determine whether there is a difference in the abnormal returns of highly searched-for and less searched-for securities, we run the FF3FM model for different portfolios and a hedge portfolio according to their GSVI. Second, we run the model at the stock level with the entire study sample.

As pointed out in the Introduction, in the five years of research data, the Vietnamese stock market has experienced two distinct periods, which is due to the impact of the COVID-19 epidemic. Therefore, with each model in the two analysis steps above, we divide it into two periods, before COVID-19 and during COVID-19, to see how environmental factors affect the relationship under consideration.

2.1.1. Group regressions

In this section, following Takeda and Wakao (2014) and C. Nguyen et al. (2020), we categorize stocks into four quartiles based on their search index: Q1 is the group with the lowest search intensity, while Q4 is the group with the highest search intensity. Q41, called the hedge portfolio, is the combined portfolio of both Q4 and Q1. The hedge portfolio Q4-Q1 whose strategy is on the long position on the most-searched-for stocks (Q4) and the short position on the least-searched-for stocks. These groups are rebalanced weekly. We then estimate the abnormal returns by applying the FF3FM to the four groups and the hedge portfolio according to Equation (1).

$$R_{p,t} - R_{f,t} = \alpha + \beta_m (R_{m,t} - R_{f,t}) + \beta_s SMB_t + \beta_h HML_t + \varepsilon_{i,t} \quad (1)$$

R_p is the weekly portfolio return, R_f is the risk-free rate, and R_m is the weekly market return. The portfolio return is the average of the securities returns in the portfolio. SMB is the difference between the weekly returns of the small and large stock portfolios. HML is the difference between the weekly returns of high and low book-to-market portfolios. According to FF3FM, small and value stocks tend to have higher risk premiums. In Equation (1), parameter α is the weekly abnormal return of the portfolio.

To assess the models, we follow Takeda and Wakao (2014) and C. Nguyen et al. (2020) and use three proxies for search intensity, including lnGSVI, ΔlnGSVI, and AGSVI. The validity of search intensity comparison among stocks may be severely affected by large shocks; therefore, using ΔlnGSVI and AGSVI can mitigate this problem (Takeda & Wakao, 2014). ΔlnGSVI_t measures the change in search intensity over week *t* and is computed as follows:

$$\Delta\text{lnGSVI}_t = \text{lnGSVI}_t - \text{lnGSVI}_{t-1}$$

AGSVI_t measures the abnormal level of search intensity:

$$\text{AGSVI}_t = \text{lnSGSVI}_t - \text{median}(\text{lnSGVI}_{t-1}, \ldots, \text{lnGSVI}_{t-7})$$

The group regression is performed three times, as we use three proxies for search intensity. Additionally, we run the models in two phases, before and after the COVID-19 outbreak, to observe changes in the portfolios' abnormal returns.

2.1.2. Stock-based regressions

Short-term model

Based on the FF3FM applied to each stock, we include the search intensity variable in addition to the other variables to determine whether search intensity can explain the stock returns. The model equation is as follows:

$$R_{i,t} - R_{f,t} = \alpha + \delta GSVI_{i,t-j} + \beta_m(R_{m,t} - R_{f,t}) + \beta_s SMB_t + \beta_h HML_t + \varepsilon_{i,t} \quad (2)$$

where $GSVSI_{i,t-j}$ is the search intensity for stock i with lag j. Some studies, such as C. Nguyen et al. (2020), C. P. Nguyen et al. (2019), Da et al. (2011), and Joseph et al. (2011), included a lag for the variable SI, assuming that stocks had been initially observed and analysed for a period before investing decisions were taken place rationally, which usually led to a higher stock return. However, Ekinci and Bulut (2021) and Takeda and Wakao (2014) found no relationship between searches made in period $t-1$ and stock returns in period t. Ekinci and Bulut (2021) confirmed the relationship between non-lagged search intensity and stock returns. We believe that Ekinci and Bulut's (2021) results were reasonable because, on modern stock markets with effective information systems, investors' decisions are often executed simultaneously on receipt of the information or after only a very short delay. This finding aligned with Barber and Odean's (2008) statement that individual investors were net buyers of stocks with extremely high or low previous-day returns.

As a result, we believe that the relationship between the non-lagged $GSVI$ and Ri may be more robust. Owing to the limitations of the $GSVI$ data, which is only available weekly, we cannot determine the daily lag of the $GSVI$ variable. Therefore, we run model (2) as non-lagged with $GSVI0$ variable and as including 1-period lag with $GSVI$(-1) variable.

Long-term model

According to Barber and Odean (2008), the effect of investor attention on increasing stock returns through buying is temporary. Subsequently, investors adjust their investment behavior based on complete information, resulting in decreased stock returns. To examine the long-term effect of search intensity on stock returns, we run the long-run effect model described in Equation (3). In this equation, lag j of the $GSVI$ variable ranges from 1 to n; statistical standards AIC and BIC are used to determine n in the models (Akaike, 1998).

$$R_{i,t} - R_{f,t} = \alpha + \sum_{k=1}^{n} \delta_k GSVI_{i,t-j} + \beta_m (R_{m,t} - R_{f,t}) + \beta_s SMB_t + \beta_h HML_t + \varepsilon_{i,t} \quad (3)$$

Models with substituted variables

In Equations (2) and (3), the regression of all returns over the period on the factor loadings of the FF3FM assumes that the beta factors of all stocks are identical. To mitigate this issue, we follow Takeda and Wakao (2014) and C. Nguyen et al. (2020) and substitute SMB with firms' capitalization (MK) and HML with firms' price-to-book ratio (PB). We use Equation (4) instead of Equation (2) and Equation (5) instead of Equation (3).

$$R_{i,t} - R_{f,t} = \alpha + \delta GSVI_{i,t-j} + \beta_m (R_{m,t} - R_{f,t}) + \beta_s MK_t + \beta_h PB_t + \varepsilon_{i,t} \quad (4)$$

$$R_{i,t} - R_{f,t} = \alpha + \sum_{k=1}^{n} \delta_k GSVI_{i,t-k} + \beta_m (R_{m,t} - R_{f,t}) + \beta_s MK_{i,t} + \beta_h PB_{i,t} + \varepsilon_{i,t} \quad (5)$$

2.2. Data

This study used data from securities listed on the Ho Chi Minh City Stock Exchange (HOSE), Vietnam's largest stock exchange. The data was obtained for five years, from October 9, 2016, to October 3, 2021, which totals 260 weeks. The market had 402 listed companies as of October 2021.

The $GSVI$ was obtained from Google Trends for the G*SVI* variable for the keyword "stock tickers." While there may be various reasons for individuals to search online for a company's ticker, Joseph et al. (2011) argue that the

effort required to process the results of such a query is only worthwhile for someone genuinely considering an investment decision. In contrast, searching for other terms, such as company name, yields a range of information that cannot be related to investment decisions (e.g., product information and store location). GSVI is a weekly index with values ranging from 0 to 100 over a 5-year collection period. The search command was restricted to Vietnam to filter search data of other countries, which could have been performed for various reasons unrelated to security investigation. The GSVI data were filtered to ensure the search keywords were associated with the target stock ticker. Each keyword search result was manually cross-checked against related queries. A stock ticker was considered disqualified if the first 5/10 related queries were unrelated to a company or securities investment; the same key-

Table 1. Data statistics

Pre-COVID-19					
Variable	**Number of observation**	**Mean**	**Standard deviation**	**Min**	**Max**
$R_i - R_f$	24.578	0.0013	0.0542	–1.0009	0.9505
$R_m - R_f$	26.660	0.0011	0.0217	–0.0923	0.0548
R_f	26.660	0.0009	0.0001	0.0005	0.0012
$GSVI_i$	26.660	22.1595	19.8398	0	100
SMB	26.505	0.0004	0.0139	–0.0477	0.0353
HML	26.505	–0.0010	0.0117	–0.0270	0.0311
MK_i	24.627	28.4096	1.8574	23.9775	33.6671
PB_i	23.711	0.0001	0.0008	–0.0041	0.0035
During-COVID-19					
$R_i - R_f$	13.426	0.0087	0.0657	–1.0004	0.4006
$R_m - R_f$	13.640	0.0044	0.0329	–0.1459	0.0794
R_f	13.640	0.0005	0.0001	0.0004	0.0007
$GSVI_i$	13.640	31.1488	21.2913	0	100
SMB	13.640	0.0014	0.0140	–0.0291	0.0376
HML	13.640	0.0012	0.0159	–0.0365	0.0441
MK_i	13.432	28.6564	1.9065	24.2840	33.8125
PB_i	13.361	0.0001	0.0007	–0.0022	0.0035

Source: own work.

words were searched, but for different purposes. After filtering, the sample includes 155 securities.

Companies' stock and financial data were obtained from the Refinitiv database of Thomson Reuters. These data were collected weekly for consistency with the GSVI data. The risk-free rate of return was derived from 10-year government bond yields from the State Bank of Vietnam. We consider January 23, 2020 as the benchmark to divide the data sample, as it marks the date when the first case of COVID-19 was detected in Vietnam. The sample period before the COVID-19 outbreak serves as a normal trading stock market. The COVID-19 period witnessed a change in market conditions, where several new individual investors entered the market for the first time, and market transactions surged. Stata 16 was used to implement the regression models.

Table 1 summarizes the statistics of the key variables of the models divided into the two research periods. There are notable changes in the means of the variables between the two periods. While the risk-free rate R_f witnesses a slight decline, stock premium $R_i - R_f$, market premium $R_m - R_f$, and $GSVI_i$ tend to rise from the pre-COVID-19 to the during-COVID-19 period. Figure 1 displays the variation in the GSVI over time. The SMB has a positive mean, which suggests that small company securities have higher returns than large company securities.

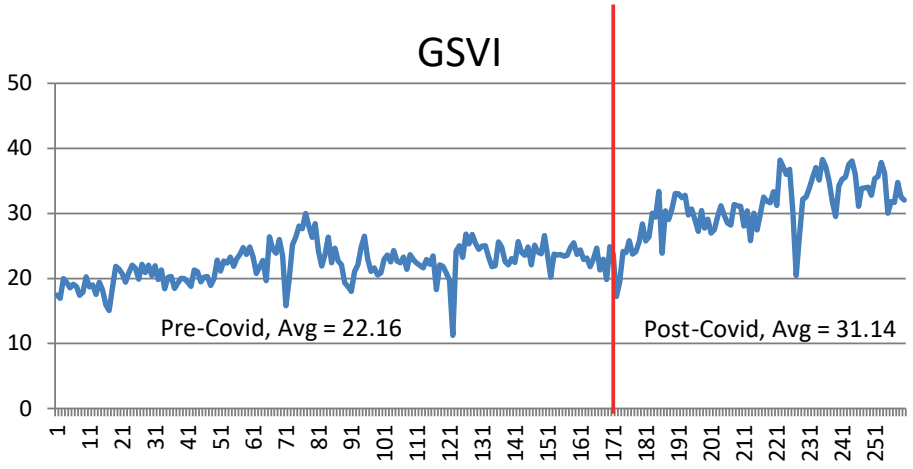

Figure 1. Variation of GSVI pre- and during-COVID-19 in Vietnam

Source: own work.

3. Results

3.1. Portfolio regressions

The models run with the portfolios are time series models. The ADF test shows that all variable series are stationary; therefore, the OLS estimation is suitable. As most models have heteroscedasticity, a robust option is included to address this issue. In most cases, the model statistics confirm the significance of the FF3FM on the Vietnamese stock market. R-squared values in the models above 0.40 in Table 2 and above 0.20 in Table 3 are low. However, these are acceptable levels with impact assessment studies. According to Ozili (2022), an R-squared between 0.10 and 0.50 is acceptable in social and economic science research only when some or most explanatory variables are statistically significant. In our paper, in the models in Table 2 and Table 3, two-thirds of the independent variables were statistically significant, thus the fitness of the models with the level of R-squared could be acceptable. Alphas in Tables 2 and 3 are intercepts of the models, presenting the risk-adjusted returns of stock portfolios. In some models, the intercepts are not significant, i.e., there is insufficient statistical evidence to assume that the constants are different from zero. However, sometimes, even if the constants are not statistically significant, it is still essential to include them in the research model for theoretical reasons and use them for analysis.

The model results for portfolios in the pre-COVID-19 period (Table 2) show a difference in the abnormal returns of different portfolios; however, there is no notable trend for all portfolios. The portfolio Q4 has a higher alpha coefficient than Q1. This implies that stocks that are searched for more often can have higher abnormal returns than those searched for less frequently.

The results for the during-COVID-19 period (Table 3) indicate a clear trend in the alpha coefficients of the four portfolios. For example, in the model with the GSVI*'s* proxy lnGSVI, the alpha coefficient for portfolio Q1 is 0.00378, Q2 is 0.00505, and Q3 is 0.00812, increasing to 0.01551 for portfolio Q4. This propensity is also true for models with other G*SVI* proxies, including ΔlnGSVI and AGSVI. As discussed in section 3.2, the Vietnamese during-COVID-19 stock market was characterized by a new wave of individual investors entering the market. From January 2020 to November 2021, 1,477,089 new accounts were opened, equivalent to nearly 74,000 new accounts per month, compared to 18,000 in the pre-COVID-19 period. Of the newly opened accounts, 99.4% were retail accounts (State Security Commission of Vietnam, 2022). Most account holders were inexperienced, lacked knowledge of stock investing, worked from home, and sought new investment channels because of social restrictions. In such instances, search engines become the primary

Table 2. Portfolio analysis of search intensity and stock returns pre-COVID-19

Variable	Intercept	Rmf	SMB	HML	R^2	Adjusted R^2	Number of observation
lnGSVI0							
Q1	0.00037	0.52147***	0.09687	0.12681	0.40127	0.39051	171
Q2	–0.00006	0.52459***	–0.14572	0.34021***	0.46100	0.45132	171
Q3	0.00007	0.61893***	–0.00828	0.36746***	0.49831	0.48930	171
Q4	0.00056	0.66200***	–0.09536	0.31121**	0.48163	0.47232	171
Q41	0.00047	0.59173***	0.00075	0.21901***	0.43618	0.43117	342
ΔlnGSVI0							
Q1	–0.00197**	0.51877***	0.04945	0.19973*	0.42742	0.41707	170
Q2	0.00054	0.62787***	–0.05201	0.25187**	0.50240	0.49341	170
Q3	0.00082	0.62574***	–0.15583	0.34479***	0.46785	0.45823	170
Q4	0.0013	0.54278***	–0.0437	0.37829***	0.40292	0.39213	170
Q41	–0.00034	0.53077***	0.00288	0.28901***	0.40732	0.40203	340
AGSVI0							
Q1	–0.00192*	0.55917***	0.03331	0.27511***	0.45825	0.44846	170
Q2	0.00075	0.62743***	0.00638	0.10152	0.50712	0.49821	170
Q3	0.00044	0.61037***	–0.14831	0.36612***	0.48583	0.47654	170
Q4	0.00136	0.51408***	–0.04929	0.43298***	0.40383	0.39306	170
Q41	–0.00028	0.53662***	–0.00799	0.35405***	0.42411	0.41897	340

* Indicates statistical significance at the 10% level.
** Indicates statistical significance at the 5% level.
*** Indicates statistical significance at the 1% level.
Note: lnGSVI0, ΔlnGSVI0, AGSVI0 are search intensity proxies with 1-period lagged variables.

Source: own work.

Table 3. Portfolio analysis of search intensity and stock returns during-COVID-19

Variable	Intercept	Rmf	SMB	HML	R^2	Adjusted R^2	Number of observation
lnGSVI(–1)							
Q1	0.00378	0.05227	–1.19392***	1.47230***	0.27831	0.25253	171
Q2	0.00504	0.06733	–1.52581***	1.58381***	0.28438	0.25882	171
Q3	0.00812**	0.07977	–1.40154***	1.52150***	0.26604	0.23983	171
Q4	0.01551***	0.06114	–1.45534***	1.62325***	0.25650	0.22994	171
Q41	0.00964***	0.05671	–1.32463***	1.54777***	0.25662	0.24365	342
ΔlnGSVI(–1)							
Q1	0.00286	0.07422	–1.24804***	1.43894***	0.25846	0.23197	170
Q2	0.00483	0.0676	–1.44522***	1.48527***	0.27622	0.25037	170
Q3	0.01146***	0.03479	–1.56697***	1.70220***	0.31879	0.29446	170
Q4	0.01323***	0.0931	–1.30411***	1.58904***	0.23426	0.20692	170
Q41	0.00805***	0.08366	–1.27607***	1.51399***	0.23815	0.22486	340
AGSVI(–1)							
Q1	0.00344	0.05352	–1.29103***	1.39546***	0.25159	0.22486	170
Q2	0.00424	0.04178	–1.44266***	1.52903***	0.26950	0.24341	170
Q3	0.00877***	0.07475	–1.45641***	1.52154***	0.27832	0.25254	170
Q4	0.01590***	0.09702	–1.37499***	1.75481***	0.28952	0.26414	170
Q41	0.00967***	0.07527	–1.33301***	1.57513***	0.25861	0.24568	340

* Indicates statistical significance at the 10% level.
** Indicates statistical significance at the 5% level.
*** Indicates statistical significance at the 1% level.
Note: lnGSVI(–1), ΔlnGSVI(–1), AGSVI(–1) are search intensity proxies with 1-period lagged variables.

Source: own work.

mode of gathering information for decision-making on various subjects, implying that search intensity has a significant effect on Vietnamese investors' trading behavior. It appears that a market with a greater number of new individual investors is less professional, and the impact of investor attention exhibited through $GSVI$ is more pronounced.

3.2. Stock-based regressions

Considering the panel dataset, we consider three models: OLS - Ordinary Least Square, FE – Fixed Effect, and RE – Random Effect models. We used the F test to decide between the OLS and FE model, with the null hypothesis of no fixed effects in stock-based models. The OLS model is selected if the p-value is greater than 5%. If it is less than 5%, rejecting the null hypothesis, we continue to perform Hausman's test to choose between the FE and RE models. After selection, most models—whether FE, RE, or OLS—have heteroscedasticity and/or autocorrelation problems. To overcome these problems, we use GLS estimation with corr(ar1) or panels(hetero) options from the Stata program.

Table 4 shows that with a no-lag search intensity, all models have good statistical indicators. The variables Rmf, SMB, and HML are statistically significant in the model at 1%. The correlation between GSVI and stock return is proven to be positive and significant. This result indicates that stocks experiencing higher search intensity undergo price increases and provide higher returns to investors. This impact is immediate, or there may be a delay of up to one week. This result is consistent with Ekinci and Bulut (2021). Comparing the estimated parameters of the GSVI variables (lnGSVI, ΔlnGSVI, and AGSVI) between the periods before and after the COVID-19 outbreak, the parameter values in the during-COVID-19 models are significantly higher than those in the pre-pandemic period. For example, the estimated impact parameter of lnGSVI to stock return is 0.00042 in the pre-COVID-19 model, while this number is 0.00225 in the during-COVID-19 model. This is consistent with the results found in the analysis of the relationship between search intensity and stock returns in the portfolio-based models in Tables 2 and 3. During the pandemic, the impact of investor attention is more robust. However, the GSVI coefficients are generally smaller than those of the other three traditional factors in the FF3FM model.

The results of the models change significantly when one-week lag GSVI variables are used. No statistically significant relationship exists between GSVI and stock returns before, during, and after the COVID-19 outbreak. This result diverges from those of Da et al. (2011), C. Nguyen et al. (2020), and C. P. Nguyen et al. (2019) but is consistent with Ekinci and Bulut (2021) and Takeda and Wakao (2014). Combined with the results of the models with no

Table 4. Stock-based analysis of search intensity and stock returns, pre- and during-COVID-19

Lag = 0	**Pre-COVID-19**			**During-COVID-19**		
Variable	**lnGSVI0**	**ΔlnGSVI0**	**AGSVI0**	**lnGSVI(–1)**	**ΔlnGSVI(–1)**	**AGSVI(–1)**
$R_m - R_f$	0.52069***	0.51956***	0.52006***	0.05525***	0.07462***	0.05692***
SMB	–0.18862***	–0.19075***	–0.19060***	–1.24598***	–1.23730***	–1.25010***
HML	0.25230***	0.25442***	0.25579***	1.23680***	1.24127***	1.23890***
GSVI0	0.00042**	0.00044***	0.00050***	0.00225***	0.00130***	0.00145***
Intercept	0	0.00107***	0.00111***	–0.0002	0.00648***	0.00679***
Number of observation	24428	24302	24302	13426	13426	13426
Lag = 1	**Pre-COVID-19**			**During–COVID–19**		
Variable	lnGSVI0	ΔlnGSVI1	AGSVI0	lnGSVI(–1)	ΔlnGSVI(–1)	AGSVI(–1)
Rmf	0.51995***	0.51919***	0.51948***	0.05557***	0.07567***	0.05530***
SMB	–0.19065***	–0.18980***	–0.18900***	–1.20297***	–1.18698***	–1.20240***
HML	0.25439***	0.25026***	0.25043***	1.20860***	1.20856***	1.20815***
GSVI(–1)	–0.00019	–0.00014	0.00001	0.00009	–0.00002	–0.00047
Intercept	0.00153***	0.00108***	0.00108***	0.00641***	0.00658***	0.00663***
Number of observation	24302	24176	24176	13276	13276	13276

* Indicates statistical significance at the 10% level.
** Indicates statistical significance at the 5% level.
*** Indicates statistical significance at the 1% level.
Note: lnGSVI0, ΔlnGSVI0, AGSVI0 and lnGSVI(–1), ΔlnGSVI(–1), AGSVI(–1) are search intensity proxies with non-lagged variables.

Source: own work.

lag SI, the results reaffirm that the impact of search intensity on stock returns occurs within one week. One possible explanation is that an increasing number of investors consider Google Search a valuable tool in their decision-making process, starting with information-seeking behavior. Consequently, the information obtained from Google searches is being incorporated into the market faster. Additionally, with the challenges faced in evaluating which individual stocks to purchase among hundreds of available stocks, investors tend to choose those that draw their attention, increasing stock prices (Odean, 1999). Therefore, in-week data can indicate the positive impact of investor attention reflected in the GSVI in stock returns.

We gradually add GSVI variable lags to the models from two-period lag onwards to identify long-term models. We denote the lagged variables as GSVI(–1) – GSVI(–9), which means the 1-to-9-period lag of the GSVI variable. The AIC and BIC statistics are employed to select the appropriate models. In principle, the smaller these values, the better the model fits the data sample. The lag of the GSVI variables selected according to the AIC and BIC statistical standards is nine. However, the model results for nine lags of GSVI variables show an unclear long-run relationship between search intensity and stock returns (Table 5). Several lag variables are statistically significant in the models using the ΔlnGSVI proxy before and after the COVID-19 outbreak. However, the lag variables are not statistically significant in most other models.

Table 6 presents the regression results when the variables SMB and HML are replaced by MK and PB, respectively, allowing for more variability in the variables for each stock included in the model. The results in Table 6 are consistent with those in Table 4, confirming search intensity's spontaneous, positive impact on stock returns. For the models with a one-week lag SI, two out of six models, i.e. the lnGSVI0 and AGSVI1 models, indicate a statistically negative impact of a one-week lag GSVI on stock returns. These models confirm the PPH and AT (Barber & Odean, 2007). Attention stimulates investors to purchase stocks, increasing stock prices; however, stock prices decrease the following week. This result is also consistent with (Bijl et al., 2016). We insist that owing to the fast flow of information on stock markets, one-week lag data only enables us to detect subsequent negative returns. The results in Table 7 are generally similar to Table 5.

Conclusions

This study examines the relationship between Google Search intensity and stock returns for stocks listed on the Vietnamese stock market. We investigated various aspects of the relationship by analysing portfolios with differ-

Table 5. Stock-based analysis of search intensity and stock returns in the long-term

	Pre-COVID-19			During-COVID-19		
Variable	lnGSVI0	ΔlnGSVI0	AGSVI0	lnGSVI(–1)	ΔlnGSVI(–1)	AGSVI(–1)
$R_m - R_f$	0.51104***	0.50990***	0.50852***	–0.03494**	–0.00952	–0.03552**
SMB	–0.19274***	–0.18024***	–0.18160***	–0.86164***	–0.83276***	–0.85909***
HML	0.25454***	0.24017***	0.24063***	1.00541***	1.00495***	1.00627***
GSVI0	0.00068***	0.00074***	0.00062***	0.00266***	0.00274***	0.00198***
GSVI(–1)	–0.00024	0.00049*	–0.00019	–0.00038	0.00232***	–0.00028
GSVI(–2)	0.00014	0.00064**	0.00026	–0.00051	0.00176***	–0.00035
GSVI(–3)	–0.00024	0.00044	0.00005	–0.00048	0.00124*	–0.0001
GSVI(–4)	0.00024	0.00071**	0.00045**	–0.00032	0.00089	0.00004
GSVI(–5)	–0.00008	0.00061*	0.00013	–0.00019	0.00064	0.00047
GSVI(–6)	0.00006	0.00068**	0.00033*	–0.00025	0.00036	0.00031
GSVI(–7)	–0.00005	0.00062*	0.00014	–0.0006	–0.00027	–0.00003
GSVI(–8)	–0.00053**	0.00013	–0.00023	–0.00024	–0.00055	–0.00012
GSVI(–9)	–0.00029	–0.00015	0.00014	0.00073*	0.00013	0.00103***
Intercept	0.00201**	0.00125***	0.00138***	0.00808***	0.00912***	0.00979***
Number of observation	23288	23162	23162	12075	12075	12075

* Indicates statistical significance at the 10% level.
** Indicates statistical significance at the 5% level.
*** Indicates statistical significance at the 1% level.
Note: lnGSVI0, ΔlnGSVI0, AGSVI0 and lnGSVI(–1), ΔlnGSVI(–1), AGSVI(–1) are search intensity proxies with non-lagged and 1-period lag variables.

Source: own work.

Table 6. Stock-based analysis of search intensity and stock returns with substituted variables

Lag = 0	**Pre-COVID-19**			**During-COVID-19**		
Variable	lnGSVI0	ΔlnGSVI0	AGSVI0	lnGSVI(–1)	ΔlnGSVI(–1)	AGSVI(–1)
$R_m - R_f$	0.55619***	0.55542***	0.54298***	0.06534***	0.06583***	0.06678***
MK	0.00123***	0.00128***	0.00130***	0.00191***	0.00226***	0.00220***
PB	–2.68872***	–2.67267***	–3.22327***	–7.90936***	–8.21793***	–8.10782***
GSVI0	0.00036*	0.00047***	0.00054**	0.00195***	0.00122***	0.00125***
Intercept	–0.03517***	–0.03573***	–0.03601***	–0.05232***	–0.05639***	–0.05459***
Number of observation	23699	23587	23587	13361	13361	13361
Lag = 1	**Pre-COVID-19**			**During–COVID–19**		
Variable	lnGSVI0	ΔlnGSVI1	AGSVI0	lnGSVI(–1)	ΔlnGSVI(–1)	AGSVI(–1)
$R_m - R_f$	0.55573***	0.55504***	0.55492***	0.06457***	0.06458***	0.06368***
MK	0.00134***	0.00127***	0.00127***	0.00250***	0.00241***	0.00245***
PB	–2.70239***	–2.69152***	–2.69124***	–8.71815***	–8.63844***	–8.71622***
GSVI(–1)	–0.00033*	–0.00017	–0.00008	–0.00049	–0.00046	–0.00081**
Intercept	–0.03657***	–0.03552***	–0.03550***	–0.06125***	–0.06022***	–0.06138***
Number of observation	23587	23475	23475	13211	13211	13211

* Indicates statistical significance at the 10% level.
** Indicates statistical significance at the 5% level.
*** Indicates statistical significance at the 1% level.
Note: lnGSVI0, ΔlnGSVI0, AGSVI0 and lnGSVI(–1), ΔlnGSVI(–1), AGSVI(–1) are search intensity proxies with non-lagged and 1-period lag variables.

Source: own work.

Table 7. Stock-based analysis of search intensity and stock returns in the long term with substituted variables

	Pre-COVID-19			During-COVID-19		
Variable	lnGSVI0	ΔlnGSVI0	AGSVI0	lnGSVI(–1)	ΔlnGSVI(–1)	AGSVI(–1)
R_{mf}	0.54767***	0.55037***	0.54934***	–0.04163***	–0.03983**	–0.04044**
MK	0.00140***	0.00130***	0.00130***	0.00310***	0.00278***	0.00275***
PB	–2.85966***	–2.86437***	–2.80484***	–1.1e+01***	–1.1e+01***	–1.1e+01***
GSVI0	0.00069***	0.00076***	0.00059***	0.00228***	0.00243***	0.00168***
GSVI(–1)	–0.00035	0.00046*	–0.00025	–0.00070*	0.00189***	–0.0006
GSVI(–2)	0.00011	0.00064**	0.00031*	–0.00025	0.00181***	–0.00006
GSVI(–3)	–0.00023	0.00047	0.00005	–0.00087**	0.00108	–0.00043
GSVI(–4)	0.00024	0.00075**	0.00043**	–0.00071*	0.00052	–0.00024
GSVI(–5)	–0.00013	0.00063*	0.00011	–0.00031	0.00035	0.0003
GSVI(–6)	–0.00001	0.00066*	0.00029	–0.00034	0.00015	0.00022
GSVI(–7)	–0.0001	0.00061*	0.00014	–0.00068	–0.00037	–0.00008
GSVI(–8)	–0.00053**	0.00014	–0.00021	–0.00066	–0.00088	–0.00043
GSVI(–9)	–0.00035*	–0.00019	0.00012	0.00048	–0.00024	0.00074**
Intercept	–0.03747***	–0.03618***	–0.03579***	–0.07027***	–0.06651***	–0.06549***
Number of observation	22691	22579	22579	12010	12010	12010

* Indicates statistical significance at the 10% level.
** Indicates statistical significance at the 5% level.
*** Indicates statistical significance at the 1% level.
Note: lnGSVI0, ΔlnGSVI0, AGSVI0 and lnGSVI(–1), ΔlnGSVI(–1), AGSVI(–1) are search intensity proxies with non-lagged and 1-period lag variables.

Source: own work.

ent search intensity levels, stock-based regressions, and models comparing small and large stocks. We used the GSVI variable with no lag and a one-week lag for short-term models and ran the long-term model with lag GSVI variables from 0 to 9 to investigate the timing of the effect. Each model is divided into two phases, before and after the COVID-19 outbreak, to simultaneously analyse and examine the relationship under different market conditions and check the robustness of models. The conclusions of this study are as follows:

First of all, the results show that GSVI positively affects stock returns in the short term. This means that the Barber and Odean's attention theory (2007) is true in the context of a frontier market. Proxied by Google Search intensity, investor attention can push investors to purchase more securities, leading to higher stock prices and returns. Moreover, the positive impact occurs within one week and reverses the following week. This result differs from most previous empirical studies, which show that the previous week's GSVI predicts the following week's stock returns (Da et al., 2011; Joseph et al., 2011; C. Nguyen et al., 2020). This result can be attributed to the fact that we used a recent dataset from 2016 to 2021. Recently, information and communication technology has penetrated and increased the speed of information on stock markets; thus, the impact of the $GSVI$ on stock returns should be faster. This also indicates that investors must react immediately to seize the opportunity of a stock price increase to make a profit.

Secondly, the search intensity impact on stock returns in Vietnam is more robust in the "during-COVID-19" period than in pre-pandemic conditions. The basic feature of Vietnam's stock market during the COVID-19 pandemic was a sharp increase in the number of first-time individual investors and online trade volume. The results suggest that when there is an event causing a sudden increase in the attention of individual investors, especially inexperienced individual investors, the impact of $GSVI$ on stock returns tends to be stronger.

Finally, the findings of this study also propose some practical implications for businesses and investors. On the one hand, the results support individual investors' use of online information, such as Google Search volume, in analysing behavioral and market trends to formulate profitable trading strategies. On the other hand, companies should focus on attracting investors' attention during share issuances. When investors pay attention to a particular stock, they Google Search more, and the stock price tends to increase.

Like other studies, this study has some limitations. First, the model is limited because GSVIs are weekly data. Therefore, it is difficult for the authors to observe accurately the day-impact and recovery period of $GSVI$'s impact on stock returns. Second, although the research has given reasons for choosing the FF3FM model, testing the data set on other models, such as CAPM, CF4, and FF5FM, will make it possible to strengthen the research results further. Finally, the study provides the GSVI impact on Vietnamese stock returns. As presented above, the Vietnamese market has all the outstanding character-

istics of a frontier stock market, and the results of this research can be representative of the group of frontier markets. However, to have firm results for emerging countries, more research is required in the future for other frontier stock markets.

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sciendo Economics and Business Review https://www.ebr.edu.pl Vol. 10 (1), 2024: 57–80 https://doi.org/10.18559/ebr.2024.1.1211

The asset-backing risk of stablecoin trading: The case of Tether

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Abstract

This article aims to analyse the asset-backing risk of stablecoins, focusing on international accounting standards, classification criteria, and auditing standards and using Tether as a case study. It examines Tether's issuance, backing, controls, ratios, and regulations to assess risk transmission and mitigation. The results suggest a need for unified and strengthened accounting and auditing standards to enhance user confidence. Liquidity, solvency, and debt ratios were applied to Tether's balance sheets; while Tether has made efforts to increase its transparency, and although it possesses highly liquid assets, challenges remain regarding its liquidity, solvency, and debt. An independent auditors' valuation is crucial for investor confidence, demonstrating that more specific regulations are required for stablecoins. Future research should explore other stablecoins to comprehensively understand the accounting and auditing challenges in the field.

Keywords

- stablecoins
- auditing
- IFRS
- risk management
- volatility
- balance sheet

JEL codes: G15, M21, M41, M42, M48

Article received 23 December 2022, accepted 3 March 2024.

Funding: Research supported by project Finance for all (F4A), funded by the "Institución Gran Duque de Alba" and "Diputación provincial de Ávila" to Sergio Luis Náñez Alonso; under the grant 3364/2022.

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Suggested citation: Fernández, J. J., Fernández, M. Á. E., Alonso, S. L. N. (2024). The asset--backing risk of stablecoin trading: The case of Tether. *Economics and Business Review*, *10*(1), 57–80. https://doi.org/10.18559/ebr.2024.1.1211

Introduction

Stablecoins are defined as assets that attempt to replicate the behaviour of money issued by a central bank in order to stabilize their value (Giudici et al., 2022; Liao & Caramichael, 2022). Stablecoins have a strong correlation with Bitcoin (Elsayed et al., 2022; Náñez Alonso et al., 2021; Yi et al., 2018) and act as a "haven" against the high volatility of the cryptocurrency asset market (Almeida & Gonçalves, 2022; Conrad et al., 2018; Łęt et al., 2023), addressing this shortcoming by linking their value to an underlying entity (Berentsen & Schär, 2019). To this end, stablecoins are backed fully or partially by legal tender (such as the dollar, pound, or euro) (Hoang & Baur, 2021); highly liquid reserves (such as government treasuries) (Benedetti & Smith, 2022; Chen, 2020; Lyons & Viswanath-Natraj, 2020); or commodities such as precious metals (Chowdhury, 2019). Stablecoins are also widely used to provide liquidity in decentralized exchanges (Catalini & Shah, 2021; Giudici et al., 2022) and they play an essential role as a peer or counterparty to many cryptocurrencies, allowing the investor to make a quick conversion from their wallet to a centralized exchange, from which users withdraw their funds as fiat currency (Catalini & Shah, 2021; Grobys et al., 2021; Jarno & Kołodziejczyk, 2021). In January 2024, the market capitalization of the three largest current stablecoins—Tether (hereafter USDT), USD Coin (hereafter USDC), and DAI—exceeded USD 125 billion, according to CoinMarketCap (2024). Stablecoins aim to offer investors price stability, either by being backed by specific assets or using algorithms to adjust their supply based on demand (Arslanian, 2022). Cryptocurrencies are normally used for speculative purposes (Auer & Tercero-Lucas, 2022), although they have also been adopted by some countries as legal tender (see the case of El Salvador) (Alonso et al., 2024). Stablecoins, on the other hand, are not an object of speculation but are used "to facilitate everyday transactional activities" (Arslanian, 2022; Barry, 2020). However, stablecoins also present several risks that all users (both individuals and companies) should be aware of (Arner et al., 2020). First, there is counterparty risk; by relying on a third party to print money and maintain a stable cryptocurrency, the currency used as backing could be fractionally reserved rather than fully backed (Arner et al., 2020; Mikhaylov, 2023). Second, there is a risk of centralization;

accounts can be misappropriated, locked, or accessed by unauthorized third parties (Mikhaylov, 2023), which are the same centralization risks as those faced by fiat currencies. Third, there is the risk of algorithm manipulations (Clements, 2021); as most decentralized stablecoins live inside smart contracts, in protocols such as Ethereum or Stellar, there is a risk that the algorithm that keeps the currency stable could be manipulated by a third party. In this research, given the current importance of stablecoins and their potential use by companies (Moura de Carvalho et al., 2022), we have focused on the stablecoin Tether (USDT) as a representative of the stablecoin sector in order to analyse these risks from an audit and accounting point of view. Currently, there is no consensus on how to treat assets stored in the blockchain that are part of the financial statements of an entity such as Tether (Alvarez-Pincay et al., 2018; Hsieh & Brennan, 2022).

The objective of this article is threefold. Firstly, this article analyses the accounting and auditing rules governing stablecoins. Secondly, this article analyses the evolution of risk support by studying Tether reserves using third-party audit reports. Thirdly, this article measures Tether's risk support in terms of its liquidity, solvency, and debt ratios.

This article is structured as follows: Section 1 examines stablecoins through the lens of international accounting and auditing standards such as the International Financial Reporting Standards (IFRSs), International Accounting Standards (IASs), Generally Accepted Accounting Principles (GAAPs), and Accounting Standards Codification (ASC). Section 2 provides a literature review of the accounting and auditing standards that are applicable to stablecoins. Section 3 shows the methodology of this research. Section 4 analyses the composition of Tether's assets and its liquidity, solvency, and debt ratios. The conclusions are presented in the last Section.

1. Accounting and auditing standards for stablecoins

This paper starts by analysing whether stablecoins should be treated as "money" or as a different asset class. The International Accounting Standards Board (IASB) is the regulatory body that creates and issues the International Financial Reporting Standards (IFRSs). These have been applied or adapted by individual countries and the EU. According to the EU regulation 1606/2002 (BOE, 2002), the IFRSs adopted by the EU are mandatory for the annual accounts of listed consolidated companies, including banks and insurance companies. However, member states of the EU have the right to implement these IFRSs as mandatory or optional elsewhere.

Regarding stablecoins, the EU has not expressly stated its position on the appropriate way to record and value cryptocurrencies. However, it has im-

plemented a regulation known as the "MiCA" (Market in Crypto-Assets). Moreover, under its umbrella, so-called electronic money tokens (EMT) or e-money tokens are considered a type of crypto asset and regulated with respect to the value of a fiat currency of legal tender in order to grant them a stable value. Although MiCA demands that crypto assets have a white-paper, authorization to operate, and a series of responsibilities and obligations to their providers (Sempere et al., 2021), it does not regulate their accounting or auditing. On the other hand, there is draft regulation called the "Cryptocurrency Holding", dating from 2019, which includes cryptocurrencies, stablecoins, etc., and may register them in inventories in the form of a "stock", as in the "stock of cryptocurrencies". They may be recorded in inventories, in case they are held for sale in the ordinary course of business, as established in the International Accounting Standards (IAS) 2 (ICAC, 2023). In other cases, as they are intangible assets, according to IAS 38, that rules out the possibility of recording them as financial assets or cash, according to IAS 32 (ICAC, 2023). This is because, according to the IASB committee, "cryptocurrencies should not be recognized in the financial statements according to the provisions of IAS 32" (ICAC, 2023), as, due to their nature, they do not comply with any of the definitions of financial assets, which are, according to the IAS, "(a) cash; (b) an equity instrument of another entity; (c) a contractual right to receive cash or another financial asset from another entity; (d) a contractual right to exchange financial assets or financial liabilities with another entity under specified conditions; or (e) a specific contract that will or may be settled using the entity's equity instruments" (IASB, 2019; 2021). Uniquely, stablecoins meet two of these definitions: in some cases, they behave as a contractual right to receive cash or another financial asset from another entity (Baker et al., 2023; Procházka, 2018; Torchelli & Símaro, 2021); in other cases, they are a contractual right to exchange financial assets or liabilities with another entity under specific conditions (Baker et al., 2023; Liao & Caramichael, 2022). It follows from the operation of Tether and other stablecoins that a token (USDT), once issued, becomes the user's property, giving the user an immediate settlement right for the principal payment minus fees. On the other hand, the company expects to earn economic returns through the interest it earns using the capital received in exchange for the issuance of these tokens, and not through the token itself (Torchelli & Símaro, 2021). In other words, the company does not sell USDTs; it simply issues them in exchange for collateral in trust (Murialdo & Belof, 2022).

Regarding their valuation using IAS 2—Inventories, as stated in the IASB report (IASB, 2019), cryptocurrencies have characteristics that are compatible with inventories, as, although they do not meet all the conditions of an inventory, they can be held for sale in the entity's ordinary course of business. Therefore, when stablecoins are controlled by an entity and held for sale, they are initially recognized as having a lower cost (acquisition or transformation

cost) and net realizable value. Upon subsequent measurement, a net realizable value model should be applied. In addition, IAS 2 (ICAC, 2023) allows for the assigning of their value using the retail method, the specific identification of their costs, and the First in, First Out (FIFO) approach. Finally, before their derecognition as inventories, impairments and reversals are to be recorded where applicable.

Regarding IAS 38—Intangible Assets (IASB, 2021), the IASB determines that, in cases where IAS 2 does not apply due to the lack of a "held for sale in the ordinary course" status, stablecoins should be recognized as an intangible asset following IAS 38 (IASB, 2019). The IASs state that intangible assets should be initially recognized at cost. Upon subsequent measurement, an entity can choose between cost and revaluation models. The IASB defines the disclosure of certain financial information as necessary to properly understand the entity's financial statements. In this respect, it delineates the following points: If stablecoins are valued as inventories, the disclosures indicated in IAS 2, paragraphs 36 to 39, must be made (IASB, 2019). If stablecoins are measured as an intangible asset, the disclosures indicated in IAS 38, paragraphs 118–128 (IASB 2019), shall be required. The IASB indicates, contrary to the valuation methods suggested in its report, that disclosures should be made if the asset is measured at a fair value, and that the disclosures required in paragraphs 91 to 99 of IFRS 13 should be made (IASB, 2019).

In the United States, accounting standards derive from the Financial Accounting Standards Board (hereinafter the FASB), recognized by the American Institute of Certified Public Accountants (hereinafter the AICPA). This work consists of developing financial and accounting reporting standards, which the FASB decrees in the form of regulations known as Generally Accepted Accounting Principles (GAAPs). The FASB has not explicitly applied GAAPs to cryptocurrencies, stablecoins, etc. However, the AICPA expressed its opinion on the correct treatment of cryptocurrencies, stablecoins, etc., in the US in the Audit Evidence—Specific Considerations for Selected Items (AICPA, 2019, 2020). According to this report, cryptocurrencies should be recognized as intangible assets and, therefore, they must be recognized in line with FASB standards for accounting purposes. Specifically, the Accounting Standards Codification (ASC) 350 on intangible assets, goodwill, and others should be followed. According to this standard, intangible assets should be recognized at cost on initial recognition, and subsequent measurements should consider whether the asset has a specified useful life, in which case it should be amortized, or whether its useful life cannot be reliably determined. In this case, no depreciation should be recognized. With regard to the recognition of impairment, FASB ASC 350-35-15 states that impairment should be recognized when appropriate, but, unlike the IFRSs, it prohibits the reversal of impairment. The AICPA also disallows the treatment of cryptocurrencies as cash or cash-equivalent items because they are not backed by government agencies

and because of the volatile nature of their prices (AICPA, 2019, 2020). They also may not be defined as financial assets, as they do not involve a contractual right that guarantees the owner a receipt of cash or other financial assets. In addition, in the US, these assets may not be considered inventory, because of their intangible nature, even if the sole purpose of holding them is for sale in the ordinary course of business. In the case of exchanges involving cryptocurrencies, the company must treat the receipt of cryptocurrencies in accordance with ASC 606: Revenue from contracts with customers, according to which the price of the cryptocurrencies received is measured at market value on the agreed date of the transaction. In their subsequent valuation, the cryptocurrencies will not be amortized, as they will be recognized as intangible assets with an indefinite useful life. However, they will be subject to depreciation if their market value is lower than the carrying amount, and the difference between these values will be recognized as a depreciation expense. The difference will be the new carrying amount of the asset, without the possibility of reversal. When an entity holds cryptocurrencies, stablecoins, etc., through a third-party custodian, the recognition of these cryptocurrencies may be made in the financial statements of the third party or of the entity. The control of the assets is the parameter that will indicate which statements they should appear in.

The fair value of a cryptocurrency should be determined by considering the value available in its principal market or, if it does not have a principal market, the most profitable market. Because cryptocurrencies are traded in multiple markets, an entity needs to assess the volume and reliability of their information to consider one market as the principal market. Moreover, because cryptocurrency markets are not typically closing markets, a closing price is not available and other means of establishing the closing time must be used. These can be the closing time of the entity, the usual closing time of local markets, etc. (AICPA, 2019, 2020). These standards are set out in Table 1.

The auditing standards applicable to stablecoins depend on how they are classified. In the European Union, the standards that define an entity's audit responsibilities for inventories are the ISA 501 (Audit Evidence-Specific Considerations for Certain Areas) and ISA 505 (External Confirmations). Stablecoins held by EU companies may also be classified as intangible assets, in which case ISA 540 (Audit of accounting estimates and related disclosures) applies. Assuming that the stablecoin reserves held by the company have been accounted for as intangible assets, the auditor should consider whether the company prepares IFRS financial statements at an early stage and whether management has decided to do so. The auditor should also validate the impairments and reversals of impairments made by the entity.

In the United States, the Audit Evidence—Specific Considerations for Selected Items (AICPA, 2019) applies. In this case, it is recommended that stablecoins and cryptocurrencies should only be classified and presented in

Table 1. Accounting classifications of stablecoins according to IFRS-EU and US-GAAP

Classification	Period	IFRS-EU	US-GAAP
Inventory/ stocks	initial assessment	the lower value of the cost (cost of acquisition or processing) and the net realizable value	not applicable
	subsequent valuation	net realizable value	not applicable
	impairment and reversal	yes	not applicable
Intangible assets	initial valuation	cost	cost
	subsequent valuation	cost model, or revaluation model	amortized cost, if depreciation applies, otherwise at cost
	impairment and reversal	yes	yes, but no reversal is applied

Source: author's work based on IAS 2, IAS 38 (IASB, 2019), and ASC 350 (AICPA, 2019).

the financial statements of US companies as intangible assets. The US auditing standard particularly relevant for an auditor's work, in terms of verifying and obtaining evidence of intangible assets, is AU-C 540—Auditing Accounting Estimates and Related Disclosures.

Concerning EU audits, since stablecoins are not a physical component in practice, ISA 501 is not applicable to this type of asset audit. However, in its application guidance and other explanatory notes, there is a reference to another standard, specifically in paragraph A15, which refers to ISA 505 on external confirmations. According to this, as long as the stablecoins are held in a wallet, the auditor may request confirmation from the manager of the wallet. Again, this is a matter of confirming the existence and status of the stablecoins held by the audited client.

2. Literature review on the accounting and auditing of stablecoins

Ultimately, stablecoins have proven challenging for many regulators, as they represent the difficult task of balancing financial stability with innovation (Ferreira, 2021; Giudici et al., 2022; Hsieh & Brennan, 2022; Náñez Alonso, 2019).

Various authors have pointed out the need to improve accounting and auditing procedures, such as Moura de Carvalho et al. (2022), who indicated that "we identify the need to adapt current auditing procedures and create new ones". The same position is defended by Kampakis (2022), who, in his article auditing a project based on stablecoins, concludes that "the audit of stablecoins is still a new area and there is no established set of methods to carry it out" in such a way that risk can be minimized. In addition, Melo et al. (2022); Náñez Alonso (2019); Sanz-Bas et al. (2021) or Vučinić & Luburić (2022) argue that regulation is necessary, but that national and international collaboration is key for it to have the desired effects. Ultimately, as pointed out by Almeida & Gonçalves (2022), this regulation can ensure that these assets are seen as safe places. Therefore, regulators must take a broader, long-term view of stablecoins beyond their perceived risks and accept their advantages as well (Ferreira, 2021; Vučinić & Luburić, 2022). However, one should not lose sight of what is indicated by Náñez Alonso (2019) or Travkina et al. (2022); these currencies can be used to avoid international sanctions or restrictions. In addition, another risk is that stablecoins' regulation is very changeable, so it is possible that these issues will be resolved in the medium term and that a stable, reliable, and unified framework for the accounting and auditing regulation of stablecoins will be generated.

The large-scale use of global stablecoins can have an impact on both large and small open economies, with a greater impact on the sovereign monetary system of small economies (Li & Shen, 2021; Liao & Caramichael, 2022). To address these potential impacts and risks, Li and Shen (2021) propose strengthening judicial investigations and planning global cooperation and coordination arrangements. There are some academic studies on the regulatory need for stablecoins. Arner et al. (2020) focus on financial regulation and conclude that it would be best to integrate supervisory requirements into the stablecoin systems themselves, which would allow for "integrated supervision". Sood et al. (2023) identify the lack of a clear regulatory framework as the second biggest risk and difficulty for the acceptance of stablecoins and their use. The same conclusion is reached by Andryushin & Kochergin (2022) and Bullmann et al. (2019), who indicate that the integration of stablecoins into a modern monetary and payment system can only occur if there is an adequate and coordinated regulation of them by all monetary authorities. Briola et al. (2023) argue that the lack of adequate regulation and collateral, inadequate decentralised financial frameworks, and a dependence on liquidity providers are valuable lessons from the collapse of USDTs. Sidorenko (2019) points to the need for a clear financial regulatory framework to reduce volatility and risk. Meanwhile, Kozhan and Viswanath-Natraj (2021) analyse risk based on the case of the Maker DAO DAI stablecoin and conclude that the introduction of secure collateral has increased parity stability. Regarding accounting and auditing procedures, several authors such as Moura de Carvalho et al. (2022)

have pointed out the need to adapt current auditing procedures and create new ones. Additionally, Kampakis (2022) indicates that "the audit of stablecoins is still a new area and there is no established set of methods to perform it" so that risk can be minimised. Melo et al. (2022), Náñez Alonso (2019) and Sanz-Bas et al. (2021) argue that accounting regulations are necessary, but national and international collaboration is key for them to have the desired effects. Ultimately, as noted by Almeida and Gonçalves (2022), such regulations can ensure that these assets are considered safe havens. However, despite various studies, it is not yet clear how best to regulate these assets, given their global reach (Klages-Mundt et al., 2020). There are several studies that have dealt with stablecoins and the regulation and management of their risk from an accounting and auditing point of view. Thus we can cite the study by Eichengreen et al. (2023), where the risk of the devaluation of Tether is analysed, indicating that "The average probability of devaluation during a year is 60 basis points, increasing to 200 basis points during the cryptocurrency crashes in March 2020 and March 2022"; thus, it is necessary to develop risk management models from an accounting point of view, as proposed by Klages-Mundt et al. (2020), and from an audit point of view (Liu et al., 2020) using the Mover system. These authors, joined by Kampakis (2022), agree on the need to develop a three-step risk assessment framework to investigate stablecoin arrangements and quantitatively assess their risks. To all this, Catalini & Shah (2021) and Smith (2023) propose that "stablecoin issuers comply with the capital and liquidity standards codified in the Basel accords and maintain adequate capital and liquidity buffers".

3. Data and methodology

3.1. Data

To analyse the evolution of Tether's assets, information has been extracted from all the audits available at the date of this study. These audit reports and their dates are listed in Table 2.

Table 2. Tether audit reports

Audit report by	Date
Audit by Friedman LLP	September 15, 2017
Audit by Freeh, Sporkin & Sullivan LLP	June 1, 2018

Audit report by	Date
Audit by MOORE	February 28, 2021
Audit by MOORE	March 31, 2021
Audit by MOORE	June 30, 2021
Audit by MOORE	September 30, 2021
Audit by Mha CAYMAN	December 31, 2021
Audit by Mha CAYMAN	March 31, 2022
Audit by BDO	June 30, 2022
Audit by BDO	September 30, 2022
Audit by BDO	December 31, 2022
Audit by BDO	March 31, 2023
Audit by BDO	June 30, 2023
Audit by BDO	September 30, 2023

Source: own work, data from (Tether, 2023).

3.2. Methodology

A qualitative analysis of Tether is conducted using the IFRS methodology, consistent with previous assessments of other assets (Ramos, 2021; Smith, 2023; Tache, 2020). This analysis utilizes information extracted from the audits available before the date of the study, as detailed in the data section. This qualitative analysis examines the impact of Tether, a stablecoin, on accounting and auditing procedures, employing the IFRS methodological perspective (Coccaro, 2021; Hsieh & Brennan, 2022; Kampakis, 2022; Smith, 2023). In addition, other queries were raised with the bodies that interpret and promulgate the accounting standards mentioned in the regulatory review above. Given the novelty of stablecoins, the support of these consultations is crucial to understanding their nature and, therefore, their place in the financial statements of both the issuers and companies that use cryptocurrencies or tokens for other purposes (Liao & Caramichael, 2022; Moura de Carvalho et al., 2022). Accurately classifying stablecoins and executing their audits will mitigate their risks and decrease financial stress for firms (Echarte Fernández et al., 2022; Kaczmarek et al., 2021; Moura de Carvalho et al., 2022; Smith, 2023). Proper classification and auditing will ensure their precise placement within financial statements, including the position of USDTs on Tether's balance sheet, further reducing their potential risks (Echarte Fernández et al., 2022; Kaczmarek et al., 2021; Moura de Carvalho et al., 2022; Smith, 2023).

Firstly, audit risk, which is the risk of expressing an inadequate opinion, can be defined as follows (Schultz et al., 2010; Smith, 2023):

Audit Risk = Risk of material misstatement + Risk of detection

Audit risk is composed of two other risks. First, the detection risk reflects the uncertainty of whether errors are detected during the audit. The risk of material misstatement is the likelihood of misstating financial statements before an audit engagement (Zaiceanu et al., 2015). The risk of misstatement is expressed by the formula:

Risk of material misstatement = Inherent Risk + Control Risk

Inherent risk is the susceptibility that an assertion about an item or another disclosure has been made before controls are performed. This assertion contains a misstatement that may be material (Schultz et al., 2010; Zaiceanu et al., 2015). On the other hand, control risk is identified as the likelihood that a misstatement is not prevented, detected, or corrected by the audited entity's internal control system (Schultz et al., 2010).

In the case of Tether, as the most representative stablecoin, scholars have analysed whether its reserves and backing have been sufficient to avoid transmitting these risks to the companies that have Tether on their balance sheets, which in turn could lead to them passing on this risk to their customers and other companies that operate with stablecoins (Kaczmarek et al., 2021; Kampakis, 2022; Moura de Carvalho et al., 2022).

Figure 1 illustrates the steps in the risk analysis of stablecoins from their use until they reach the end consumer. This is due to the existence, or not, of sufficient backing from the initial phase (issuance) and throughout the process of stablecoins being accounted for and audited.

In order to complete the above methodology, we have applied liquidity, solvency, and debt ratios to the data extracted from Tether's balance sheets. The

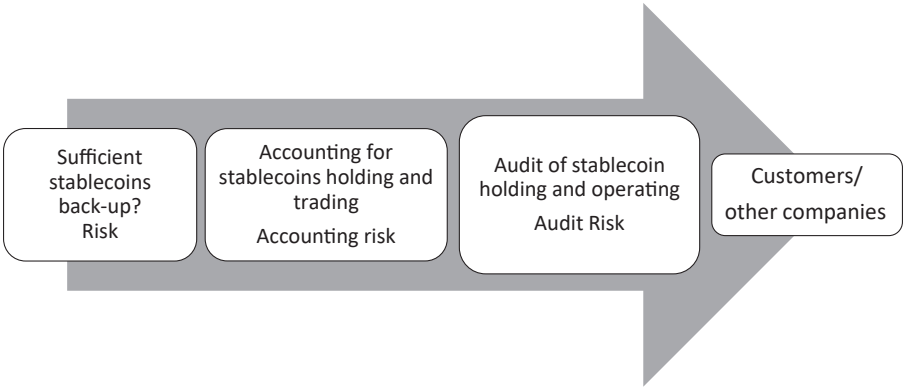


Figure 1. Applied methodology

Source: own work.

objective is to answer the question of whether Tether is sufficiently backed. This methodology has been previously applied in other sectors by authors such as Lessambo (2018, 2022), Lin et al. (2011), Xu et al. (2014), and Husna & Satria (2019).

Firstly, we applied two liquidity ratios, following Lessambo (2018, 2022); a liquidity ratio (short-term solvency), which measures a firm's ability to meet its short-term debt payments through its operating cycle, i.e. with all its current assets, and a cash ratio, which measures a company's ability to pay its short-term debts using only its cash on hand and cash receivable from customers or other debtors (realisable).

Then, we applied a solvency ratio, following Lessambo (2018, 2022) and Lin et al. (2011), which measures the firm's ability to pay all its debts through all its assets (the solvency and bankruptcy risk of the firm). We also applied a debt quality ratio, following Lessambo (2018, 2022), Xu et al. (2014) and Husna and Satria (2019), which measures the ratio of current liabilities to total liabilities. The results obtained are shown in Table 3.

4. Results and discussion

Tether is the largest stablecoin, with a market capitalization on November 1, 2023 of close to USD 100 billion, as shown in Figure 2.

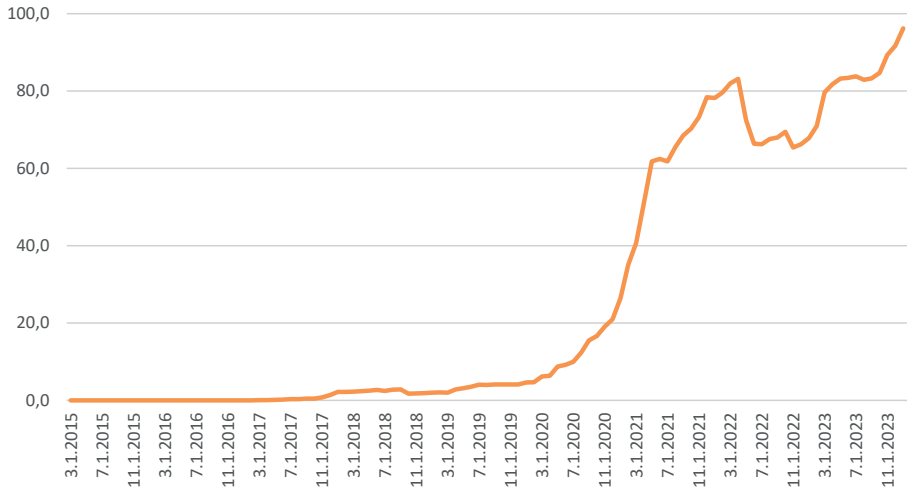


Figure 2. Market capitalization of Tether (billion USD)

Source: based on data extracted from (CoinMarketCap, 2024).

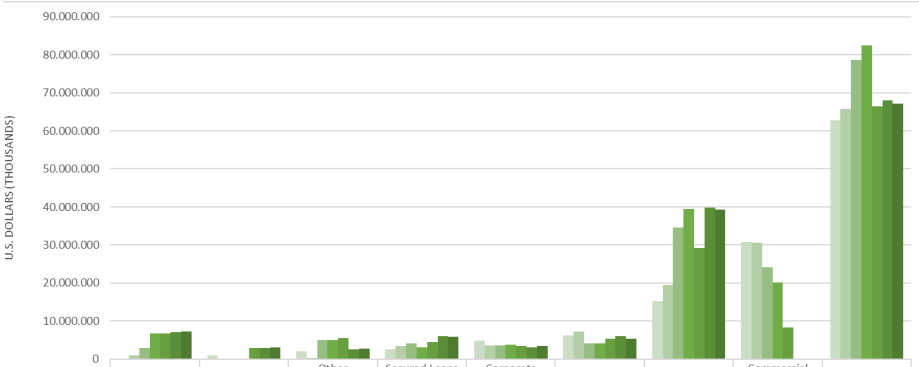
One of the elements that make up a company is its assets (which can be physical or intangible). Therefore, it is important to consider them as one of the aspects that provide a constant economic income. Tether is a stablecoin backed by US dollars, and its value remains stable at around USD 1 (Berentsen & Schär, 2019; Hoang & Baur, 2021). Additionally, stablecoins serve a crucial function in decentralized cryptocurrency exchanges, acting as a reliable counterpart to various cryptocurrencies and thus facilitating liquidity provision (Catalini & Shah, 2021). They enable investors to move their assets swiftly from their digital wallets to centralized exchanges, enabling an easy withdrawal to fiat currency (Catalini & Shah, 2021; Grobys et al., 2021; Jarno & Kołodziejczyk, 2021).

Therefore, knowledge of the assets of issuing entities is essential for stablecoin users, and they must be well registered (Almeida & Gonçalves, 2022), follow accounting regulations, and be audited appropriately to avoid some bankruptcies, such as the one that affected TerraUSD and Luna (Baker et al., 2023).

Concerning the audit of Tether conducted by Friedman LLP, it should be noted that the audit firm did not conduct an exhaustive review of Tether's contracts with the banks in which it deposits its funds. This raises substantial concerns about the singularities that these agreements may contain: Does Tether have immediate access to these funds? Among the risks of this practice is the possibility that the accounts may not be solely owned by Tether and may be shared with other entities in the group, giving them license to use the funds for purposes other than their original purpose.

FSS was appointed to review Tether's reserves; however, unlike the previous firm (FLLP), it is not subject to AICPA standards and does not base its opinion on them. Although its procedures do not differ from those performed by FLLP, there is a major problem: the lack of the independence of the auditor. As FSS is not subject to AICPA standards and, consequently, to those of its auditors, it is not bound by independence laws. Therefore, it is possible that FSS's opinion could be motivated by economic interests contrary to the presentation of reliable and true information. This is far from the objective of auditing, which is to offer a service to the recipients of the report, the clients, or those interested in knowing the state of the company's reserves. Figure 3 shows the composition and evolution of Tether Ltd.'s assets, validated using the audit reports indicated in the data section.

As of Moore Global's June 2021 audit, more detail has been presented on Tether's assets than in previous audits. Tether's assets are reflected in Figure 4. The ISAE 300 (revised) implies that this is distinct from an audit or review of historical financial information that as covered by the International Standards on Auditing (ISAs). Thus, both Tether and Moore Global are subject to the "Code of Ethics for Professional Accountants". Both entities are also subject to IAS 1: Quality Controls for Firms Engaged in Audit and Review of Financial Statements and Other Assurance Engagements and Related Services.



	Money Market Funds	Reverse Repo Notes	Other Investments (including digital tokens)	Secured Loans (none to affiliated entities	Corporate Bonds, Funds & Precious Metals	Cash & Bank Deposits	Treasury Bills	Commercial Paper and Certificates of Deposit	TOTAL
30/06/2021 Moore	0	1.000.662	2.054.626	2.517.140	4.830.821	6.282.757	15.279.529	30.807.654	62.773.190
30/09/2021 Moore	999.989	0	383.044	3.452.029	3.607.629	7.237.205	19.434.280	30.595.198	65.709.375
31/12/2021 Mha Cayman	3.000.084	0	5.023.389	4.142.957	3.628.506	4.187.005	34.527.886	24.165.815	78.675.643
31/03/2022 Mha Cayman	6.798.151	105.331	4.959.634	3.149.732	3.729.530	4.100.486	39.485.377	20.096.580	82.424.821
30/06/2022 BDO	6.810.253	2.992.016	5.551.836	4.494.373	3.486.897	5.418.232	29.253.585	8.402.427	66.409.619
30/09/2022 BDO	7.101.936	3.023.814	2.617.268	6.135.946	3.194.370	6.077.722	39.860.580	49.982	68.061.618
30/12/2022 BDO	7.372.926	3.046.094	2.685.786	5.852.823	3.444.098	5.318.312	39.324.109	0	67.044.148

Figure 3. Composition of Tether Ltd's assets as validated in audit reports

Source: based on data extracted from Tether audits (2023).

This implies that the engagement partner is responsible for the overall quality of the audit.

MHA CAYMAN and BDO's audits have a scope of reporting and applicable regulatory framework that are similar to those of the Moore Global reports. In this regard, the same limitations of scope are also found; the engagement only covers the period from 30 June to 30 September 2022, with no review of previous or subsequent events that might allow for the identification of significant capital transfers or unusual events. This generates the possibility that Tether repeats the strategy it used in the audits conducted by Friedman LP. On the other hand, one of the most striking assessments we have made is a comparison of the data issued in the reserves report reviewed by BDO and all previous reports, in order to detect significant variations between the different periods. Although the materiality and, therefore, the significance criterion applied is unknown, it is noted that no mention is made of any of these changes, even though Tether's reserves were reduced by approximately 25% in less than three months, from USD 82.4 billion on 31 March 2022 to USD 66.4 billion on 30 June 2022. This change, irrespective of the criterion chosen, is significant given the magnitude of the numbers discussed. The reduction in Tether's reserves is mainly explained by a decline in their short-term notes and certificates of deposit, as shown in Figure 3. This component, and their

treasury bills, represent the two largest assets on the balance sheet, and the ones that fluctuate the most. The remaining components are fairly balanced and far smaller the two mentioned above. This is shown in Figure 4, which presents the average composition of the Tether issuers' assets.

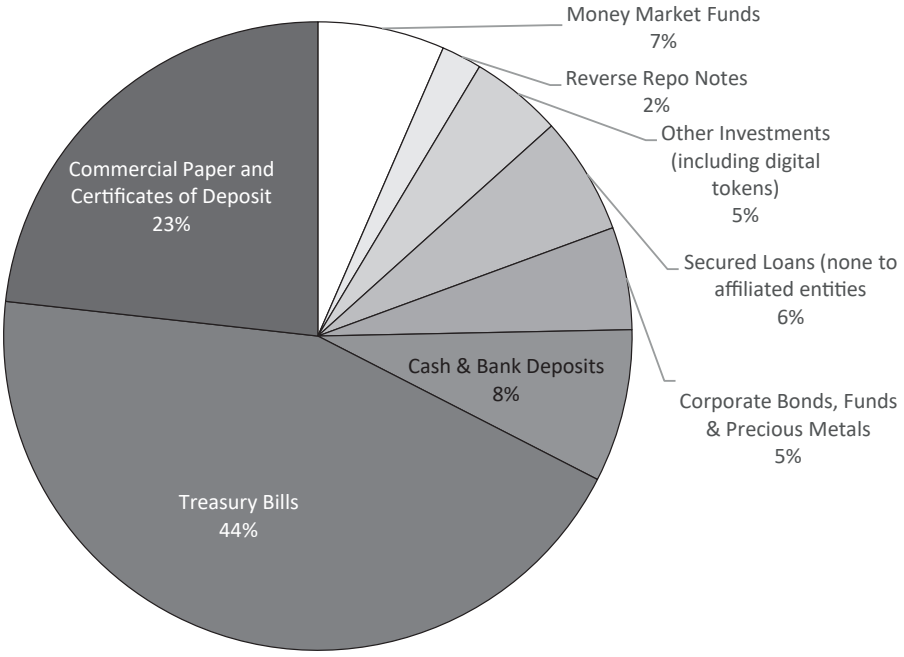


Figure 4. Historical average asset composition of Tether Ltd. as validated in its audit reports

Source: based on data extracted from Tether's audits (2023).

These assets are highly liquid and can reasonably ensure users' backing, reducing the risks associated with these digital assets. However, the risk of treasury bonds is significantly higher than that of other assets because of the materiality involved and because interest rate hikes by the Federal Reserve reduced the price of these financial assets. In the most recent period, the treasury bonds in Tether's portfolio represent more than 50% of its balance sheet. In the event of a massive withdrawal of deposits, the bank would be forced to realize these investments at a loss due to rising interest rates, which would pose a high solvency risk for the bank.

These ratios, with their optimum levels defined, act as beacons to guide prudent financial decision making. The liquidity ratio parameter provides a clear view of whether the company has sufficient liquid assets to cover its short-term financial obligations. A level between 1.5 and 2 indicates a healthy financial position, providing the company with the necessary peace of mind to

Table 3. Measurement of Tether's backing in terms of liquidity, solvency, and debt ratios

Ratio	Liquidity ratio	Cash ratio	Solvency ratio	Debt quality ratio
Formula	current assets/current liabilities	cash/ current liabilities	total assets/ total liabilities	current liabilities/total liabilities
optimum level	1.5-2	0.8-1.0	1.5-2	0-0.5
Auditing 15 September 2017	1.001	1.001	1.001	1.000
Auditing 1 June 2018	1.003	1.003	1.003	1.000
Auditing 28 February 2021	1.005	1.005	1.003	1.001
Auditing 31 March 2021	1.004	1.004	1.004	1.000
Auditing 30 June 2021	1.003	1.003	1.002	1.000
Auditing 30 September 2021	1.002	1.002	1.002	1.000
Auditing 31 December 2021	1.002	1.002	1.002	1.001
Auditing 31 March 2022	1.003	1.003	1.002	1.001
Auditing 30 June 2022	1.003	1.003	1.003	1.000
Auditing 30 September 2022	1.001	1.001	1.004	1.000
Auditing 31 December 2022	1.014	1.014	1.015	1.000
Auditing 31 March 2023	1.026	1.026	1.031	0.996
Auditing 30 June 2023	1.039	1.039	1.040	1.000
Auditing 30 September 2023	1.011	1.011	1.039	1.000

Source: based on data extracted from Tether's audits (2023).

face immediate commitments to solvency (Lessambo, 2018, 2022). The cash ratio, which focuses on the availability of liquid funds to cover current liabilities, should be maintained between 80% and 120% to ensure an adequate cash reserve to provide financial guarantees in times of need (Lessambo, 2018, 2022). The solvency ratio examines the proportion of total assets and total liabilities. A range between 1.5 and 2 reflects an adequate balance between debt and equity, reducing the risk of insolvency and strengthening the company's long-term financial position (Husna & Satria, 2019; Lin et al., 2011; Xu et al., 2014). Finally, the debt quality ratio evaluates the proportion of short-term debt in relation to the company's total debt. A range between 0 and 0.5 indicates a balanced debt structure, reducing the risk of the company facing refinancing problems and ensuring more stable financial management (Husna & Satria, 2019; Xu et al., 2014).

Tether's liquidity ratio has remained consistently below the optimal range of 1.5 to 2 throughout the audited period. This persistent weakness suggests that Tether may have difficulty covering its short-term obligations with its liquid assets. Tether's cash ratio has remained consistently above the optimal range of 0.8 to 1.0 throughout the audited period, suggesting that Tether has a significant amount of cash relative to its short-term obligations, and thus a healthy ability to cover short-term obligations solely with cash. Tether's solvency ratio, based on the data provided, remains consistently below the optimal range of 1.5 to 2 in all audits. This may raise concerns about its ability to cover its long-term financial obligations. Tether's debt quality ratio has remained consistently above the acceptable range of 0 to 0.5 throughout the audit period, ranging from 0.996 to 1.001. Tether has had a relatively high ratio of current liabilities to its total liabilities. This suggests a lower quality of its debt.

Although the use of stablecoins is growing steadily (Włosik et al., 2022), stablecoin trading and use are not without risks (Echarte Fernández et al., 2022; Moura de Carvalho et al., 2022; Vučinić, 2020). These risks can be summarized into three categories: counterparty risks (Arner et al., 2020; Mikhaylov, 2023); centralization risks (Mikhaylov, 2023); and the risk of algorithm manipulations (Clements, 2021). These are risks that could be transmitted between the issuer, the operator, and the customer in the chain of relationships (Ferreira, 2021; Vučinić, 2020).

Users and companies that issue, hold, and operate stablecoins on their balance sheets can take several steps to mitigate risks. The first step is to ensure that the operator of the digital currency has sufficient backing (Baughman & Flemming, 2023). Another measure to reduce risk may be to increase the transparency of company balance sheets (Liao & Caramichael, 2022; Sobański et al., 2023). While stablecoins face regulatory hurdles arising from banking, financial monitoring, and security laws (Clark et al., 2020), in some cases because these regulations do not apply to stablecoins, other authors indicate that nine of the eleven fiat-backed stablecoins meet the objective requirements for cash equivalents and could be reported as such under the IFRSs (Hampl & Gyönyörová, 2021; Muhetaer, 2022).

Previous studies have addressed the accounting and characteristics of the mathematical modelling of stablecoins (Tarasova et al., 2020); others have analysed audited stablecoin companies to demonstrate the challenges in establishing their accounting (Moura de Carvalho et al., 2022; Smith, 2023). There are also studies that propose general principles that can be followed when performing a tokenomic audit (Kampakis, 2022), and others that defend the need for the existence of smart contract auditors to avoid situations such as TerraUSD (Bhambhwani & Huang, 2023). Our research seeks to close an existing gap in the scientific literature on the accounting and auditing of stablecoins. Using Tether as a case study, we analysed the issuance and backing of

the stablecoin, studying Tether reserves through third-party audit reports. Not only that, but we also performed a measurement of Tether's backing through its liquidity, solvency, and debt ratios.

As a limitation of this research, it should be noted that only one type of stablecoin (trust-asset-backed) has been considered. As a future line of research, we propose extending our analysis to other stablecoins with high market capitalization.

Conclusions

This research approached stablecoin accounting and auditing regulations analytically, from an economic regulatory perspective. To do so, it analysed the issuance and backing of Tether, the different phases of its accounting and auditing, and the controls and regulations in place for the end consumer or business customer. As becomes clear throughout this article, despite the various efforts made by accounting regulators, there is still a need for more precise and specific regulations that are applicable to stablecoins. Current accounting and auditing regulations mitigate, but do not prevent, the transmission of risks.

From our research, we conclude that Tether has made great efforts to increase the transparency of its reserves. In addition, its assets are highly liquid, which gives us reasonable confidence that it will have sufficient backing to cover its USDT issues in dollars. However, it also has a high number of treasury bonds, which, in a situation of a loss of confidence and possible deposit withdrawals, may lead to a discount sale of these securities, especially in a rising interest rate environment. Taken together, these findings show that while Tether has maintained a healthy ability to cover its short-term obligations with cash, it faces challenges related to its liquidity, solvency, and debt levels. In addition, the quality of its debt is also an aspect that should be considered as part of its overall financial health, which is reflected in our ratio analysis.

Tether's liquidity ratio has been consistently below the optimal range of 1.5 to 2. This suggests that the company may face difficulties covering its short-term obligations with its liquid assets. Nevertheless, Tether's cash ratio has consistently remained above the optimal range of 0.8 to 1.0, which indicates that Tether has a significant amount of cash relative to its short-term obligations, reflecting a healthy ability to cover these obligations solely with cash. Tether's solvency ratio has consistently remained below the optimal range of 1.5 to 2 in all audits, which raises some concerns about its ability to cover financial obligations. In turn, Tether's debt quality ratio has been consistently above the acceptable range of 0 to 0.5, suggesting an elevated risk.

It is also concluded that valuation by independent auditors is essential in a market that generates a lot of uncertainty among investors. For this reason, an external auditor must certify the composition of assets of these entities. It is also necessary to develop more specific and updated regulations for stablecoins and, consequently, unify and strengthen accounting and auditing regulations to generate more confidence among stablecoin users. As a limitation of this research, we point out that our study only focuses on Tether, the stablecoin with the largest market capitalization. Thus, the lack of an analysis of other stablecoins with high market capitalization suggests the need for future research for a more complete understanding of the accounting and auditing challenges in the stablecoin ecosystem.

Acknowledgements: We wish to express our thanks to Universidad Católica de Ávila and Institución Gran Duque de Alba for their support.

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sciendo Economics and Business Review https://www.ebr.edu.pl Vol. 10 (1), 2024: 81–100 https://doi.org/10.18559/ebr.2024.1.1019

Determinants of consumer adoption of biometric technologies in mobile financial applications

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Abstract

This study aims to identify what determines the use of biometric technologies in the financial applications of banks and FinTechs. The analysis uses data from a survey of 1,000 adult Polish residents. The estimated logit model indicates that the probability of using biometric solutions decreases with age and increases with the level of education and technological sophistication related to personal innovativeness, experience with biometric technology and the use of digital technology in both financial and non-financial areas. The work identifies the COVID-19 pandemic as a factor accelerating the adoption of biometric solutions and fostering awareness of the threat of digital technologies invading respondents' privacy. The study demonstrates the positive impact of trust that phone manufacturers use to ensure the security of stored funds and data processing on the acceptance of biometric solutions in financial services. This relationship underpins the recommendation to financial institutions in the field of promoting biometric technologies.

Keywords

- biometric technologies
- mobile payments
- mobile banking
- personal finance apps
- technology acceptance
- FinTech
- COVID-19 pandemic

JEL codes: D14, G21, O33

Article received 27 October 2023, accepted 3 March 2024.

Funding: this work was supported by the National Science Centre, Poland under Grant No. 2017/26/E/HS4/00858 and the Nicolaus Copernicus University in Toruń "Excellence Initiative—Research University" programme for years 2020–2026.

Suggested citation: Piotrowska, A. I. (2024). Determinants of consumer adoption of biometric technologies in mobile financial applications. *Economics and Business Review*, *10*(1), 81–100. https://doi.org/10.18559/ebr.2024.1.1019

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Introduction

Biometric technologies make use of each person's unique physiological and behavioural characteristics which can be measured and used for automatic identification purposes. These technologies are very diverse due to the different characteristics to be measured. There are solutions on the market based on fingerprint, vein pattern, facial construction, iris, retina, hand geometry, voice, gait, or signature (handwriting) (Tassabehji & Kamala, 2012), among others. Since biometric authentication methods provide a high level of convenience and security they are being increasingly used for different types of applications. They have also found their place in a number of financial processes that require customer identity verification, such as logging into a mobile application of a bank or another financial institution, authorising ATM and mobile device operations and signature-based branch service access (Agidi, 2018; Byun & Byun, 2013). In addition, biometric technologies meet the most important criteria for verification techniques in FinTech industries showing great potential for growth in this area (J. S. Wang, 2023).

However, the wide range of applications of biometric technologies in the financial sector does not translate into their expected mass popularisation (Piotrowska et al., 2017; Trawnih et al., 2023). Little has changed in this respect even after payment service providers were made to use strong customer authentication. Although technological advances made in image, voice and motion analysis software, as well as the increased availability of mobile devices equipped with cameras, a microphone, or a fingerprint reader have fostered the implementation of various types of biometric solutions in mobile applications they have not resulted in a significant increase in the use of biometric solutions in the financial area (Mastercard, 2018). In fact it could be argued that the field of biometric technology has not been sufficiently involved in the digital transformation of the financial world that is taking place before our eyes. On the other hand biometric technologies have been present long enough for these solutions to find their supporters. It is, therefore, useful to know their characteristics, behaviours and preferences. Additionally, it is also worth finding out whether an extreme phenomenon such as the COVID-19 pandemic has affected the use of biometrics in financial services. The focus on the indicated factors also results from research gaps diagnosed during literature studies. It turns out that research on the accep-

tance of biometric technologies uses a narrow range of socio-demographic variables which limits the understanding of the importance of consumers' technological advancement in the area of digital finance, with a particular focus on mobile payments. There is also little work that examines the impact of the pandemic on the acceptance of biometric technologies. Gaining this knowledge may allow financial institutions to take more effective steps to promote biometric technologies, especially in mobile banking. Indeed this area appears to be particularly attractive for the widespread use of the technologies analysed due to the provision of high levels of security and convenience (Agidi, 2018).

The aim of this study is to identify what determines the use of biometric technologies in the financial applications of banks and FinTech entities. The study focuses on the three most popular technologies used in this area namely fingerprint, facial and voice biometrics. The paper poses the following research questions:

RQ1: Does the technological sophistication of consumers influence the adoption of biometric solutions in financial applications?

RQ2: What impact has the COVID-19 pandemic had on the acceptance of biometric technologies in financial applications?

The paper uses the results of a survey conducted on a sample of 1,000 adult inhabitants of Poland representative in terms of age, gender and place of residence. In the logit model analysis socio-demographic and economic variables were employed relating to consumers' digital sophistication and addressing the issue of trust in institutions responsible for processing personal data. The contribution of this paper is manifested by a broad consideration of consumers' experience in the use of digital technologies, mainly in the area of finance. In addition an important aspect of the paper is the analysis of the issue of trust with banks and mobile device providers as well as its consideration of the impact of the COVID-19 pandemic on the acceptance of biometric technologies in financial applications.

The paper is organised as follows: Section 1 contains the literature review focusing on the application and acceptance factors of biometric technologies in finance. Section 2 describes the research material used and the research methodology. Section 3 presents the results of the study indicating the main factors for the acceptance of biometric technologies. The last Section of the paper concludes with key findings from the research and contains managerial implications.

1. Literature review

1.1. Main areas of research into biometric technologies

The use of biometric technologies in processes requiring reliable user authentication is often the subject of studies. Many of the publications are technical in nature and focus on presenting the characteristics of individual biometric solutions. Authentication technology based on fingerprints, facial recognition (Rio et al., 2016; Tovarek et al., 2018; Yu et al., 2018), hand vein patterns, voice scanning and iris scanning is widely presented in the literature (Nguyen et al., 2018; Unar et al., 2014). There are also publications related to biometric technologies using gait (Y. Zhang et al., 2019), touchstroke authentication (Alpar, 2018), keystroke recognition (Fouad et al., 2016), or tongue print (Jeddy et al., 2017; D. Zhang et al., 2010). Some researchers indicate that it is a promising direction for development to explore other characteristics and features such as the periocular region (area around the eye) which can be used when the subject is uncooperative, either as a stand-alone method or in support of face and iris biometrics (Kumari & Seeja, 2022). New biometric authentication technologies using some bio signals that are generally used in medicine (K. Wang, Yang et al., 2020) are also being extensively developed. Examples include research on brain biometrics using electroencephalograms (EEG) (M. Wang et al., 2020).

Some researchers point to the advantages of using several technologies together—biometric fusion—to analyse one (unimodal biometrics) or multiple (multimodal biometrics) biometric traits in the authentication of individuals. This helps avoid several limitations in terms of accuracy of biometric identification occurring when a single biometric trait is analysed with one technology. These limitations are: universality, understood as the ubiquity of the trait among individuals, distinctiveness in the biometric pattern among the population, public acceptability of the technology in everyday life (Lumini & Nanni, 2017; Singh et al., 2019).

In addition to the technical aspect issues related to the collection and disposal of biometric templates analysed from a regulatory, ethical (Amankwaa & McCartney, 2020; Baichoo et al., 2018; Kindt, 2018; Sanchez-Reillo et al., 2019; Štitilis & Laurinaitis, 2017) and security (Gomez-Barrero & Galbally, 2020; Sadhya & Singh, 2017; Sun et al., 2023) perspective are widely addressed in the literature. An important aspect of the analyses is the issue of user privacy and user trust in entities storing biometric patterns (Byun & Byun, 2013; Carpenter et al., 2018). The analysis of biometrics implementation cases indicates privacy threats even in situations where government institutions are responsible for implementing the solutions (Ganesh, 2018).

1.2. Acceptance factors of biometric technologies

The theoretical basis for many studies on the acceptance of biometric technologies, similarly the adoption of other digital solutions is the technology acceptance model (TAM) proposed by Davis (1989). Extended TAM is used to analyse the adoption of different types of biometric technologies that are used in areas such as the hotel, restaurant, entertainment, financial and travel industries, as well as self-service machines, smartphones and FinTech applications (Dang et al., 2022; Garrido et al., 2024; J. H. Kim et al., 2023; J. S. Kim et al., 2008; Morosan, 2011, 2012; Nakisa, Ansarizadeh, Oommen, & Kumar, 2023; Nakisa, Ansarizadeh, Oommen, & Shrestha, 2023; Norfolk & O'Regan, 2021; Soto-Beltrán et al., 2022; Wahid & Pratama, 2022; J. S. Wang, 2021, 2023). Other research methods that replace or complement TAM include: the stimulus-organism-response (S-O-R) model (Liébana-Cabanillas et al., 2022) and the novelty hybrid multiple-criteria decision-making (MCDM) approach (J. S. Wang, 2023).

The results of several studies indicate that perceived usefulness and perceived ease of use (Soh et al., 2010) positively influence consumers' attitudes towards using biometric payments (Dang et al., 2022; Morosan, 2011). These factors are often indicated in research results on the acceptance of innovations in the payment services market (Polasik et al., 2012; Raj et al., 2023). In addition to those already indicated important factors for the acceptance of biometric technologies in online applications are: perceived credibility (Soh et al., 2010), perceived privacy, performance expectancy, social influence and familiarity (experience) with technology (Hino, 2015).

The literature on the acceptance of biometric technologies postulates a combined analysis of characteristics of innovations as perceived by consumers and consumers' personal factors (Miltgen et al., 2013). The results of the study by M. Kim et al. (2019) indicate that consumers with positive attitudes towards technologically advanced products or services were more likely to prefer biometric payment systems. Similarly consumers with higher personal innovativeness (Dang et al., 2022; Miltgen et al., 2013; Morosan, 2011) and self-efficacy (Al-Janahi et al., 2021; Soh et al., 2010) are more likely to accept biometric technologies.

Breward et al. (2017) note that popular models of technology deployment focus only on the positive utility associated with the use of technology. The authors point out that research into the acceptance of biometric technologies should also take into account possible concerns that can affect consumers' attitudes. Indeed biometrics is seen as a controversial information technology that can both benefit and harm the well-being of the user. The type and extent of information that this technology exploits breeds concerns in actual and potential users as to its use (Breward et al., 2017). The study by Prince and

Wallsten (2022) shows that people, regardless of their country of origin, attach the most value to the privacy of financial information (bank balance) and biometric information (fingerprint). In addition the authors pointed out that when it comes to smartphones the privacy hierarchy of different types of data is consistent across the globe—people value their biometric data much more than location data or receiving advertisements. This is because the personal data the system handles may be misused. Byun and Byun (2013) noticed that users worried about the risks related to information privacy when using ATMs with a fingerprint reader. The results of Miltgen et al. (2013) shows that consumers who have greater privacy concerns will perceive acceptance of a biometric system as riskier. The results of other studies confirm that perceived risk negatively impacts consumer attitudes towards using biometric payments (Dang et al., 2022), while perceived security (Morosan, 2011; Mróz-Gorgoń et al., 2022) significantly affects attitudes towards using biometric systems. In the case of research on the acceptance of biometric technologies in payment services security is analysed in comparison to existing authentication methods. Ogbanufe and Kim (2018) indicate that consumers treat biometric authentication as more secure than credit card only (or credit card + PIN) authentication.

Other researchers also analyse biometric technology in comparison to the traditional, well-known and frequently used solutions with which it competes. J. S. Wang (2023) compares biometric verification techniques with the three most commonly used verification techniques by consumers in FinTech industries such as password, NFC and QR code. The results show that biometrics has the greatest growth potential in FinTech applications due to perceived usefulness of the solution and the perception that it is secure and enhances privacy compared to other solutions. Similarly J. S. Wang (2021) emphasises the importance of perceived privacy and perceived trust in user acceptance of biometric identification in FinTech applications. In the case of the use of biometrics in online banking, Tassabehji and Kamala (2012) determine that although users have a favourable attitude towards the use of biometrics in online banking bank managers need to pay special attention to system security and privacy issues when implementing biometrics (Al-Janahi et al., 2021). The results of Soto-Beltrán et al. (2022) also highlight the importance of security issues indicating that the propensity to accept biometrics in banking increases if, in addition to its usefulness, users have a positive opinion of the ability to identify them securely in the system and the secure execution of transactions.

The literature review carried out has shown considerable academic interest in the application of biometric solutions in the financial sector. However, previous research on the acceptance of biometrics has focused on the technological solution and consumer expectations regarding its functionality. This paper presents a different approach to the issue of selecting acceptance factors and emphasises the importance of technological advancement in the area of mobile payments.

2. Material and methods

The source data used to estimate the logit model were obtained in a survey conducted using the CATI (Computer Assisted Telephone Interview) method by a professional research agency in July–August 2020 in Poland on a nationwide sample of 1,000 adult consumers representative in terms of age, gender and place of residence. Due to the wide access of Polish citizens to telephones (of all types), this method allowed for representative results (Kagerbauer et al., 2013) and was also feasible during the pandemic period. The survey was anonymous. Participants were informed of the purpose of the survey and were able to opt out at any time. As the study was non-interventional and non-clinical the Research Ethics Committee of the Faculty of Economic Sciences and Management of the Nicolaus Copernicus University in Toruń considered ethical approval to be unnecessary in this case.

A logit model was employed in order to identify the determinants of the use of biometric technologies in banking and FinTech financial applications. The model takes the following form:

$$logit(p_i) = Z_i = x_i'\beta = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_n X_{ni} \quad (1)$$

where $logit(p_i)$ stands for $\ln\frac{p_i}{1-p_i}$ (Maddala, 1992). The parameters β_0, β_1, ..., β_n which are elements of the vector were estimated using the maximum likelihood method.

The logit model is used to study economic phenomena when qualitative variables are available (Cramer, 2003; Dhrymes, 2017; Kufel, 2011). It serves to determine what factors, and in what way, influence the analysed phenomenon expressed as numbers in a dependent variable (Kochaniak & Ulman, 2020). The study used the a posteriori method sequentially eliminating non-significant variables (Kufel, 2011).

The dichotomous dependent variable denotes the respondent's use of biometric technologies, more specifically fingerprint biometrics, facial biometrics and voice biometrics to log in to the bank's or FinTech's financial application. At the time of the survey these were the most popular biometric technologies used in mobile applications (J. S. Wang, 2021).

A description of the variables used in the model is presented in Table 1.

In addition to the basic socio-demographic variables (Gender, Age, Residence, Education), the model included variables related to the characteristics of the technology (Ease of use), security (Biometrics more secure than PIN), experience in using biometric technology (Biometrics experience) as well as social influence (Social influence) and attitudes towards new technologies (Personal innovativeness) (Table 1). The study also took into account

Table 1. Description of the variables used in the logit model

Variable	Variable description
Y	the respondent logs in with a fingerprint, voice, or facial recognition (selfie) on the bank's or FinTech's financial app: 1: yes; 0: no
Gender	gender: 1: female; 0: male
Age	Age of the respondent in ranges: 1: 18–24; 2: 25–34; 3: 35–44; 4: 45–54; 5: 55–64; 6: 65+
Residence	size of the respondent's place of residence: ordinal variable with 6 settlement size categories: 1: village; 2: village–suburban area; 3: city with population up to 20,000; 4: city with population up to 100,000; 5: city with population up to 500,000; 6: city with population over 500,000
Education	educational attainment of the respondent: 1: primary and lower secondary education; 2: basic vocational education; 3: general or technical secondary education; 4: bachelor's degree or incomplete master's degree; 5: master's or higher education
Personal innovativeness	the respondent likes to test new technologies: 1: definitely not; 2: probably not; 3: I don't know / it is difficult to say; 4: probably yes; 5: definitely yes
Self-service devices	the respondent use self-service devices: 1: yes; 0: no
Instant messaging services	the respondent uses instant messaging services such as WhatsApp and/or Skype: 1: yes; 0: no
Smartphone bills	the respondent pays bills by transfer from a smartphone using the bank's or FinTech's financial app: 1: yes; 0: no
BLIK-online shopping	the respondent pays with smartphone using BLIK for online purchases: 1: yes; 0: no
Biometrics experience	the respondent unlocks smartphone with fingerprint: 1: yes; 0: no
Ease of use	the respondent believes that approving fingerprint payments on his/her smartphone would be easy to master: 1: definitely not; 2: probably not; 3: I don't know / it is difficult to say; 4: probably yes; 5: definitely yes
Biometrics more secure than PIN	the respondent believes that a fingerprint is more secure than using a PIN: 1: definitely not; 2: probably not; 3: I don't know / it is difficult to say; 4: probably yes; 5: definitely yes
PIN preference	the respondent prefers to approve payments with a PIN rather than a fingerprint as the PIN can be changed: 1: definitely not; 2: probably not; 3: I don't know / it is difficult to say; 4: probably yes; 5: definitely yes
Social influence	the respondent uses the new solution if it is frequently used by their friends: 1: definitely not; 2: probably not; 3: I don't know / it is difficult to say; 4: probably yes; 5: definitely yes

Variable	Variable description
Bank trust	the respondent trusts banks to ensure the security of funds and financial and personal data: 1: definitely not; 2: probably not; 3: I don't know / it is difficult to say; 4: probably yes; 5: definitely yes
Smartphone trust	the respondent trusts smartphone manufacturers to ensure the security of funds and financial and personal data: 1: definitely not; 2: probably not; 3: I don't know / it is difficult to say; 4: probably yes; 5: definitely yes
Contactless card payments	as compared to before the COVID-19 pandemic, during the pandemic the respondent uses contactless card payments at retail and service outlets by bringing the card close to the terminal: 1: much less frequently, 2: probably less frequently, 3: as frequently as before the pandemic, 4: probably more frequently, 5: much more frequently
Pandemic surveillance	the COVID-19 pandemic has made the respondent fear wider surveillance of their finances and lifestyle: 1: definitely not; 2: probably not; 3: I don't know / it is difficult to say; 4: probably yes; 5: definitely yes
Pandemic biometrics	the COVID-19 pandemic has made the respondent more likely to start logging in with a fingerprint on a bank's or FinTech's financial app: 1: definitely not; 2: probably not; 3: I don't know / it is difficult to say; 4: probably yes; 5: definitely yes

Source: own elaboration.

the technological sophistication of the respondents in the area of making cashless payments by using variables related to making mobile payments to pay for bills (Smartphone bills) and using an innovative payment solution specific to the Polish market such as BLIK (BLIK-online shopping). Since consumers' payment habits are difficult to change (Liu et al., 2019; van der Cruijsen et al., 2017) the study also took into account the advantages of traditional PIN authentication (PIN preferences). Taking into consideration that a biometric system inherently requires the use of personal data and the transfer of the customer's biometric template to an external entity the model also includes variables related to trust in the entities holding the users' data. The study distinguishes between trust in banks (Bank trust) and trust in the manufacturers of smartphones on which financial applications are installed (Smartphone trust).

An important aspect of the paper is to determine the impact of the COVID-19 pandemic on the acceptance of biometric technologies. The pandemic has disrupted the current pattern of reacting to external stimuli and forced the adoption of non-standard behaviours. It has also introduced new factors in the process of motivating consumers to use technology (Huterska et al., 2021). The literature indicates that societies have made significant progress in the use of digital technologies during the pandemic period (Piotrowski, 2022). It reduced the risk of disease and facilitated functioning with social distance rules in place. Therefore the study introduces variables that relate to the use of instant messaging services (Instant messaging services), self-service

devices (Self-service devices) and contactless card payments (Contactless card payments). While these solutions were known before the pandemic they began to be used on a much larger scale and in unprecedented contexts during the pandemic. Moreover the study took into account the propensity to use biometric technologies in mobile financial applications due to the pandemic (Pandemic biometrics). The COVID-19 pandemic also highlighted new opportunities for states to control citizens through the use of tracking applications or other surveillance systems to protect citizens from the spread of the virus (Wnuk et al., 2020). Therefore the study also analyses the significance of the impact of the pandemic on perceptions of the negative effects of the wider use of digital technologies in everyday life on the use of biometric solutions in financial mobile applications (Pandemic surveillance).

3. Results and discussion

The results of the estimated logit model are presented in Table 2. Among the socio-demographic variables analysed in the study the respondent's age and level of education had a significant impact on the likelihood of using biometric technologies in financial applications, with the former having a negative impact and the latter a positive one. The validity of these variables is often demonstrated in research on the acceptance of ICT (Jünger & Mietzner, 2020) and cashless payments, including during pandemics (Huterska et al., 2021). This is related to the fact that young and well-educated people are characterised by a greater openness to technological change making it easier and quicker for them to accept innovations.

A positive influence on the likelihood of using biometric technologies in mobile financial applications was also exerted by variables related to declared personal innovativeness and actual use of digital technologies. The results presented in Table 2 indicate that the use of new technologies in the financial area when making transfers using financial apps and making payments for purchases using BLIK[2] have a strong positive impact on the likelihood of using biometric technologies in mobile financial apps of banks and FinTechs. In addition experience in the use of digital technologies in the non-financial sphere manifested by the use of self-service devices (the benefits of which were particularly evident during the COVID-19 pandemic) also significantly increased the likelihood of using biometrics in financial applications.

[2] BLIK — a payment system using a six-digit code introduced in Poland in 2015 mainly used for m-commerce and e-commerce payments. Since 2021 the system has allowed contactless payments at retail and service outlets. BLIK becomes a very popular way of making payments in e-commerce in Poland with 15 million users at the end of 2023.

Table 2. The results of the estimated logit model before and after a posteriori elimination

	Before a posteriori elimination	After a posteriori elimination
const	−11.1340*** (1.90070)	−10.6784*** (1.61154)
Gender	−0.248038 (0.264204)	
Age	−0.196603** (0.0837188)	−0.167675** (0.0799834)
Residence	0.0883747 (0.0763325)	
Education	0.195566** (0.0975747)	0.222830** (0.0917585)
Personal innovativeness	0.247221* (0.146145)	0.298000** 0.139205
Self-service devices	0.754212** (0.315172)	0.786122** 0.308965
Instant messaging services	0.889260 (0.715354)	
Smartphone bills	0.926061*** (0.280016)	0.971559*** (0.276620)
BLIK-online shopping	1.66120*** (0.292903)	1.60738*** (0.285238)
Biometrics experience	2.61589*** (0.297621)	2.53270*** (0.284827)
Ease of use	0.715180*** (0.254884)	0.783458*** (0.250587)
Biometrics more secure than PIN	0.225744* (0.130605)	
PIN preference	−0.438032*** (0.112333)	−0.509387*** (0.103304)
Social influence	−0.0714988 (0.119877)	
Bank trust	0.0560672 (0.162244)	
Smartphone trust	0.216271 (0.148267)	0.247991* (0.137960)
Contactless card payments	−0.226803 (0.158147)	
Pandemic surveillance	0.240730** (0.0954426)	0.233801** (0.0908020)
Pandemic biometrics	0.372088*** (0.0980052)	0.380146*** (0.0938546)
McFadden *R*-squared	0.551536	0.542270
Number of cases 'correctly predicted'	921 (92.1%)	924 (92.4%)

Notes: The table shows coefficients and standard errors (in parentheses).
*** The statistically significant variable at the level of 1%; ** at the level of 5%; * at the level of 10%.

Source: own calculation, *n* = 1000.

Another group of variables that proved statistically significant relates directly to the use of biometric technologies. The ease of use of the technological solution lies at the heart of the TAM design. The study indicated that the belief that the technology is easy to master positively influenced the likelihood of using the bank's or FinTech's financial app thus confirming the findings of previous studies. In addition, the use of biometrics in financial applications is positively influenced by the experience of using phone unlocking through the use of a fingerprint. Therefore, the results confirm that, as shown in the literature, user familiarity with a technology is an important factor in its adoption (Bauer et al., 2005; Hino, 2015).

The study contrasted the use of PIN and fingerprint. Although consumers generally consider biometric authentication more secure than a payment card with PIN authentication (Ogbanufe & Kim, 2018) the study results indicate that respondents' belief in the superiority of PIN over biometrics due to the ability to change it reduces the likelihood of using biometric technologies in financial applications. Moreover, this factor has a stronger impact on the use of biometrics than the belief in the security advantages of biometrics authentication over PIN authentication. The study results therefore highlight the controversies raised in the literature regarding immutable biometric patterns which can be considered as both advantages and disadvantages of this technology (Breward et al., 2017). In this context the results of model estimation are very valuable as they show that trust in smartphone manufacturers is an important factor positively influencing the likelihood of using biometrics in mobile financial applications. This trust relates to ensuring the security of users' personal and financial data. The use of applications from different providers results in a lot of consumer data being stored on smartphones while the use of biometric solutions on a smartphone is linked to the transmission of an individual and immutable biometric template. Respondents' belief that the manufacturers of these devices have adopted solutions to ensure the security of funds and personal data increases the likelihood of using biometric technologies in mobile financial applications of banks and FinTechs. The study also found that trust in banks to ensure the security of funds and financial data does not affect the likelihood of using biometrics in financial applications. This may be due to the fact that the dependent variable was related to financial applications provided by both banks and FinTechs. It may also be indicative of respondents' knowledge that the biometric template is stored on the mobile device.

The last variables found to be statistically significant relate to the impact of the COVID-19 pandemic. With two variables the impact is positive, i.e. leading to an increased likelihood of using biometric solutions in mobile financial applications. The first one expresses respondents' belief that, influenced by the pandemic, they have become more likely to start logging in with their fingerprint on a bank's or FinTech's financial app. The second variable indica-

tes that the pandemic has contributed to increased concerns about greater surveillance of citizens' personal finances and lifestyles. The relevance of both variables may be indicative of respondents' high level of knowledge of how digital technologies work, including the risks involved, and their belief that the choice of a biometric solution best meets their expectations particularly in the area of privacy protection.

Although the social influence of family members and friends became even more pronounced during the pandemic in terms of individual decision-making regarding mobile payments (Sleiman et al., 2023; Zhao & Bacao, 2021), the estimation results indicate that this factor did not significantly affect the likelihood of using biometric technologies in financial applications of banks and FinTechs. This may be due to the fact that biometric technology, unlike cashless payments, has not been widely recommended in the context of reducing the risk of contracting the virus. In addition, to start using biometric technologies a person has to transfer an immutable biometric template so the decision to do so becomes more individual and requires convincing each user to trust the entities holding the personal data.

The results of the estimated logit model further indicate that the increase in the use of contactless payment cards at retail and service outlets did not affect the likelihood of using biometric technologies in the financial applications of banks and FinTechs. Indeed for some respondents this increase may have been due to a reduction in the use of cash for fear of contracting the SARS-CoV-2 virus. Contactless cards payments do not require touching the terminal. In addition the use of contactless payment cards requires much less technological skill than the use of biometric technologies in financial applications.

Conclusions

The time of the COVID-19 pandemic saw an increase in the use of digital technologies which began to be perceived as useful and safe by many societies. Pandemic factors also impacted the use of biometric technologies in mobile financial applications provided by banks and FinTech entities. The stated propensity to use biometric technologies in mobile financial applications and the reluctance to use a PIN has created an opportunity for a greater use of biometrics in finance. However, during the pandemic biometric technologies analysed in the paper had strong competition in the form of contactless payments. The use of contactless technology was a natural consumer response to the threat of contracting the virus during the payment process. Importantly its use required no additional effort on the part of consumers as almost all payment cards in Poland, as well as all payment terminals, were equipped

with contactless technology. It is also important to note that the act of making a contactless payment is very simple. In addition, the contactless transaction limit (CVM limit) was increased during the first months of the pandemic.

The results of the study indicate that biometric technologies in finance are perceived by consumers as solutions to protect against unauthorised intrusion by external parties. Biometric technologies provide security and protect privacy. The uniqueness of the biometric template is an asset in the context of ensuring security of access to data held in financial applications. However, financial institutions must make consumers aware of the disadvantages of such an arrangement. A given biometric pattern, unlike a password or PIN, cannot be changed. Moreover, the pattern is closely linked to a specific individual, which raises privacy challenges.

The study results have implications in terms of communication with consumers for companies providing mobile financial services planning to implement biometric technologies. These entities have received some evidence that the people more likely to use their services are young, well-educated and actively using new mobile technologies. Moreover, the acquired technological experience makes this group of consumers highly aware of the negative consequences of the increasing digitalization of many areas of life. Therefore, a very important piece of information for financial institutions is the importance of consumer trust towards smartphone manufacturers in ensuring the security of personal and financial data storage as is shown in the study. This fact should be exploited by banks and FinTechs in the implementation of payment innovations. In particular it is recommended that financial institutions emphasise the privacy protection of mobile device users in their communications to consumers. This aspect becomes particularly important in an increasingly anonymous digital world. It should be emphasised that biometric patterns are stored only on the mobile device and are not shared with any entities. This is particularly relevant for FinTech managers whose business is mainly based on phone-based apps. In turn professionals involved in the design of financial services using biometric technologies should bear in mind that the ease of use of these solutions is one of the key elements of their acceptance by users. Services should meet users' expectations in this area as any negative experiences can quickly and effectively discourage consumers from using biometric technologies. The above findings have implications for financial entities which can be used both at the design stage of a biometric technology solution and at the implementation stage.

In the modern world consumers are increasingly aware of the importance of data and the impact of processing it. This is particularly true for sensitive data which also includes biometric data. It seems, therefore, that ensuring adequate privacy protection is becoming a pivotal factor for the development of biometrics. This area should therefore be the subject of further in-depth research. In order to eliminate the limitation of the study regarding the ana-

lysis of users from one country future research should target respondents from different countries with different legal and regulatory environments in terms of personal data protection.

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sciendo Economics and Business Review https://www.ebr.edu.pl Vol. 10 (1), 2024: 101–124 https://doi.org/10.18559/ebr.2024.1.1039

Central bank communication in unconventional times: Some evidence from a textual analysis of the National Bank of Poland communication during the COVID-crisis

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Abstract

The article analyses the communication of the National Bank of Poland (NBP) one year after the announcement of the crisis response package adopted after the outbreak of the COVID pandemic. It presents the perspective of a central bank that first entered unconventional monetary ground during the COVID-crisis. The analysis aims to answer the question of what message about monetary policy objectives may have been conveyed in communication with regard to possible interpretations of the response actions by economic agents. Misinterpretations of policy actions at the time, fuelled by the increased attention to inflation, could later contribute to higher inflation persistence. The article presents findings based on the innovative use of MAXQDA Pro 2022 solutions for textual analysis of central bank's communication. It points to three inconsistencies in the NBP's communication that could potentially lead to misinterpretation of the NBP's policy actions in response to the crisis and thus affect the formation of expectations.

Keywords

- Central bank communication
- textual analysis
- financial stability
- price stability
- monetary policy
- attention to inflation

JEL codes: E52, E58

Article received 10 November 2023, accepted 3 March 2024.

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Suggested citation: Voloshchenko-Holda, L., & Niedziółka, P. (2024). Central bank communication in unconventional times: Some evidence from a textual analysis of the National Bank of Poland communication during the COVID-crisis. *Economics and Business Review*, *10*(1), 101–124. https://doi.org/10.18559/ebr.2024.1.1039

Introduction

The COVID-crisis is associated with an unprecedented simultaneous easing of monetary and macroprudential policies in many countries. A year following the massive response of central banks to the outbreak of the pandemic, countries in many regions were confronted with a marked increase in inflation and short-term inflation expectations, leading to a significant tightening of monetary policy. A number of factors contributed to the rise in inflation, including the significant role of supply-side factors. However, the continued persistence of inflationary pressure raises concerns about whether central banks' unprecedented policy response to the COVID-crisis may have been excessive and whether communication played a sufficient role in explaining monetary policy actions to economic agents.

Traditionally, central banks have relied more on communicating with an expert audience and trying to influence their expectations. Recently, this approach has changed, partly as a result of the lessons learned from the COVID-crisis. The unprecedented nature and urgency of the latter brought central banks to the forefront of public debate. The demand-shock nature of the COVID-crisis may have drawn even more public attention to monetary policy actions than it did during the Global Financial Crisis (GFC), which was triggered in the financial system. In order to enhance the accountability of monetary policy and thus to better guide inflation expectations, it may be worth directing central bank communication towards a broader audience and explaining policy actions better. However, reaching the general public as well as improving the clarity of communication in order to avoid misinterpretation and unwanted reactions by economic agents seems to be quite a challenge (Blinder et al., 2022).

In contrast to the vast majority of studies on central bank communication in unconventional times, which focus on the experiences of the major central banks,[3] the article presents the perspective of a central bank that entered

[3] The title of this article is inspired by Coenen et al. (2017), which is part of the literature on central bank communication in unconventional times, focusing mainly on the experiences

unconventional monetary ground for the first time during the COVID-crisis and found itself in the spotlight with no experience of "unconventional communication". It examines the communication of the National Bank of Poland (NBP) one year after the announcement of the crisis response package adopted after the outbreak of the COVID pandemic in March 2020 (hereinafter "COVID-communication"). It aims to answer the question of what message about monetary policy objectives it might have conveyed in terms of how the NBP's COVID response actions might have been interpreted by economic agents. Misinterpretations of policy actions by economic agents at the time, fuelled by their increased attention to inflation, could have later contributed to the persistence of higher inflation.

The article attempts to link the NBP's COVID-communication, which has traditionally been addressed to an expert audience, with its possible impact on the interpretation of monetary actions by economic agents. In this context, the choice of the NBP for the study was motivated by the presumed greater attention given to inflation by economic agents in Poland. The article proposes some assumptions about the transmission of the NBP's COVID-communication to the broader public, supported by the results of the literature review and also by measures constructed to illustrate economic agents' demand for information on inflation and how this was supplied by the news media before, during and after the crisis.

The article presents an innovative use of MAXQDA Analytics Pro 2022 solutions for textual analysis of central bank communication, allowing the entire research to be based on textual data in a national language without compromising the general applicability of the methods used. Four dictionaries were created for the purposes of the study. Three of them are attributed to the main domains of the NBP's accountability: 'price stability', 'economic policy/development' and 'financial stability', and are used in the topic modelling of NBP's COVID-communication for the further content analysis. One, created to compute an 'alarmist' proxy, designed to examine a change in the 'alarmist' tone of the NBP's financial stability communication. The article also presents two measures of inflation attention computed for Poland: one based on Google search intensity for the term 'inflation' (following Buelens, 2023), and the other based on inflation topic intensity in news titles (inspired by Marcellino & Stevanovic, 2022).

The article is structured as follows: Section 1 provides an overview of the literature on central bank communication studies and is divided into two parts. Section 1.1 focuses on the textual analysis of central bank communica-

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of major central banks that used unconventional measures in response to the GFC. This confluence of titles is intended to contribute to the debate by providing an overview of the experiences of central banks that have initiated the use of unconventional measures from different backgrounds.

tion, while Section 1.2 focuses on recent findings regarding the transmission of central bank communication to economic agents, including their beliefs, attention to inflation, and possible transmission channels. Section 2 provides the background to the NBP's COVID monetary policy actions, and discusses the data collection and methodology used. Section 3 presents the results. The conclusions summarise three inconsistencies found in NBP's communication that could potentially lead to misinterpretation of its policy actions in response to the crisis. These findings could be valuable for enhancing the design of central banks' communication, especially when directed at the general public.

The results of the study may have implications for the design of central bank communications, especially those aimed at the general public. The results highlight the importance of economic agents' attention to inflation. Additionally, they confirm the significance of central banks explaining monetary policy in a more transparent manner and clearly separating it from financial stability communication. The latter should aim to enhance the credibility of monetary policy.

1. The literature review

1.1. Textual analysis of central bank communication

The study presented in the article contributes to the rapidly growing literature on textual analysis of central bank communication. A considerable part of such studies based on textual analysis aims to quantify central bank communication by measuring its tone and sentiment. The proxies obtained for sentiment or tone of communication are mainly tested for their abilities to predict future interest rate movements (e.g., Apel & Blix, 2014). In some studies, they are used for studies on communication effectiveness in reducing noise, i.e. its ability in reducing volatility in financial markets (e.g., Born et al., 2011; Londono et al., 2022), communication's influence on economic variables (Hansen & McMahon, 2016) or expectations of financial experts (e.g., Baranowski et al., 2021). Another important group of studies focuses on differences in communication strategies (e.g., Bennani & Neuenkirch, 2017; Keida & Takeda, 2019).

The most common approach is based on the dictionary method, due to its relative simplicity. The textual-analysis-literature on central banks' communication draws on findings from studies exploring ways of using qualitative information in finance. Those studies have shown that the linguistic content of corporate reports or news stories about firms is useful in explaining their

stock variables and a noncomplicated quantification (based on word counts) of such qualitative information offers decent predictive abilities. An example of such studies is the one by Li (2006), who found that frequency measures for words 'risk' and 'uncertainty' in corporate annual reports predict low annual earnings and stock returns. The widely known findings of Tetlock et al. (2007) showed that a high level of pessimism in the popular Wall Street Journal's column determined by word count (dictionary method) precedes lower returns the next day. However, these dictionary-based studies highlight the inadequacy of common dictionaries, such as the widely used Harvard-IV-4 classification dictionary, for sentiment analysis of financial texts—most of the words which this dictionary identifies as negative are not considered negative in the financial context (Loughran & McDonald, 2010). This led to the development of dictionaries specially dedicated to financial texts.

This expertise was used in central banks' communication studies and also resulted in the creation of specialized dictionaries, particularly ones aimed at analysing monetary policy documents and Financial Stability Reports (FSRs). Apel and Blix (2014), for example, developed a list of phrases to capture the predictive power of MPC minutes for future monetary policy decisions. The dictionary constructed by Bennani and Neuenkirch (2017) is tailored to measure the tone of public speeches by the ECB Governing Council members. Correa et al. (2020) developed a dictionary specifically for FSR sentiment analysis and demonstrated that FSR sentiment can be a good predictor of banking crises. Londono et al. (2022) used this dictionary to link the design of macroprudential governance structures with central banks' communication strategies. The authors found robust evidence that communication by central banks involved in inter-agency financial stability committees is more effective in mitigating a deterioration in financial conditions.

Some of the literature on textual analysis of communication uses more sophisticated methods. Rybinski (2019) employs a supervised machine-learning framework to create expert dictionaries for central bank communication topics, and then examines how they are conveyed to the news media. Statistical natural language processing such as LDA (see, e.g., Hansen & McMahon, 2016; Jegadeesh & Wu, 2015; Keida & Takeda, 2019), although more demanding compared to dictionary methods, could be more accurate in content descriptions because it allows the same word to appear in multiple topics with different probabilities (Hansen & McMahon, 2016). LDA also helps to avoid some of the limitations of dictionary methods, such as the subjectivity of the authors inherent in the development of an expert dictionary.

For a number of obvious reasons, textual analysis studies of central bank communication based on dictionary methods and specialised dictionaries are mainly applicable to the English language. However, using the English version of the text rather than the national language version in communication studies has certain limitations due to a potential missing of nuances (see, e.g.,

the discussion in Szyszko & Rutkowska, 2022). For example, Baranowski et al. (2021) examine how the interest rate and inflation expectations of private sector experts in Poland respond to NBP communication. The communication is quantified by measuring the tone of the NBP's documents using the English dictionaries of Apel & Blix (2014) and Bennani & Neuenkirch (2017), whereas the local experts whose opinions are studied perceive this communication in their national language (Polish) and also respond to the expectations survey in their native language. Another important issue for communication studies associated with the texts' language is a possible difference in the content of central bankers' speeches, depending on whether they are addressed to audiences abroad (and therefore delivered in English) or at home (and therefore delivered in the respective national language). Bennani and Neuenkirch (2017) showed such 'home' bias in the speeches of European central bankers, members of the ECB's General Council, who seem to adjust the content to the audience.

1.2. Transmission of central bank communication to economic agents: A background for textual analysis

The article attempts to link central bank communication, addressed rather to experts, with its possible impact on economic agents' interpretation of monetary actions. A body of literature confirms the strong influence of central bank communication on expert audiences, as they follow this channel of communication very closely and response promptly. Although a subject of rapidly growing interest, how central banks' communication reaches economic agents and might thus influence their expectations remains under-researched. This line of research could, in a sense, be divided into a part that considers the demand for information on inflation and monetary policy actions by economic agents and a part that focuses on the supply of such information.

An important line of research concerns the economic agents demand for information on inflation and monetary policy through their attention that they pay to monetary actions. Coibion, Gorodnichenko, Kumar et al. (2020) find evidence suggesting that monetary policy in advanced economies with a low inflation environment tends to gain little attention from individuals. The situation is different in countries with higher and volatile inflation—economic agents cannot afford not to follow the actions of the monetary authorities, as the costs of ignoring macroeconomic realities in decision-making are substantially greater (Cavallo et al., 2017). A number of studies confirm that episodes of macroeconomic turbulence lead economic agents to pay more attention to monetary authorities' actions, in line with the theory of rational inattention. Coibion and Gorodnichenko (2015), e.g., show how for Ukraine

the proportion of firms that follow the actions of the central bank increases sharply in times of crisis (the first priority of such tracking was to shape exchange rate expectations and then inflation expectations). Buelens (2023) measures agents' attention to inflation by the intensity of Google searches for the topic 'inflation', arguing that this type of direct measure reveals 'active' intrinsic attention compared to proxies that measure the intensity of the topic in the news media. The study shows that agents' attention to inflation increases at an accelerating rate as inflation rises. Marcellino & Stevanovic (2022) also show an increase in the importance of agents' attention proxy, measured similarly, during high and low inflation episodes and since the start of the COVID pandemic, confirming the important role of such attention for inflation expectations.

However, the links between central bank communication and economic agents' attention to monetary policy actions appear to be more complex. Paying attention to inflation does not necessarily translate into tracking central bank actions, and even if it does, the impact of such actions can still be misinterpreted. Binder (2020) shows that only just over a third of respondents in the US consumers survey sample were aware of the Fed's historic interest rate cut in response to the COVID-pandemic outbreak a few days after its announcement and may have trouble interpreting it: this group was found to be relatively more pessimistic about future unemployment and had higher inflation expectations. Coibion, Gorodnichenko and Weber (2022a) examine how the Fed's announcements concerning the policy response to the COVID-crisis affected economic agents' expectations, and show that the effect was quite limited.

The beliefs of economic agents are another concern for central bankers in designing their communication. Recent literature points to some inconsistencies between economic agents' beliefs and the fundamentals underlying monetary policy decisions. In contrast to central bankers and expert audiences who associate demand shocks with a deterioration of the economy, which for them implies a downward revision of inflation forecasts, households associate "bad times" with higher inflation (Andre et al., 2019; Candia et al., 2020; Coibion, Gorodnichenko, Kumar et al., 2020; Dräger et al., 2014). Such inconsistencies may lead to misinterpretations of central bank actions and thus require special communication treatment. Coibion, Gorodnichenko and Weber (2022b) show that the use of simple messages that address the price stability domain appears to be a more effective form of communication with the general public. Rybinski (2019) finds evidence for Poland that central banks' communication on price stability is more effective in influencing media discourse, and thus stands a better chance of gaining the attention of economic agents. Lamla & Vinogradov (2019) show that announcements of monetary policy decisions are more likely to be received by economic agents (with a probability about 10% higher in the case of FOMC press conferenc-

es) compared to other central bank communication events. Ter Ellen et al. (2022) examine the news media transmission channel of monetary policy to the public for Norway by identifying narrative monetary policy surprises (using textual data on central bank communication and news media), and show the significant effect of these surprises on subsequent media coverage. These findings are consistent with those of Rybinski (2019) for Poland, regarding the ability of central bank communication events to influence news media discourse. Marcellino & Stevanovic (2022) measure the supply of information about inflation by standardising the count of Wall Street Journal (WSJ) articles containing the stem "inflat" in their title. They show that media communication about inflation, measured in this way, plays an important role in shaping inflation expectations.

In the context of the demand for/supply of information on inflation and monetary actions, it also seems relevant to consider general insights into individuals' news consumption. Flaxman et al. (2016) confirm that in the case of online news consumption, which tends to dominate over time, individuals are more likely to delegate their information choices to specialised, typically mainstream, news providers. Nimark & Pitschner (2019) show that individuals' beliefs and actions are influenced by both the information conveyed in a news story and the choice to convey it. In line with this evidence, the article consider news media attention to inflation and monetary actions in Poland measuring the topics' intensity in the news stories titles (inspired by Marcellino & Stevanovic, 2022) of the most popular local online news providers.

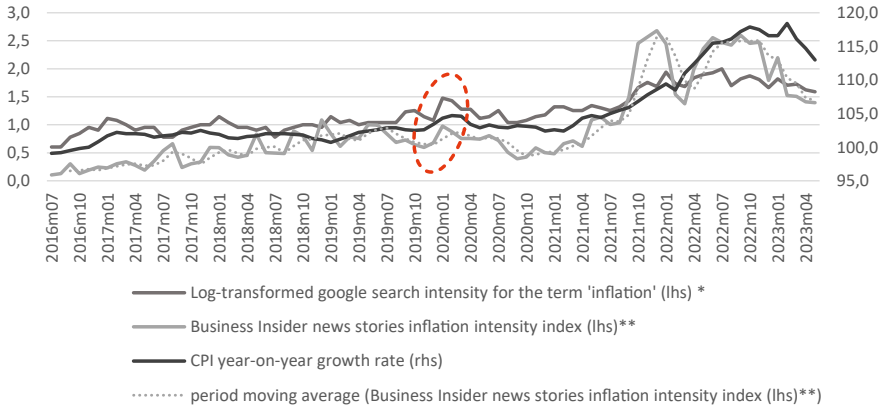
2. Data and methodology

2.1. The case of Poland: Monetary policy and communication background

The NBP's response to the COVID-19 crisis was prompt and large-scale. In March 2020, the NBP implemented an extensive package of monetary easing measures (the list of easing measures can be found in NBP, 2020a, p. 29). In addition to monetary easing, macroprudential policy was eased as well. During the following two months after the crisis's outbreak, the NBP in total cut the reference rate three times (by 140 bps in total from the pandemic's outbreak onwards) to the historically lowest level of 0.10%. The announcement of the response package, as well as further NBP's communication, did not explicitly tie implied response-measures to specific policy objectives. It is important to note that during the COVID-19 crisis, due to safety concerns,

the NBP suspended the press conferences that were traditionally held after MPC meetings. These conferences were an important communication event with proven power to influence media discourse (Rybinski, 2019).

Immediately before the crisis began, inflation in Poland was running above the upper limit for deviations from the inflation target. The NBP expected the anticipated economic slowdown would engineer a 'natural' decline in prices. The NBP's communiques of that time even contained warnings about deflationary risks, referring to the inter-crisis experience of the Eurozone with a low inflation environment, despite the extensive use of unconventional monetary tools. However, the economic slowdown associated with the COVID-crisis did not lead to a marked drop in inflation in Poland, as was expected. The slump in demand associated with the COVID-crisis caused a notable drop in CPI inflation globally. The downward trend was also observed in Poland. Inflation fell to 3.3% year-on-year in June 2020, back within the deviation band, while remaining one of the highest among the non-Eurozone CES countries (see NBP, 2020b, pp. 12–13) and still above the inflation target of 2.5%. Thereafter, along with other countries, Poland experienced unfavourable post-COVID inflation dynamics.



Note: * – refers to the Google Trend time series for the term "inflation" in Poland, sample period: July 2016–May 2023, collected according to the recommendations of Buelens (2023) from (pp. 51–53). The correlation coefficient with CPI is 0.89, which is statistically significant at the 0.001 level. ** – the index counts Business Insider Poland news stories containing the words "inflation" and "price" in their title (the analysis is done for titles in Polish). Business Insider Poland provides business news to the most popular (according to the Reuters' Institute for the Study of Journalism Digital News Report 2023) online information provider https://www.onet.pl/. News stories inflation intensity index = (word count)/(news stories count), $t \in$ [Jul 2016–May 2023], normalised to the mean, the correlation coefficient with CPI is 0.85, which is statistically significant at the 0.001 level.

Figure 1. Attention to inflation in Poland and its relationship with inflation developments in 2016–2023

Source: based on (GUS,2023).

The choice of the NBP case for this study is also motivated by greater attention to inflation among economic agents, probably reflecting the historically short experience of low inflation. Figure 1 demonstrates a high sensitivity of inflation attention in Poland to inflation developments over the entire sample period.[4]

The inflation attention measures show an increase at the end of 2019, as inflation exceeded the ceiling for deviations from the inflation target. This increase may have led to greater attention of economic agents to the monetary actions taken in March and April 2020 in response to the pandemic outbreak, and may have been transmitted to expectation formation through the country's high sensitivity of short-term inflation expectations to inflation (Chmielewski et al., 2020; Goel & Tsatsaronis, 2022).

2.2. Data and methods

Like many central banks around the world, the NBP's ability to clearly explain the policy decisions in response to the COVID-crisis was affected by the urgency and scale of the crisis. The lack of explicit information in the NBP communication on the objectives behind the policy decisions taken in response to the pandemic outbreak suggests an examination of an implicit message that may have been conveyed in its communication. The aim of the content analysis of the NBP's COVID-communication is therefore to answer the question of what message about monetary policy objectives it might have conveyed in terms of the possible interpretations of the NBP's COVID response actions on the part of economic agents.

The article uses a topic modelling framework (see, e.g., Gentzkow et al., 2019) to analyse the content of the NBP's COVID communication. The topic modelling is based on the dictionary method by tagging keywords specific to NBP's communication when its talk focuses on one of three domains (topics) of its accountability: 'price stability', 'economic policy/development'[5] or 'financial stability' (hereafter "topic dictionaries"). The analysis of communication is conducted in MAXQDA Analytics Pro 2022. The MAXQDA solutions

[4] The period selected partly overlaps with the periods presented in the charts below and covers the time series after the COVID period. The time interval was chosen to show attention dynamics starting from the end of the deflation period in 2016 and the high inflation period which started in the middle of 2021. This is consistent with the findings of Marcellino and Stevanovic (2022), who show a special role of attention to inflation during periods of very high or low inflation.

[5] The NBP's mandate is to maintain price stability (according to the Act on the National Bank of Poland) while supporting the government's economic policy (the secondary remit), provided it does not interfere with the primary objective.

used allow to solve the dilemma of language choice: due to the support of Unicode text in every MAXQDA function, a textual analysis project could be implemented in any language by simply importing the relevant text data. Although the study presented in this article is based on data for Poland, the methodology and tools used are general and can be applied to or replicated with other textual data.

In addition, the article considers the role of financial stability communication. Although this domain of central bank communication has less of an impact on the general public and thus the formation of inflation expectations, its role in counteracting the deterioration in financial conditions during the crisis by reducing uncertainty and thereby supporting the effectiveness of monetary policy could be significant. It could be argued that the NBP, due to its direct role in the Financial Stability Committee, was able to use the regularly published FSRs to more effectively counter the deterioration caused by the pandemic outbreak (see Londono et al., 2022; Matysek-Jędrych, 2018). The direct role of the central bank in macroprudential supervision, according to Londono et al. (2022), leads to the transmission of "calmer messages". In contrast, central banks without such a role should rely more on communication to convey financial stability concerns to other supervisors as well, resulting in the transmission of more "alarmist messages". To show whether the NBP used this ability, the article examines the change in tone in the NBP's financial stability communication, using a specially developed dictionary to create an 'alarmist' proxy. The analysis focuses on the change in the 'alarmist' tone over a longer period, 2007–2020, and aims to make a comparison between the reaction to the COVID-crisis and to the GFC.

The data is organized within the MAXQDA Project (Project) into a document system, which consists of three document groups: 1. *MPC minutes group* – a series of the NBP's MPC minutes published in the period from 2008–2020 (a total of 145 issues), 2. *FSRs group* – a series of the NBP's FSR issues published in the period from 2007–2020 (a total of 26 issues), 3. *COVID communication events* – a total of 12 documents, texts and transcripts of all NBP communication events held during the first year of the COVID crisis, i.e. speeches, interviews, Q&A sessions (speeches and Q&A recordings were transcribed into text specifically for the purposes of this study).

A *COVID communication dataset*, covering the entire COVID-communication of the NBP on monetary policy, includes *COVID communication events* (12 documents, 71% of the dataset text corpus by word count) and 10 documents from the *MPC minutes group* published after the outbreak of the pandemic from March 2020 onwards (29% of the dataset text corpus by word count). All documents defining the project are in Polish.

Given its key role in monetary policy communication, the MPC minutes series was chosen for the development of the NBP-specific keyword dictionaries for the domains/topics of "price stability" and "economic policy/devel-

opments". The choice is also justified by the power of this document to influence the media discourse (through policy announcements, higher publication frequency, regular press conference after MPC meetings) and thus a higher likelihood of eventually reaching the general public. The choice of the FSRs series as a key financial stability communication document with proven efficiency in 'news creation' and 'noise reduction' (Born et al., 2011) also seems natural. The FSRs are used to develop the NBP-specific keyword dictionary for the financial stability domain, as well as a special dictionary for the construction of a Financial Stability Alarmist Index (FSAI).

2.3. The content analysis

The study covers two-step topic modelling of "COVID-communication". In the first step, the MAXDictio function was used to develop NBP-specific keyword dictionaries for the three domains of the bank's accountability. In the second step, the *COVID communication dataset* documents were coded with the dictionary items. Methodologically, the function used to develop the dictionaries employs the bag-of-words (BoW) technique (see, e.g., by Bholat et al., 2015; Gentzkow et al., 2019). BoW is based on the representation of a document as a vector of words and word counts, which enables an assessment of the importance of single terms within the document by applying a weighting, the most common of which is the proportional occurrence method.

It is worth noting that the length of the text corpus substantially differs between the two groups of documents: *MPC minutes group* and *FSRs group*,[6] without affecting the accuracy of group-specific keywords identification due to the proportional occurrence method used; more relevant to such accuracy is the length of the series and its relative comparability for both groups. The series covers 16 MPC interest rate decisions, including 5 tightening decisions between 2011 and 2012 and 11 easing decisions between 2012 and 2015. The series also includes the two changes of NBP Governor in 2010 and 2016, as well as the change in the composition of the MPC in 2016. It covers the GFC, the sovereign debt crisis, and the COVID-crisis. These events contribute to smoothing out possible variations in the vocabulary used.

Several built-in procedures were used to clean the data, ignoring the following: hyperlinks, email addresses, hashtags, numbers, text in square and curly brackets, minimum number of characters, and applying the following: stop word list and case sensitivity, lemmatisaton of words. The lemmatisation procedure for the Polish language gave quite precise results for the project

[6] The first covers 145 documents with total text corpus of 222,000 words and the second – 26 documents with total text corpus of 1,235,000 words.

documents, although in some few cases it was necessary to combine some rows in the results table, as they contained words with similar meanings in the context. The basic stop-words list was uploaded from the Countwordfree[7] website and then elaborated by adding common words, neutral for the topic modelling within the project (such as 'current'). Around thirty top-ranked (by frequencies) terms lists obtained for both documents' groups were then analysed with the use of built-in functions for keywords' context through their most likely collocation. Analysis was needed to: 1) divide the top-ranked terms obtained for the text corpus of *MPC minutes group* into two topics, *'T1: price stability'* and '*T2: economic developments'*; 2) reject some terms that are used in the text only in certain combinations, such as 'council' in 'monetary policy council', and which do not define topics in the context of the further content analysis. It resulted in the creation of keywords dictionaries specific to NBP's communication when it talks about : *'T1: price stability'*, *'T2: economic developments* (within monetary policy mandate)' and '*T3: financial stability'*.[8] The topic dictionaries obtained were subjected to a robustness analysis to check the stability of the results in view of small variations in the dictionaries. The analysis included the dependent *t*-test for altered keyword lists (obtained by reducing the dictionary lists). The test results showed a minimal average difference.

An additional technical dictionary of keywords (most frequently used terms, defining the context) specific to the NBP's COVID-communication was also developed. The dictionaries obtained were used for coding the documents from the *COVID communication dataset*. The further summative content analysis of the NBP's COVID-communication is based on counting the occurrences of the topics' keywords and measuring the intensity of the topics, in order to identify a balance between them. The technical dictionary is needed for quantifying and visualizing proximity of the topics within the text corpus.

2.4. The 'alarmist' dictionary

A special dictionary was developed to compute a proxy for examining the NBP's response to the COVID-crisis in communication on financial stability. The 'alarmist' dictionary was constructed, involving an assignment of terms

[7] Retrieved from https://countwordsfree.com/stopwords/polish

[8] 'T1 Price stability': 'inflation', interest, rate, price, monetary, policy, expectations….; 'T2 economic developments": (within monetary policy mandate)': 'growth', 'economy', 'situation', 'GDP', 'economic/business conditions', 'enterprise'…; 'T3 financial stability': 'bank', 'credit', 'finance', 'sector', 'risk', 'fund', 'asset'... Only sample words are presented here, translated into English. The actual dictionaries in Polish that are applicable to the analysis of the text are available on request.

by hand from the terms' frequencies list obtained for the text corpus of *FSRs group* with a key classifying feature—a negative connotation, mostly irrespective of collocation or context (in total 61 words).[9] The process of selecting the terms was supported by the use of MAXQDA's word explorer tools, as well as PELCRA's collocation search engine for Polish (Pęzik, 2012).[10]

Limiting the method to negative words is in line with the objective of the analysis: the 'alarmist' proxy is designed to examine a change in the 'alarmist' tone of FSRs over time, identifying an 'alarmist' attribute as a word's negative connotation. The construction of a traditional sentiment proxy is based on the neutralization of negative terms by positive ones, with an equal weight for both groups, whereas negative information has a greater relevance for the textual analysis of tone, because, as psychological studies show, it is better remembered than neutral. The method used is also supported by the findings of Tetlock et al. (2007) or Li (2006), e.g., which confirm the good performance of proxies based on negative word counts. Negative terms tend to dominate in financial texts, e.g., the special dictionary developed by Correa et al. (2020) for quantifying the sentiment communicated in FSRs contains 391 words, of which 96 are positive and 295 are negative.

As with the topic dictionaries, the 'alarmist' dictionary was subjected to a robustness analysis to check the stability of the results to small variations in the dictionaries. In addition, in order to strengthen the robustness of the results, an alternative alarmist dictionary was used, based on the well-known financial stability dictionary proposed by Correa et al. (2020). The list of negative words from this dictionary was translated into Polish. Both the resulting 'alarmist' dictionaries were used for coding the *FSRs group* of documents to create 'alarmist' proxies: *FSAI* (Financial Stability Alarmist Index) and *FSAI Correa.*[11]

3. Results

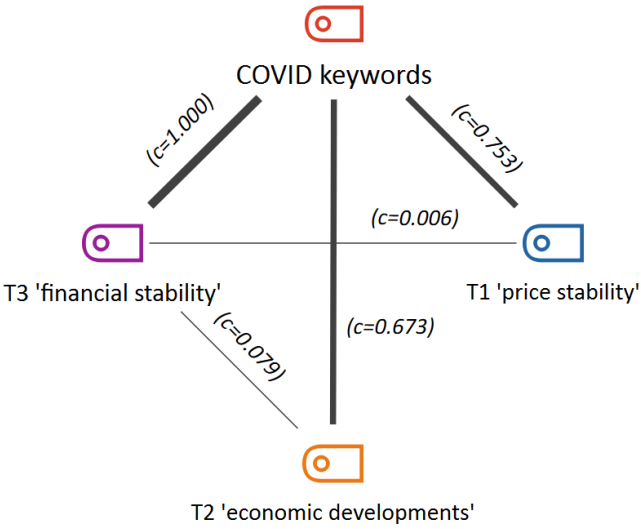
The analysis of the *COVID communication dataset's* content is divided into two parts based on the types of coding used, depending on the text range: for a 'search item' (a keyword attributed to the dictionaries) and for a 'sentence'

[9] For example, the dictionary contains words such as 'deficit', 'erosion', 'crisis', 'confrontation', 'destabilisation', 'problem', etc. These are just a few examples common to both English and Polish to give an idea of the approach to attribution. Due to article size limitations, the complete dictionary cannot be included, although it is available upon request.

[10] 'Risk' in non-financial texts has a negative connotation in Polish. However, the collocation 'risk-free', used only in financial texts, cancels out the negative connotation. Therefore, it should be properly adjusted in the methods used.

[11] The obtained frequencies for the "alarmist" dictionary: *FSAI=('alarmist' words count)/(total words count), $t \in$ [2007:2020]*, normalised to the mean.

(a complete sentence containing a keyword). The former enables the quantification of the similarity between the keywords used in COVID-communication and those attributed to the main domains of NBP's accountability based on their intensity. The latter enables the quantification of the text thematic similarity to the topics associated with the three main domains of NBP's accountability. Figure 2 shows item-level code relations visualising the similarity of COVID-keywords (obtained for COVID-communication) to the wording traditionally used by the NBP when speaking in one of the three domains of its accountability.



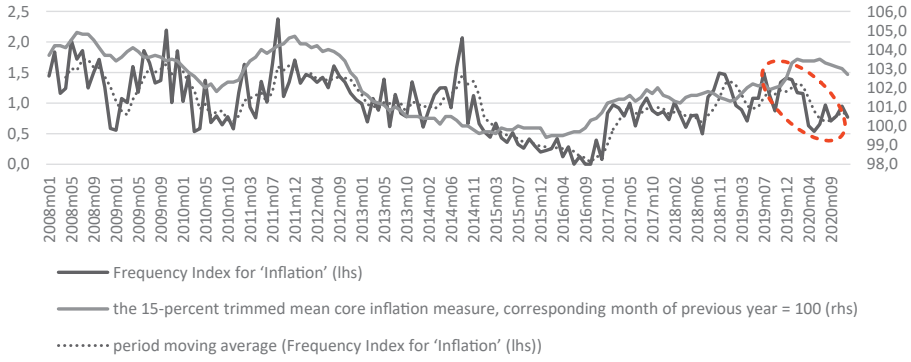
Note: *c* – frequency of codes' co-occurrence, scaled by the most frequent between 'COVID keywords' dictionary and T3 'financial stability' (*c* = 1) (also shown by the thickness of the lines).

Figure 2. Code co-occurrence model for "COVID-communication"

Source: own work.

Figure 2 demonstrates that the wording used by the NBP in COVID--communication overlaps to a greater extent with the wording traditionally used in 'financial stability' communication. This is primarily due to the prevalence of financial stability wording in the text corpus of COVID communication events (accounting for 70% of the total NBP communication in the COVID--crisis, in terms of number of words). As mentioned above, due to the COVID pandemic, the NBP discontinued the tradition of holding press conferences after MPC meetings. Therefore, the communication events in the text corpus examined here are the only direct communication events that took place at that time with the potential to impact the news media discourse and reach a broader audience.

The prevalence of the 'financial stability' wording is also partly due to the decline in the importance of the 'inflation topic' in the MPC minutes in 2020. Figure 3 demonstrates a gap between the importance of the topic of 'inflation', which declined after the outbreak of the pandemic in March 2020, and inflation, which did not fall much in the wake of the downturn.



Note: [1] – one of four measures of core inflation published by NBP (2023), calculated with the use of statistical method, which allows to eliminate the groups of prices that have changed most significantly; [2] – *Frequency Index for 'Inflation'* = (*'inflation' word count*)/(*total words count*), $t \in$ [2008:2020]), normalised to the mean.

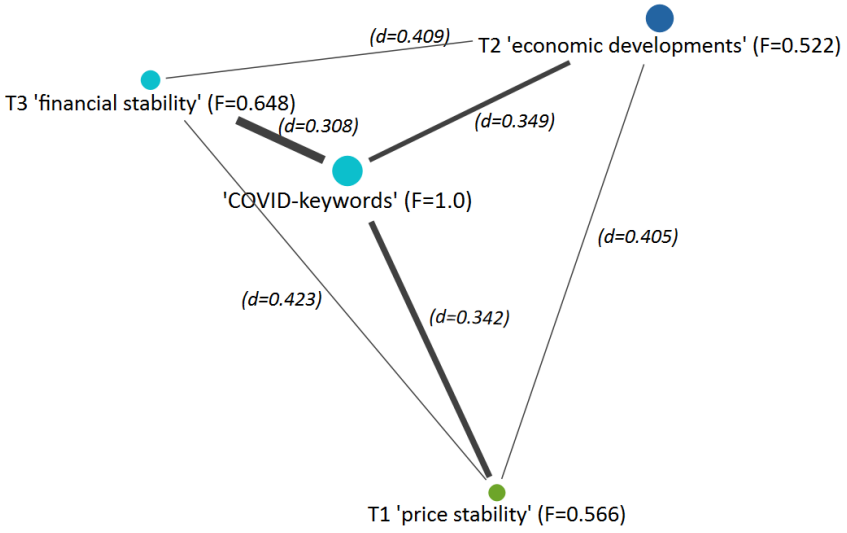
Figure 3. The monthly 15%-trimmed mean core inflation index (year-on-year)[1] versus Frequency Index for 'inflation', obtained for the NBP's MPC minutes[2], 2008–2020

Source: own work.

The declining importance of 'inflation' at MPC meetings is striking in all three crises covered in the chart (see Figure 3): the GFC, the sovereign debt crisis and the COVID-crisis—the central bank then expects that the anticipated economic slowdown caused by a demand shock would lead to a 'natural' fall in prices, inflation forecasts are therefore revised downwards and the importance of the 'inflation' topic drops significantly. The decline in importance, which appears to be a natural consequence for the central bank, has the effect of undermining the topic in its communication (MPC minutes). However, it is important to note that economic agents may perceive a crisis differently to central bankers. As discussed in Section 1.2, they may associate a crisis not with a fall in inflation but with a rise. Although the article cannot confirm whether these beliefs are also characteristic of economic agents in Poland, the results of the analysis indicate a disconnect between the increased attention paid by economic agents to inflation at the end of 2019 (see Figure 1), a few months before the pandemic outbreak, and the near absence of the topic of 'inflation' in NBP's communication after the massive monetary easing actions undertaken in response to the pandemic outbreak. This incon-

sistency may have led economic agents to misinterpret the monetary policy measures taken at that time.

The second type of coding involves coding at the sentence-level. This means that a whole sentence containing a dictionary keyword is coded. If a sentence contains a few words from the same dictionary, it is only coded once. This method allows for an analysis of thematic overlaps. Figure 4 shows a visualisation of the similarity of codes based on their overlap and frequency.



Note: *F* – frequency of a code, scaled to the most frequent code 'Tech dictionary for COVID communication' (shown on the map as 'COVID keywords'), *d* – distance between codes from a distance matrix, converted from a similarity matrix of codes: takes the range from 0 to 1, where 0 means that two codes always occur together (never without each other), 1 means that codes never occur together—the lower the meaning, the higher the similarity (the thicker the line on the map, the higher the similarity).

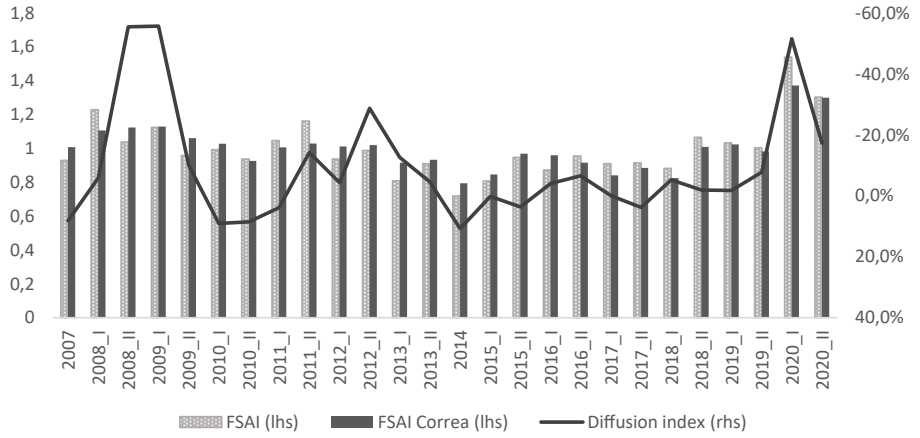
Figure 4. Map of codes for *COVID communication dataset* at the sentence-level clustered due to their similarity

Source: own work.

The distances between the codes and their frequencies obtained also suggest that communication during the COVID-crisis was thematically more similar to the texts from the NBP addressing the topic of financial stability. The topic of 'price stability' is less presented in COVID-communication. It also hardly concerns the 'inflation' topic (less than 10% by word count for T1 'price stability' dictionary code). The demand-shock nature of the COVID-crisis could imply that central bank policy is focused on economic recovery, and thus NBP's COVID-communication would rather address issues related to economic developments. The results of the content analysis do not confirm this. In the absence of an explicit link between crisis measures and policy objectives, the

dominance of 'financial stability' over other topics in COVID-communication could have been perceived by audiences as implying that financial stability concerns were behind the unprecedented easing of monetary policy. This could have led to a further misinterpretation of the effects of monetary policy measures at the time.

The further analysis of the tone of the FSRs published by the NBP suggests that its financial stability communication could support such perception. Figure 5 shows the dynamics of the specially constructed 'alarmist' proxies, which appear to be much higher during the COVID-crisis than they were during the previous crises, the GFC and the sovereign debt crisis.



Notes: [1] – The diffusion index for the option "risk related to the expected general economic situation" indicated by respondents in the corporate loan segment (relatively high importance of this loan category compared to GDP) (NBP Senior Loan Officers Opinion Survey); [2] – FSAI and FSAI Correa constructions are discussed in Section 3; [3] – FSR is a biannual publication with pre-defined release schedules. In Poland, after 2016, it is regularly published in June and December. However, there were irregularities during the sample period. For instance, only one report was published in 2007 and 2014. In 2015, two publications were released in January and July. Similarly, in 2016, two publications were released in February and December. 'I' and 'II' on the chart represent the first and second releases respectively. The diffusion index was averaged to correspond with the period of publication.

Figure 5. Diffusion index for banks' responses indicating the risk related to the expected general economic situation with respect to corporate loans[1] compared to the FSR 'alarmist' indices[2], 2007–2020[3]

Source: own work.

The increase shown by the 'alarmist' proxies in 2020 is consistent with the findings of Yang et al. (2020), which confirm a deterioration in financial stability sentiment in 15 out of 17 countries' FSRs published in 2020, including Poland. The authors also note a disconnect between central banks' perception of the pandemic's impact, as measured by FSR sentiment, and tangible financial stability and real-time economic indicators.

Figure 5 compares the behaviour of the 'alarmist' indices obtained with the dynamics of the diffusion index, which can be considered as a proxy for the economic uncertainty perceived by the banking sector (negative values correspond to an increase in uncertainty), in line with Hołda (2019). The change in tone in the FSRs is moderately correlated with an increase in economic uncertainty perceived by the banking sector. The correlation coefficient is –0.57, which is statistically significant at the 0.02 level. The moderate relationship (with the exception of the COVID-crisis) between the tone change and uncertainty perception could be evidence of nonlinear relationships between the two if communication is used effectively as a tool in reducing uncertainty.

The diffusion index captures a similar peak in uncertainty during both the GFC and the COVID-crisis (see Figure 5). It is important to note, however, that the tone of the communication changes in different ways before and after these two crises. During the GFC, it could be seen a gradual increase in uncertainty perception from 2007 onwards, with a further deterioration in 2009, while the alarmist tone of the FSR increased slightly before the onset of the crisis and remained at around the same moderate level during the most stressful period. Communication during the COVID-crisis tended to be highly alarmist, which is inconsistent with the NBP's ability to use communication more effectively in countering a deterioration in financial conditions due to its direct role in the Financial Stability Committee (Londono et al., 2022, discussed in Section 1.1). There is also a striking discrepancy between the highly alarmist tone of the communication and a marked decline in perceived uncertainty in the banking sector in the second half of 2020. The crisis response package, which employed monetary and macroprudential easing measures, was probably effective in reducing uncertainty perception in the banking sector to pre-pandemic levels, as shown by the diffusion index. However, the NBP's communication tone, while slightly softened, remained highly alarmist. Central bank communication through the FSR aims to inform about risks to financial stability, and its highly alarmist tone is itself informative in this respect. Financial markets and economic agents may conclude that the deterioration in financial stability and the depth of the crisis are deeper than they actually are, which could further mislead them in the formation of expectations.

Conclusions

The article analyses NBP's communication one year after the announcement of the crisis response package adopted following the outbreak of the COVID pandemic. The analysis aims to answer the question of what message

about monetary policy objectives may have been conveyed in communication with regard to possible interpretations of the central bank actions by economic agents in Poland by economic agents. Three main inconsistencies are identified that could potentially affect the interpretation of monetary policy actions at that time.

Firstly, there is an inconsistency in the attention given to inflation. Although economic agents in Poland began paying more attention to inflation a few months before the outbreak of the pandemic, the NBP's communication on inflation markedly declined after the extensive monetary easing response to the pandemic. This was due to the expectation that the anticipated economic slowdown would lead to a 'natural' decline in prices. According to the recent literature, economic agents may perceive a crisis differently and associate it with a rise in inflation rather than a fall.

Secondly, there was inconsistency in the communication of policy priorities. The content analysis revealed that the NBP's communication during the COVID-crisis was primarily focused on the topic of 'financial stability', which was not in line with the demand-shock nature of the crisis and the degree of deterioration in financial conditions at the time. It could be argued that the eventual recipients may have inferred that concerns about financial stability were behind the unprecedented easing of monetary policy. This perception may have been reinforced by the highly alarmist tone of the NBP's financial stability communication.

Thirdly, the alarmist tone conveyed in the Financial Stability Reports released in 2020 was inconsistent with the direct role that NBP plays in macroprudential supervision and the extensive package of measures taken promptly in response to the crisis. The alarmist tone maintained in communication at the end of 2020 does not correspond with the decline in uncertainty perception by the banking sector to pre-pandemic levels at that time. The persistent alarmist tone in financial stability communication could have misled the public in their perception of the deterioration in financial conditions and thus the depth of the crisis, and also have affected the formation of expectations.

The results of the study may have implications for the design of central bank communications, especially those aimed at the general public. The results highlight the importance of economic agents' attention to inflation in designing communication. Furthermore, they confirm the significance of central banks providing transparent explanations of monetary policy, separate from financial stability communication. The latter should aim to enhance the credibility of monetary policy.

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sciendo Economics and Business Review https://www.ebr.edu.pl Vol. 10 (1), 2024: 125–152 https://doi.org/10.18559/ebr.2024.1.1004

Corporate governance and risk management: An evaluation of board responsibilities in western and Islamic banks

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Abstract

This research aims to explore the role of the board in corporate governance (CG) and risk management within the context of Islamic banking. Given the global reach of financial institutions, it is important to compare and evaluate the unique position of Shari'ah committees or Shari'ah Supervisory Board (SSB) in addressing the unique risks of Islamic banks. Using a comparative analysis, this study evaluated risk management guidelines in the CG codes of the United Kingdom, Germany, Saudi Arabia, and Malaysia. It found that board were ultimately responsible for risk management, regardless of the governance structure, and Shari'ah-related risks fell under the board's purview. An innovative blend of Western CG frameworks and Islamic principles enhanced governance robustness through the strategic collaboration between board and SSBs.

Keywords

- corporate governance
- Islamic banking
- risk management
- Shari'ah
- governance codes

JEL codes: G30, G39, G34, G21

Article received 19 October 2023, accepted 15 March 2024.

Suggested citation: Alatassi, B., & Pillai, R. (2024). Corporate governance and risk management: An evaluation of board responsibilities in western and Islamic banks. *Economics and Business Review*, *10*(1), 125–152. https://doi.org/10.18559/ebr.2024.1.1004

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Introduction

In recent years, corporate governance (CG) has evolved from its presumption of fair standards and its view of stakeholder responsibilities, board competence, and corporate sustainability as mere tick-box activities (Wadsworth, 2020). Nonetheless, the definition of 'good governance' is a controversial topic. Many shareholder-focused theorists argue that the board of directors' primary responsibility is to maximise shareholders' wealth (Friedman, 2007), and that the CG mechanism should logically aim to fulfil this purpose. In contrast, stakeholder theorists, such as Freeman (2010), claim that shareholders are only one of many stakeholders that corporations ought to be accountable to, and good CG must be designed to serve this broader range of stakeholders. Despite the range of concepts of CG, there are certain fundamentals that 'good' CG will consider, including creating sustainable and retainable businesses, achieving corporate objectives, ensuring efficiency and resource allocation, defining roles and responsibilities, balancing companies' economic and social benefits, and ensuring an efficient risk management strategy is in place (Crowther & Seifi, 2010). These fundaments are logical, given that CG started to garner attention with the onset of three major events over past decades, namely, the Asian financial crisis in 1998, the wave of corporate scandals in 2001, and the start of the global financial crisis in 2007, all of which reflected diminished risk management standards and practices (Gennaro & Nietlispach, 2021). Effective risk management strategies are capable of mitigating financial dilemmas, ensuring sustainable investments, and enhancing diligent decision-making (Gouiaa, 2018). With the recent COVID-19 pandemic, it is arguably even more critical now to form active board that are capable of taking the leading role in CG strategy and implementing a resilience plan to ensure smooth and effective operations in the financial services sector (Haben, 2020). This is because financial markets are subjected to stiff competition and rapid innovation and are vulnerable to political, economic, institutional, financial, and environmental risks, which have led to tighter profit margins and increased capital adequacy requirements (Permatasari & Yuliyanto, 2016). Lam (2014) suggests that interactions with the aforementioned risks can be mitigated through efficient governance and board. The board of directors plays a vital role in determining the appropriate levels of risk appetite, reducing information asymmetry, managing and controlling risks and strategies, and thereby increasing shareholder wealth (Gelter & Puaschunder, 2021; Gouiaa, 2018). These claims align with Geeta and Prasanna's (2016) argument that risk management effectiveness is dependent on variations in a board's structure, operating procedures, and characteristics. Nevertheless,

research on CG systems, board and risk management practices is at the embryonic stage, and thus warrants further study. For example, Gouiaa (2018, p. 14) asserts that 'the risk oversight function of the board of directors, as a central corporate governance mechanism, has never been more critical and challenging than it is today'.

To address the evident gap in the risk governance literature, this paper provides a comparative analysis of the latest CG reports in leading organisations in both Islamic and Western countries to investigate what constitutes good CG when it comes to risk management and board responsibilities in financial institutions. Previously, Alatassi and Letza (2018) explored the idea of fusing Western CG elements with Islamic principles to create an evolved CG structure led by effective board, who are able to cope with the constant challenges and risks in the contemporary world. Prior research has evinced agency problems and risk-taking behaviour in the Middle East and North Africa-based Islamic banks (IBs) (Fayed & Ezzat, 2017), identified the CG–risk management nexus in conventional banks (Permatasari, 2020), or unveiled risk management in a CG framework (Rehman et al., 2020). However, there is a dearth of empirical research related to conventional and Shari'ah governance and their relationship with risk management. This evident gap motivated this study—the first that we know of—to examine how a fusion of conventional and Shari'ah-based CG can be applied to risk management practices, particularly considering the board's contribution and responsibilities towards risk management. Furthermore, (Alatassi & Letza, 2018) has previously highlighted the unique position of CG in IBs and proposed a model for further development combining the fundamental philosophical principles of Islam with the theories and practical structures, codes, and systems developed in the West.

Through a comparative analysis, this paper sought to achieve three objectives: first, to examine the risk management policies in the United Kingdom (UK), Germany, Saudi Arabia, and Malaysia; second, to assess the role of board in leading the risk management strategy; and third, to evaluate the role of IBs' board of directors and Shari'ah Supervisory Board (SSB) in accommodating the unique requirements associated with the Islamic finance industry and traditional risks. The study makes several contributions to the CG literature. First, the paper aids Islamic financial policymakers in identifying the gaps in the current CG structure and influencing smooth operations in the global markets. Second, it guides regulators, especially in the Islamic finance industry, to optimise the guidelines and aim to achieve good CG practises. Third, by examining the differences and similarities in governance structures, risk exposures, and regulatory frameworks, this study provides valuable insights into the effectiveness of these practices in maintaining financial stability and resilience in IBs in the face of economic turbulence. Furthermore, this paper offers possible solutions to bridge the research gap by suggesting potential improvements to governance structures and risk management practices in

both Western and Islamic banks. These include identifying best practices, enhancing board oversight, and fostering a culture of effective risk management.

The rest of the paper is structured as follows: Section 1 reviews the existing literature, while Section 2 highlights the methods and materials of the study. Section 3 reflects the key findings, and the conclusions provide recommendations for future research.

1. Literature review

1.1. Theoretical overview

Following a series of corporate scandals and increasing socio-economic and political upheaval, the board of financial institutions have been assigned the principal responsibility for overseeing impending and existing risk management processes (Gupta & Leech, 2014) to avoid substantial institutional risk management failures. In terms of the theoretical approaches, Udayasankar (2008, p. 2) states that 'despite the proliferation of multiple theories of CG, including resource dependency, stakeholder, and institutional theories, the epistemological basis of this domain remains the agency theory'. The economic theory of agency conflict argues that both principals (owners) and agents (managers and board members) prefer to maximise utility, but there is a difference in the objectives behind each maximisation. 'Agency problems arise because, under the behavioural assumption of self-interest, agents do not invest their best effort unless such investment is consistent with maximising their own welfare' (Barnea et al., 1985, p. 26). As far as financial organisations are concerned, the managers (board members) are assumed to exhibit self-interest, thereby showing a misalignment with shareholders' interests; indeed, managers may display risk aversion due to their incapacity to diversify risk because they are heavily dependent on the firm (Squires & Elnahla, 2020).

Furthermore, agency theorists argue that the separation between the corporation's ownership (principal) and its management (agent) creates what is known as 'agency cost'. Agency theory aims to reduce this cost caused by the 'homo-economics' model of people, where directors are self-serving and seek to maximise their wealth at the principal's expense (Jensen & Meckling, 2019). Although agency theory has played a role in forming CG roles and regulations, it is restricted in scope and unable to explain the more complicated, non-economic factors in the organisation. In contrast, the stakeholder theory extends the directors' responsibility towards the shareholders and the broader constituencies that influence corporations, such as employees,

customers, suppliers, and society (Letza et al., 2004; Mallin, 2016). Letza and Sun (2004) and Alatassi and Letza (2018) argue that the clear-cut, stable boundaries between stakeholder and agency theorists only exist in theory, and that real-world events indicate that directors should take a more dynamic approach based on the actual situation, including a mixed approach, where both shareholder and stakeholder values are taken into consideration. Another school of thought argues for the new concept of stewardship theory, where agents can be viewed as stewards trying to pursue a higher need than self-serving or value creation (Alatassi & Letza, 2018; Bhatti & Bhatti, 2010; Donaldson & Davis, 1991).

There is no single 'best fit' theory for all countries and corporations. Each state will adopt an approach that can respond to the state's cultural and economic demands (Alatassi & Letza, 2018). For example, the UK and US models of CG (the so-called Anglo-Saxon approach) focus on maximising shareholders' wealth, therefore, requiring a more agent-theory-based course. Other countries, such as Germany, follow the broader stakeholder approach, which empowers other groups in the organisation, such as employees. In Islamic financial institutions, there is a more ethical approach, by which the banks' stakeholders have a higher, more spiritual need to fulfil. Thus, the internal stakeholders of the bank ought to act as stewards.

While the stakeholder theory discussed earlier acts as the CG underpinnings for their operationalization, the Islamic governance model upholds Aqidah belief, Shari'ah, and ethics, which are derived from the Islamic maxims of free will, unity, equilibrium, and responsibility. These all act as cornerstones for IBs' operational standards. Apart from the ethical doctrines advocated in the Holy Quran and Sunnah, al-Kahtani (2014) proposes secondary sources such as *Ijmā* (consensus of opinions) and *qiyās* (analogical deduction) as vital foundations on which to base governance under Islamic jurisprudence (as cited in Al-Malkawi & Pillai, 2018, p. 606). Furthermore, an in-depth study by Zein et al. (2008) alludes to *Amanah* (trust), *Adalah* (justice), and *Shura* (consultations) from the Tawhid and the Quranic verses to bring out the essence of the principal–agent relationship. Here, it is presumed that managers are entrusted with *Amanah* by the shareholders, and its fulfilment would bring *Adalah* to the recipients. All this can be performed through *Shura*, or mutual decision-making. Additionally, Aljifri and Khandelwal (2013) address the specific features of Islamic financing, such as mandatory compliance with Shari'ah principles, the generation of fair returns to the investor, the ethical values of curtailing self-interest, and the avoidance of excessive risk-taking, as mitigators of agency-theory problems compared with their conventional counterparts, where the sole objective is profit generation without any embedded values. Alam et al. (2020) also highlight that it is anticipated that the moral responsibility and ethical sense in IBs will reduce agency-led implications, such as lowering necessary risk-taking actions (Alam et al., 2020).

1.2. Risk management

1.2.1. Introduction

Corporate failures and scandals have often been attributed to individuals like board members and executives. However, Power (2009) argues that the system itself also bears responsibility. Risk management, as a social construct, is influenced by its surrounding environment (Bhimani, 2009). It involves identifying, assessing, and prioritising risks, followed by the efficient application of resources to minimise and control their impacts (Hubbard, 2020). Enterprise risk management represents a comprehensive approach to managing risks across an organisation, although a universally accepted definition remains elusive.

This paper focuses on the overarching risk management aspects in the context of Islamic banking. It recognises the similarities and differences between risk management and enterprise resource management while emphasising the importance of effective CG in addressing the various risks faced by financial institutions. The concept of risk management in Islamic banking is inherently interconnected with its governance structure and principles (Archer & Karim, 2007). Islamic banks are subject to unique risks that stem from their adherence to Shari'ah principles, such as the prohibition of interest (*Riba*) and excessive speculation (*Gharar*) and the requirement to engage in ethical transactions (Iqbal & Mirakhor, 2011). This necessitates the development of tailored risk management approaches that accommodate the distinctive characteristics of Islamic financial institutions (Abdul Rahman, 2010). In this regard, one such approach is the application of Shari'ah-compliant risk mitigation instruments, such as profit and loss sharing contracts, which allocate risks and returns more equitably between the parties involved (Iqbal & Mirakhor, 2011). Moreover, IBs are required to establish SSBs, which oversee and monitor compliance with Shari'ah principles, acting as an additional layer of governance (Al-Suwailem, 2008). Risk management in Islamic banking also emphasises the importance of ethical considerations and social responsibility. The Maqasid al-Shari'ah (objectives of Shari'ah) framework guides institutions in achieving overall well-being and an equitable distribution of resources in society (Chapra et al., 2008). As such, IBs are expected to engage in socially responsible investments and avoid financing activities that may harm society or the environment (Hasan & Dridi, 2010).

In summary, effective risk management in Islamic banking is a multifaceted endeavour that involves addressing both conventional financial risks and those unique to Islamic finance. This necessitates a holistic approach that integrates governance, compliance with Shari'ah principles and ethical considerations, while drawing on insights from the broader field of risk management (Archer & Karim, 2007; Iqbal & Mirakhor, 2011).

1.2.2. Risk in banking

The strength of the banking systems, regardless of whether they are conventional or Islamic, lies in their ability to identify and manage risk levels and interest-rate spreads whilst maintaining strong liquidity, credible depositor bases and lucrative loan portfolios (Winterbottom, 2014). Monitoring, identifying, managing and measuring different kinds of banking risks such as credit risk, operational risk and currency risk are amongst the main missions of risk management to prevent such risks from occurring. On this note, Brunnermeier and Yogo (2009) argue that various types of bank risks may result in a liquidity risk, which then generates a spiralling effect and impacts the bank's reputation and overall performance. Thereby, liquidity risk acts as a contributory factor in the collapse of the overall financial system in the country, or even exacerbates contagion (Adalsteinsson, 2014).

Currently, liquidity risk has emerged as the most important element in an enterprise-wide risk management framework. Liquidity risk refers to the present and future risks arising from the bank's inability to meet its financial obligations. It stems from myriad factors such as unexpected cash outflows, large credit disbursements, unexpected market movements, the crystallisation of contingent obligations (see Winterbottom, 2014), external shocks and inter-bank rivalry issues. Liquidity risk can be divided into two main types: funding/cashflow liquidity risk and market / asset liquidity risk. The former relates to the capacity of a firm to fund its liabilities and the latter refers to the degree to which it will be difficult to dispose of an asset fast enough to avoid potential losses. As the foundation of IB relies more on participation than mere financial intermediation, the scope and intensity of risks are likely to be greater due to the various roles played by IBs as partners, investors, buyers, and sellers in comparison with the customary lender status in traditional banking.

Banks have evolved from traditional practices solely based on receipts of deposits and generating loans, with new instruments being launched, such as trading in financial markets and income generation through fees (Archer & Karim, 2007). Van Greuning and Bratanovic (2020) argue that this evolution of the banking system exposes banks to higher and more variable risks associated with the newly developed instruments. Also, banks must adapt quickly and develop risk management capabilities to survive in competitive financial markets and build consumer trust (Doğan & Ekşi, 2020). Van Greuning and Bratanovic (2020) divide banking risk into three main categories: First, financial risks, including traditional risks such as credit, balance sheet, solvency, and income statement structure; second, environmental risks, including but not limited to macroeconomic and policy concerns and legal and regulatory factors; and third, operational risks including compliance, internal control, technology and IT security, fraud and business continuity concerns. In addition to the academic literature, similar risk classifications have been presented

by other guidelines, such as those of the ACCA and the UK Code of Corporate Governance (FRC, 2018; McNulty et al., 2012).

Sundararajan (2007) argues that Islamic financial institutions (IFI) had seen a growth in the global markets due to globalisation and regulatory environment changes, which necessitated a more robust risk management system that enabled them to compete in financial markets. He also emphasises that IFIs were susceptible to more complex risks than their conventional counterparts, including contractual risk based on Islamic instruments that comply with Shari'ah principles, legal risk and governance risk. Finally, one of the main unique risks for Islamic banking, as discussed in the existing literature (Grassa & Matoussi, 2014), is the reputational risk caused by non-compliance with Shari'ah rules, which is also part of the business risk identified by Archer and Karim (2007). The current paper focuses on analysing risk management according to the main three categories determined by Archer and Karim (2007) and Van Greuning and Bratanovic (2020), namely, financial, business/environment and operational risk.

1.2.3. Corporate governance and risk management

Prior research attests to the inter-relationship between the risk management–CG nexus (Bhimani, 2009; Muhammad et al., 2023; Woods, 2009). It argues that both subjects strongly influence public policy debates and corporate control. Bhimani (2009) states that management's CG and risk management concepts can only be actionable if they are construed within three primary dimensions—technical, analytical and calculable—as well as continuously reassessing and developing risk management to adapt to the world's ongoing economic fluctuations. Woods (2009) discusses risk management as a dimension of CG and argues that although the principles of risk management are globally applicable, the industry's constant challenges require unique contingencies that can be generalized and adopted by enterprises later on. More recently, Muhammad et al. (2023) emphasise the relevance of board characteristics in influencing firms' systematic and unsystematic risk.

Therefore, it is essential to understand the definition of CG and its correlation with the board's function and risk management. The 1990s were considered the tipping point in the contemporary CG system. This was influenced by a myriad of reasons, such as the reform of the governance structure in both the USA and Germany, the response to the collapse of the 1990s global stock markets, and the shift towards a more enhanced shareholder model of CG (Cioffi, 2006). The publication of the first Cadbury report in 1992 (Committee on the Financial Aspects, 1992) was considered the pinnacle of the UK code of corporate governance and was arguably one of the most influential factors in policy and practice worldwide. However, the Islamic Financial Services

Board (IFSB, 2006) argued that all the core principles that helped form the modern norm of CG have existed in Islam since its establishment more than 1400 years ago. Therefore, CG as a set of values and standards is well known to all Muslims and Islamic institutions. Moreover, IFSB (2006) argues that there are more similarities than differences between Islamic institutions and their Western counterparts when it comes to good governance and ensuring fairness, transparency, and accountability. The sole element differentiating Islamic institutions from their more conventional peers is the religious factor and the Shari'ah roots in IFIs.

Delving into the plethora of CG benefits, Charny (1998) highlighted the role that CG plays in three main areas, namely, (a) reducing agency costs by monitoring executives and ensuring that all activities maximise shareholders' value; (b) establishing a good relationship between the corporation and its stakeholders, including employees, directors, creditors, and shareholders; and (c) achieving the state's socio-political and economic goals such as shareholder primacy in the UK and US or codetermination in Germany. In addition, the chain of uncertainties looming in the economy has undermined investor trust, thereby requiring a system to document environmental, social, and corporate governance (ESG) issues as well as to recognise and manage risks (Pillai et al., 2021).

On the above basis, this paper argues that CG in Islamic banking is still at the embryonic and formation stage and requires on-going reformation and development to reach the revolutionary stage that modern capitalism urgently needs. Therefore, a fusion between Western guidelines and Islamic principles might benefit the global banking sector by achieving a more robust CG system.

1.2.4. Corporate governance and risk in conventional and Islamic banks

Banks are the backbone of any economy, due to their significant role in people's lives and in organisational development. Therefore, CG in the banking sector is a primary focus for government guidelines and policymakers (OECD, 2010). The existing CG literature shows an orientation towards the banking sector, especially since 2007–2008 (Adams & Mehran, 2003; Alatassi & Letza, 2018; De Andres & Vallelado, 2008; Doğan & Ekşi, 2020). De Andres and Vallelado (2008) argue that CG is crucial for any country's economy because it provides financial institutions with appropriate rules and regulations to manage and participate in economic development. Islamic banking differs from its conventional counterparts by sharing profit and loss, prohibiting speculation and gambling, limiting non-performing loans (Chapra et al., 2008) and, most importantly, banning fixed interests (Farag et al., 2018). Moreover, all IBs' activities should comply with Shari'ah principles and be based on real

investment, which adds new stakeholders and unique players to the banks' structure. Thus, the CG structures of IBs differ from their western counterparts and require special attention (Farag et al., 2018; Safieddine, 2009). Godlewski et al. (2014) also question the pertinence of standardization in the Shari'ah governance practices embedded in Islamic finance activities. With respect to risk, Zarrouk et al. (2016) emphasise the high degree of financial risks inherent in IBs due to the mismatch between the undertaking of risky financial operations and returns guaranteed to customers.

Two prominent and unique stakeholders differentiate IBs' structure from that of conventional banks and add risk layers that do not exist in traditional banking. Investment account holders are the first category that is considered one of the unique stakeholders in Islamic banking. They provide the banks with funds via equity-based contracts called Mudaraba and Musharaka. While depositors in conventional banks receive a fixed interest on their deposits, investment account holders in IBs share profit and loss, including losses caused by their Shari'ah compliance investments, creating an extra unique risk assessment requirement to mitigate the additional risk. In this regard, Yanikkaya et al.'s (2018) findings related to incorporation of more non-murahabah assets as a financing structure to mitigate risks in IBs offer valuable insights.

Safieddine (2009) and Farag et al. (2018) argue that the unique nature and characteristics of the Islamic banking industry cause a specific and more complex agency problem compared with the typical agency dilemma. This dilemma is attributed to the separation between management and control. In Islamic banking, all stakeholders, including shareholders, policymakers, and investors, add a layer of agency caused by the separation between depositors' and investors' rights. Therefore, the managerial decisions should not only aim to maximise shareholders' wealth but also investment account holders' return on their investment. The second category of stakeholders, namely, the SSBs, are key players in the Shari'ah governance system, which the Islamic Financial Board defined as 'the structures and processes adopted by stakeholders in an institution offering Islamic Financial Services to ensure compliance with Shari'ah rules and principles' (IFSB, 2009). The Shari'ah board's role is to assure all stakeholders that the IBs' investment and activities comply with Islamic laws and avoid any non-compliance risk (Alnasser & Muhammed, 2012).

1.2.5. The role of the board in corporate governance

The board of directors is arguably the central pillar of the CG mechanism in all economies and plays a fundamental role in enhancing CG practices by taking on the responsibilities of monitoring and supervising the available re-

sources (Doğan & Eksi, 2020; Fernandes et al., 2017). One of the main differentiators between CG models worldwide is that the board structure is affected by many factors, including social, cultural, and financial factors (Grassa & Matoussi, 2014). Therefore, the board's role might vary from one country to another based on the structure (single or dual), rules, regulations, and cultures. However, there are certain fundamentals that most CG guidelines in the world have in common.

The board's role within the governance structure is not only limited to internal processes but also encompasses external and internal duties. According to Heracleous (1999), the board of directors' duties formally include monitoring the C-level in the organisation and participating in their strategic directions. Heracleous (1999) also add that while the normative expectation from the board of directors was high, they have not delivered in the last few years, which has increased the demand for different frameworks and policies designed to support the board and boost their performance. Therefore, directors have been under pressure from their primary stakeholders, such as institutional investors, politicians, and society, driven by disquiet and discomfort (Heracelous, 1999). Shareholders in the Anglo-Saxon countries led by the USA and UK, and in the majority of the EU members, use a single board of directors, who take responsibility for all corporations' activities. They hold this board accountable for maximising the value of the companies' shares. In contrast, countries such as Germany, Denmark, and the Netherlands adopt a dual board structure model, where shareholders elect the supervisory board members. It is the supervisory board's responsibility to appoint the executive management board, who are then responsible for running the business. In the dual structure, employees might be represented on the supervisory board (Mallin, 2016). There are pros and cons of each model (Farag et al., 2018). For example, a unitary board structure might benefit from characteristics such as a faster decision process, higher meeting frequency, and having both executives and non-executives engaged in the decision-making unit. However, a single-tier board lacks any actual separation between managerial and supervisory activities. A dual-board structure allows for a broader stakeholder representation to achieve better performance. Researchers such as Farag et al. (2018) argue that IBs' governance structure is based on a unique dual board structure: the board of directors and SSB. Nonetheless, Alatassi and Letza (2018) argue that the role of the SSB fluctuates between advisory and supervisory, depending on the policies and regulations in the countries of operation.

Adding to the former, Grais and Pellegrini (2006) report that the current role of the SSBs was limited to the Shari'ah compliance process, where SSBs approve and certify all financial instruments in IBs before launching them in the market. Moreover, it is the SSBs' responsibility to monitor the banks' activities and ensure all transactions comply with Shari'ah principles.

Furthermore, the IFSB (2006) states that SSBs should consist of at least three independent non-executive members, while Farag et al. (2018) contend that policymakers should allow room for reform in IBs' governance structure by enhancing the independence of SSBs, because shareholders currently hold the board of directors responsible for appointing the members of SSBs (IFSB, 2006). Furthermore, Farag et al. (2018) argue that policymakers for Islamic financial institutions should reform the design of the current CG structure in place and, instead of holding the board of directors in IBs responsible for appointing the SSB, the members of the SSBs should be given more independence to avoid any pressure from the board members. They also state that the regulators should reconsider the role that the SSB plays, changing it from a supervisory and consultative body to being mandatorily present in organisational affairs.

1.2.6. The role of the board in risk management

A bank's board is more critical for governance aspects than its non-bank counterparts for various reasons, which Doğan and Ekşi (2020) mainly attribute to the bank's ultimate responsibility towards both regulators and shareholders. Moreover, banks arguably face a high insolvency risk due to increased leverage, which also requires a premium to be paid to depositors as compensation. Thus, risk control is a vital responsibility of the board, and regardless of its composition (unitary, dual, Islamic, or conventional), a board must develop and enhance management activities to create precise risk management mechanisms (Deloitte, 2018). Van Greuning and Bratanovic (2009) mention that the quality of bank risk management, especially the risk management frameworks, is a critical concern in guaranteeing both individual banks' security and soundness and the overall financial framework. Furthermore, the ultimate responsibility for conducting a bank's business lies with the board of directors and the supervisory board, particularly where a dual board applies. The board also has to set strategic plans, appoint managers, establish operational policies, and, most importantly, take responsibility for ensuring a bank's reliability towards risks.

Research by Deloitte (2018) discusses in depth the roles and responsibilities of risk oversight in a dynamic and turbulent business environment, where risk is constantly evolving and requires the board to provide the same level of flexibility. It is the board's responsibility to monitor and guide management's activities regarding all risk activities, including, but not limited to, identifying, assessing, and monitoring risks. Nevertheless, Deloitte (2018) argues that all board should clearly define the risks that they will review regularly, and properly delegate the rest to the appropriate board committees, mainly the audit committee.

The SSB in IBs plays a pivotal role in managing the Shari'ah non-compliance risk, which is a unique and significant risk type specific to Islamic financial institutions (Hassan & Lewis, 2007). Shari'ah non-compliance risk arises when a financial transaction or product fails to comply with Islamic jurisprudence or Shari'ah principles, leading to the potential invalidation of contracts and financial losses (Karim & Archer, 2002). This risk is distinct from conventional banking risks such as liquidity or credit risk, which are typically overseen by the main board of the bank. The SSB's expertise in Islamic jurisprudence is crucial for ensuring that all banking activities align with Shari'ah principles, including the prohibition of *Riba* (interest), *Gharar* (excessive uncertainty), and *Maysir* (gambling). This is only achieved by closely collaborating with the main board, because the SSB helps in structuring products and auditing transactions to avoid any form of non-compliance (El-Hawary et al., 2007). Their role extends to ongoing monitoring and reviewing of bank operations to ensure adherence to Shari'ah laws, thus safeguarding the bank against the reputational and financial risks associated with Shari'ah non-compliance (Sundararajan & Errico, 2002). The SSB's guidance is indispensable for IBs, because Shari'ah non-compliance not only affects the legality of transactions but also impacts customer trust and the bank's reputation in the market (Khan & Bhatti, 2008). Therefore, their strategic collaboration with the main board is essential for mitigating this unique risk and ensuring the overall sustainability and growth of Islamic banking institutions

1.3. Summary

The research gap identified in the literature pertains to the lack of comprehensive and comparative studies on the role of board structures and risk management practices in conventional and Islamic banking systems (Grassa & Matoussi, 2014). Although previous literature has acknowledged the unique dual-board structure in IBs (Farag et al., 2018) and offer some insights into risk management frameworks (Deloitte, 2018; IFSB, 2006), there is still a dearth of knowledge for understanding the comparative effectiveness of these practices in both banking systems and how they may affect financial stability and resilience. A few initiatives, such as the guidelines provided by the Islamic Financial Services Board (IFSB, 2006), have made progress in addressing the research gap by outlining the roles and responsibilities of the board and risk oversight in IBs. However, these efforts do not provide an up-to-date and comprehensive understanding of the interaction between board structures, risk management practices, and the impact on overall financial stability in both Western and Islamic banks—a gap that warrants further investigation.

2. Methodology

This section outlines the methodology used to conduct a comparative analysis of risk management guidelines in the CG codes of four countries, namely, the UK, Germany, Saudi Arabia, and Malaysia, in both Western and Islamic banking systems. The core of this methodology is a document analysis approach, tailored in order to scrutinize the roles and responsibilities outlined in the CG codes regarding risk management.

The methodology, set out in detail by Bowen (2009), facilitates an in-depth exploration of textual data to unearth themes, patterns and insights relevant to board responsibilities in both Western and Islamic financial institutions. Following a structured approach, documents including CG codes, regulatory guidelines and Shari'ah governance frameworks were systematically reviewed and analysed. This enabled a comparative analysis of risk management policies, the role of board in directing risk management strategies and the unique position of Shari'ah committees in IBs. The approach is similar to the study by Aguilera and Cuervo-Cazurra (2004), and others who have highlighted the global diffusion of governance codes and their implications on firm performance and governance practices. The document analysis approach, which is rooted in qualitative research traditions, supports the synthesis of empirical evidence on the alignment of risk management practices with Shari'ah principles, contributing novel insights into the governance structures that bolster the resilience of IBs within the global financial ecosystem.

The philosophical basis for the comparative analysis approach can be traced back to the works of several social science scholars and philosophers, most notably Emile Durkheim (1982). Comparative analysis is rooted in the belief that understanding complex social phenomena can be effectively achieved by comparing and contrasting different cases or instances. The underlying philosophy of comparative analysis is grounded in the positivist and interpretivist paradigms (Bryman, 2001). On the one hand, positivism emphasises the use of empirical, systematic and objective methods to study social phenomena, while interpretivism, on the other hand, focuses on understanding the meanings that individuals and groups ascribe to their experiences. In comparative analysis, researchers seek to identify similarities and differences between the cases being studied, as well as uncover patterns, relationships, and underlying mechanisms that can help explain the phenomena being observed (Ragin, 2014). By analysing multiple cases, comparative analysis allows for a deeper understanding of the social, political, economic and cultural contexts that shape the phenomena under investigation. Consequently, this approach helps researchers to test theories, identify factors that influence outcomes, and generate new hypotheses for future research (Bryman, 2001).

2.1. Data collection

The data for this study were obtained from secondary sources, including the latest versions of the CG codes of the UK, Germany, Saudi Arabia, and Malaysia, as well as relevant guidelines, regulations, and frameworks published by the respective authorities. The data collection process entailed searching and reviewing various academic and professional databases, such as Google Scholar, ProQuest, and EBSCOhost, using a combination of keywords like 'corporate governance', 'risk management', 'UK Code of Corporate Governance', 'German Code of Corporate Governance', 'Saudi Corporate Governance Code', 'Malaysian Corporate Governance Code', 'Shari'ah governance' and 'Islamic banking systems'. To ensure a comprehensive analysis, the paper focuses on the application and adoption of risk management guidelines in each report, as well as the roles of the board and its committees. To compare and contrast the risk management guidelines across multiple countries and banking systems, this paper uses a comparative analysis approach. Specifically, the study analyses the 2018 UK Code of CG and the 2020 German Code of CG to assess the board' roles and responsibilities in risk management. In addition, the paper analyses the 2017 Saudi CG Code and the 2021 Malaysian CG Code, which are leading countries in Islamic banking, to provide a similar analysis. To further consider the unique requirements of Islamic finance, the study analyses the Shari'ah governance guidelines published by the Saudi Monetary Authority (SAMA, 2020) and the 2010 Central Bank of Malaysia Shari'ah Governance Framework for IFIs (Central Bank of Malaysia, 2010).

The rationale for selecting the four countries in this study was based on their unique approaches to CG and Islamic banking and their prominence in the global economy (OECD, 2014a). The UK and Germany are well-known for their strong CG systems, while Saudi Arabia and Malaysia are leading countries in the Islamic banking system. The UK is a world leader in CG and employs a single board structure, while Germany follows a dual board structure. The importance of CG and Islamic banking systems in these four countries cannot be overstated because the effectiveness of these systems can significantly impact each country's economic and business conditions. For example, the 2008 global financial crisis highlighted the importance of effective risk management in CG, while the growth of Islamic finance has led to the development of new financial products and services in Saudi Arabia and Malaysia.

2.2. Analysis process

The document analysis methodology employed in this study was organized to scrutinize CG reports across the UK, Germany, Saudi Arabia, and Malaysia, with an emphasis on understanding risk management frameworks within conventional and Islamic banking systems. The process commenced with the identification of essential keywords, including 'corporate governance,' 'risk management', 'Risk', 'Committee', 'Shari'ah governance', 'Shari'ah Board', thus facilitating a targeted search for the most recent CG codes and related documents.

This preparatory step was instrumental in assembling a comprehensive database for analysis. Subsequently, a comparative document analysis was conducted, examining each CG code to delineate the roles and responsibilities attributed to board in the realm of risk management, paying special attention to the incorporation of Shari'ah governance principles in Islamic financial institutions. This analysis was pivotal in extracting and synthesizing critical information, thereby enabling a structured evaluation of the alignment between CG codes and risk management practices. Special attention was given to analysing Shari'ah governance guidelines to assess their integration into the broader CG frameworks. This methodological approach offered insights into the governance mechanisms underpinning risk management strategies, highlighting both the commonalities and disparities across different banking systems and underscoring the unique compliance with Shari'ah principles within Islamic banking.

This study built on the OECD's Risk Management and CG report (2014b), which applied similar methodology covering 27 jurisdictions, including the UK and Germany, and provided valuable insights for policymakers, regulatory bodies, and financial institutions on how to improve risk management practices. The comparative analysis of the CG and Islamic banking systems in the four countries studied provided insights into their approaches to risk management, board structures, and Shari'ah governance. This highlighted the importance of learning from the unique features of each system, which can lead to improvements in risk management practices, ultimately driving economic growth. The data analysis process involved reviewing the collected documents, extracting key information, and comparing and contrasting the risk management guidelines across the four countries. The paper focuses on specific aspects of risk management in CG codes, including application and adoption, board roles in risk management, committees and responsibilities, and Shari'ah governance.

3. Results and findings

3.1. Risk management guidelines in countries

Table 1 presents a comparative analysis to assess the risk management guidelines in the CG codes of four countries - the UK, Germany, Saudi Arabia, and Malaysia. The board' roles and responsibilities towards risk management were examined by focusing on the 2018 UK Code of CG, the 2020 German Code of CG, the 2017 Saudi CG Code, and the 2021 Malaysian CG Code. The unique requirements of Islamic finance were addressed by analysing the Shari'ah governance guidelines for Saudi Arabia and Malaysia.

In the UK, the 'comply or explain' approach struck a balance between flexibility and accountability within CG frameworks, allowing companies to adapt

Table 1. Comparison of risk management in CG codes in the UK, Germany, Saudi Arabia, and Malaysia

Country / Criteria	United Kingdom	Germany	Saudi Arabia	Malaysia
Application & adoption of the codes	comply or explain	mandatory (law enforcement)	mandatory with some guidance	mandatory (Islamic Financial Services Act)
Board's role in risk management	strategic planning, risk monitoring, and internal control	strategic decision-making, risk supervision, and compliance	comprehensive strategy, risk culture development, risk management instruments	overall governance structure and compliance, Shari'ah-related matters
Committees & responsibilities	audit committee: risk management systems, internal control, and financial reporting	supervisory board: oversight of management board, risk management, and compliance	advisory risk committee: risk plans, risk assessment, acceptable risk levels	Shari'ah Committee: Shari'ah governance, risk implication, oversight of internal audit, risk management, and compliance
Shari'ah Governance (if applicable)	N/A	N/A	Shari'ah Governance Framework	BNM Shari'ah governance

Note: Table 1 is a summary of the key aspects of risk management in CG codes in the UK, Germany, Saudi Arabia, and Malaysia. The full text is available at https://www.ecgi.global/content/codes.

Source: own work.

to dynamic market conditions while maintaining transparency. Therefore, integral to this structure was the Audit Committee, whose oversight was vital for upholding financial integrity and managing risk, ensuring that organizations adhered to high standards of financial reporting and control.

In Germany, CG was characterized by stringent legal requirements that mandated robust risk governance. The supervisory board was central to this system, functioning independently of the management board. It was tasked with compliance oversight, reinforcing the division between strategic supervision and operational management. This demarcation underlined the German model's emphasis on checks and balances.

In contrast, Saudi Arabia embedded risk management within its strategic framework, with a pronounced emphasis on fostering a risk-aware culture across corporate entities. This approach was supplemented by the Shari'ah Governance Framework, which imposed a unique set of compliance standards that ensured corporate practices were in line with Islamic principles, thereby integrating ethical considerations into the core of business operations.

Finally, in Malaysia, the CG landscape was similarly influenced by Islamic principles, as enforced by the Islamic Financial Services Act. The Shari'ah Committee was pivotal in this context, ensuring that all financial practices complied with Shari'ah law. This compliance was not just a legal formality but a defining trait of the Malaysian financial sector, distinguishing its governance model on the global stage.

Each of these countries demonstrated a unique confluence of regulatory compliance, cultural ethos, and governance mechanisms, illustrating the diversity of approaches to corporate governance in different legal and cultural settings.

3.1.1. The board's role in risk management

The UK and German codes both placed the responsibility for risk management on the board, with a focus on strategic planning, risk monitoring and internal control in the UK and strategic decision-making, risk supervision and compliance in Germany. The Saudi code placed an emphasis on setting a comprehensive strategy, developing a risk culture, and providing risk management instruments, while the Malaysian Shari'ah Governance Guidelines held the board accountable for the overall governance structure and compliance, including Shari'ah-related matters.

3.1.2. Committees and responsibilities

All four countries had designated committees responsible for specific aspects of risk management. The UK and German codes highlighted the role of the Audit Committee in overseeing risk management systems, internal con-

trol and financial reporting. The Saudi Code required companies to form an Advisory Risk Committee with duties including setting risk plans, assessing risk-taking abilities and determining acceptable risk levels. The Malaysian Shari'ah Governance Guidelines assigned the Shari'ah Committee responsibilities such as Shari'ah governance, risk implication, and oversight of internal audits, risk management, and compliance.

3.1.3. Shari'ah governance

Shari'ah governance played a significant role in the risk management guidelines of Saudi Arabia and Malaysia. The Saudi Shari'ah Governance Framework focused on setting roles and responsibilities, ensuring the integration of Shari'ah principles in finance, and reinforcing the competence of internal control and risk management committees. The Malaysian BNM Shari'ah Governance Guidelines stressed the importance of identifying, measuring, monitoring, and reporting Shari'ah non-compliance risks and emphasised the management of reputational risks associated with Shari'ah non-compliance. The UK and German codes did not directly address Shari'ah governance because it was not applicable to their banking systems.

This critical comparative analysis highlighted the similarities and differences in the risk management guidelines within the CG codes of the UK, Germany, Saudi Arabia, and Malaysia. All four countries placed significant emphasis on the board' roles and responsibilities in risk management, but they adopted different approaches in application and enforcement. The Shari'ah governance aspect played a crucial role in the Islamic banking systems of Saudi Arabia and Malaysia. While Western and Islamic banking systems differed significantly in their governance structures, there were shared principles that transcended cultural and religious boundaries. For instance, the importance of risk management, transparency and accountability were universally recognised as crucial components of a robust CG framework. Ultimately, understanding these shared principles and learning from the unique features of each system can lead to better governance practices worldwide.

3.2. Similarities and differences between the CG and risk management guidelines in the four countries

Table 2 highlights the key differences and similarities between the CG and risk management guidelines in UK, Germany, Saudi Arabia, and Malaysia. The table establishes a comparative analysis of the countries studied and identifies areas where each country's guidelines could benefit from the experience of the others.

Table 2. Key differences and similarities in risk management guidelines

Country / Criteria	UK	Germany	Saudi Arabia	Malaysia
Application & adaption	comply or explain	obligation	mandatory	comply or explain
Board structure	single board system	dual board system	single board system	single board system
Risk management role	board of directors	management board	board of directors	board of directors
Risk reporting	to stakeholders	supervisory board	to stakeholders	to stakeholders
Shari'ah governance	not applicable	not applicable	applicable	applicable
Board composition	no specific requirement	no specific requirement	encourages inclusion of Shari'ah committee member	encourages inclusion of Shari'ah committee member

Source: own work.

On the basis of the comparison, it was evident that while all four countries placed significant emphasis on the board' roles and responsibilities in risk management, they adopted different approaches in application and enforcement. The UK and Malaysian codes followed a 'comply or explain' approach, allowing for flexibility in the application of the core principles. In contrast, the German and Saudi codes leaned more towards obligatory enforcement. The German code also featured a unique dual board structure, with a management board and a supervisory board, which differed from the single-board systems adopted in the UK, Saudi Arabia and Malaysia.

The Shari'ah governance aspect constituted a crucial difference between the Islamic and Western banking systems. Both Saudi Arabia and Malaysia had specific guidelines addressing Shari'ah risk management and the roles of the board of directors in overseeing compliance with Shari'ah principles. However, it should be noted that even within the Islamic banking systems, differences exist in the application and adaptation of their CG codes, with Saudi Arabia adopting a more stringent, mandatory approach and Malaysia following a 'comply or explain' policy.

In all four countries, the board of directors had a direct relationship with the risk management and audit committees. In Germany, the management board reported to the supervisory board, which then had a relationship with the audit committee. In Saudi Arabia and Malaysia, the board of directors also had a direct relationship with the Shari'ah committee and the compliance committee. Additionally, both Saudi Arabia and Malaysia had a unique

relationship, where the board of directors was responsible for the Shari'ah governance framework.

3.3. Board-committee relationships

Finally, the structure and governance of corporate board and their associated committees played a pivotal role in the effective oversight and accountability of organisations. Table 3 offers a comprehensive perspective on the intricate relationship between the board and its committees across four distinct nations: the UK, Germany, Saudi Arabia, and Malaysia.

Table 3. Board-committee relationship

BoD's Relationship	UK	Germany	Saudi Arabia	Malaysia
Board of Directors -> Risk Management Committee	direct	via management board	direct	direct
Board of Directors -> Audit Committee	direct	via supervisory board	direct	direct
Board of Directors -> Shari'ah Committee	N/A	N/A	direct	direct
Board of Directors -> Compliance Committee	direct	via supervisory board	direct	direct
Board of Directors -> Shari'ah Governance Framework	N/A	N/A	direct	direct

Source: own work.

In the UK, the relationship between the Board of Directors and the Risk Management Committee was direct, suggesting a streamlined approach to risk management that benefited from immediate oversight from the board. However, Germany's board structure was notably distinct, embracing a dual-board system. This system bifurcated the board into a management board and a supervisory board, where the former assumed direct responsibility for the Risk Management Committee, while the latter provided oversight for the Audit Committee. This tiered structure, inherent to Germany's corporate landscape, strove to strike a balance between executive decision-making and supervisory control, even though it could introduce potential communication challenges. Both Saudi Arabia and Malaysia depicted analogous governance structures. Their Board of Directors maintained a direct relationship with the Risk Management Committee, Audit Committee, and, more uniquely, the Shari'ah Committee. The emphasis on the Shari'ah Committee and the ac-

companying Shari'ah Governance Framework underscored the profound significance of compliance with Islamic principles in Islamic banking operations. Furthermore, this commitment to Islamic principles resonates with the growing global acknowledgment of the importance of Islamic finance. Moreover, the inclusion of a compliance committee in their governance structure boosted the emphasis on rigorous adherence to both the regulatory framework and religious guidelines. In essence, while countries like the UK and Germany mould their governance structures to suit their distinct economic and regulatory environments, nations such as Saudi Arabia and Malaysia embed Islamic principles within their governance paradigms. Therefore, this analysis emphasises the importance for corporations, especially those operating across various jurisdictions, to possess a deep understanding of these diverse board and committee relationships.

In summary, the paper's findings align with those reported in the literature (Bhimani, 2009; Muhammed et al., 2023; Woods, 2009), namely, that both CG and risk management are interrelated. Moreover, results also evince that the board of directors is ultimately responsible for managing the risk regardless of the CG structure, single or dual system. Finally, the ultimate responsibility for Shari'ah risks lies with the directors and not the committees, because it is the board's responsibility to adhere to the recommendations of the SSB, also known as the Shari'ah committee.

Conclusions

The paper outlines a comparative analysis of CG and risk management guidelines in four countries, namely, the UK, Germany, Saudi Arabia, and Malaysia. It focuses on the relationship between the board of directors, committees, and various aspects of risk management in both Western and Islamic banking systems. The research aimed to compare and contrast risk management policies across the countries studied, assess the board's roles in leading risk management strategies, and review the Shari'ah committee or SSB's position in accommodating the unique risks of IBs.

The analysis found that each country's codes and guidelines aimed to boost stakeholders' confidence, increase CG effectiveness, and support institutions in managing various types of risks. Moreover, the application and adoption of these codes varied, with Western countries such as the UK adopting a more flexible approach with a 'comply or explain' policy, while Germany took a more rigid stance using terms like 'obligation' to emphasise law enforcement. In the Islamic banking sector, Malaysia followed the UK's 'comply or explain' approach, whereas Saudi Arabia's code application was mandatory.

In terms of the board's role in managing risk, all codes in both Western and Islamic countries held the board of directors ultimately responsible for risk management, establishing strategies, and forming committees. However, there were some unique requirements depending on the country and board structure. For example, Germany's dual-board structure held the management board responsible for adhering to the law, reporting to the supervisory board on strategic matters, overseeing risk operations and establishing committees.

Regarding Shari'ah risk management, Malaysia and Saudi Arabia held the board of directors ultimately responsible, while encouraging a comprehensive risk management approach that included Shari'ah aspects, with the SSB being an additional layer board. In contrast, leading Western countries such as UK and Germany neglected the Shari'ah aspect, despite the significant share of Islamic finance in their economies.

These findings align with previous research by Alatassi and Letza (2018), which explores the idea of fusing Western corporate governance elements with Islamic principles to create a more robust governance structure, including risk management. This study can assist policymakers, regulatory bodies and financial institutions in improving risk management practices by learning from the unique features of each system.

However, the paper is not free from limitations due to its focus on CG codes in only four major Western and Eastern nations and the qualitative analysis performed. Future research could explore a broader spectrum of countries in Islamic finance, perform an empirical study and analyse banks' publications and annual reports to assess compliance with best practice codes. It would also be useful to investigate the extent to which the SSB influences risk management strategies and the ethical behaviour of the board. Moreover, studies can explore the possibility of highlighting the board's responsibility to Shari'ah activities in Western countries where Islamic finance being adopted.

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sciendo Economics and Business Review https://www.ebr.edu.pl Vol. 10 (1), 2024: 153–178 https://doi.org/10.18559/ebr.2024.1.1068

Silver entrepreneurship: A golden opportunity for ageing society

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Abstract

This paper aims to discuss the notion of silver entrepreneurship in the context of the silver economy. Policy-wise knowing who silver entrepreneurs are and what it takes to support them is an essential step to productively managing the ageing population and promoting an age-ready but age-friendly approach to creating a sustainable economy and society in the new demographic reality. The paper provides a theoretical and empirical literature review of silver entrepreneurship to identify the current state of the art. It also identifies selected policies and strategies aiming to foster silver entrepreneurship, representing a more inclusive and age-diverse entrepreneurial landscape. The silver entrepreneurship proves to be a challenging research field due to the elusive nature of entrepreneurship itself and the lack of universal definitions for this phenomenon.

Keywords

- ageing population
- silver economy
- entrepreneurship
- silver entrepreneurs

JEL codes: J11, L26

Article received 28 November 2023, accepted 15 March 2024.

Suggested citation: Barković Bojanić, I., Erceg, A., & Damoska Sekuloska, J. (2024). Silver entrepreneurship: A golden opportunity for ageing society. *Economics and Business Review*, *10*(1), 153–178. https://doi.org/10.18559/ebr.2024.1.1068

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Introduction

Population ageing is an undeniable global demographic shift. According to the United Nations Department of Economic and Social Affairs, Population Division (2022), the number of older individuals in the population is on the rise, both in terms of overall numbers and as a percentage of the total population. Projections indicate that the global proportion of people aged 65 and above will increase from 10% in 2022 to 16% by 2050. By 2050 the worldwide count of individuals aged 65 and older is expected to surpass twice the number of children under 5 years old and approximately equal the number of children under 12. This shift in population demographics toward older ages is primarily attributed to lower mortality rates and increased life expectancy while a sustained decline in fertility levels contributes to the overall ageing of the population. While these statistics reshape the age pyramid and mark successes in extending human life they also raise concerns. Traditionally population ageing has been linked to negative stereotypes and challenges associated with the impact of older individuals (Officer et al., 2020). However, the dynamics of the population's age structure are evolving. The conventional three phases of life—education, employment and retirement—no longer strictly follow one another and are often overlapping.

Today's older generation is healthier and more active, challenging preconceptions. Also older people are not to be underestimated in purchasing power. Thus the 'new' elderly are emerging as a vital economic force. The economic market of older people is recognised as the silver economy, defined as the total economic activities catering to the requirements of individuals aged 50 and above (European Commission, 2015). This includes the products and services directly consumed by this group of people and the additional economic activity generated by their spending. The European Silver Economy is valued at approximately €3.7 trillion and is projected to rise to €5.7 trillion by 2025. This sector contributes 32% of the EU's gross domestic product and sustains 38% of EU employment (McGuirk et al., 2022). Interestingly if the number of people aged 50 and over in the EU would be in one country it would be the third largest in the world, behind the USA and China (Technopolis & Oxford Economics, 2018).

The ageing of the population presents numerous challenges yet it also opens possibilities for businesses. As older age brings specific needs, future solutions driven by new technologies differ from those of previous generations. Examples include telecare for prolonged independent living, age-adapted phones and biometric cash machines. This growing demand can stimu-

late the regional economy by generating jobs and companies and enhancing national competitiveness. Profitable businesses, especially in nanoscience, biotechnology, robotics and artificial intelligence, are investing in improving people's later years. The economic potential of ageing is strongly linked to innovation and entrepreneurship leading the way to silver entrepreneurship as a (pro)active answer. Thus the silver economy and silver entrepreneurship are gaining momentum in academic and business communities and with policymakers as emerging innovative areas (Diez et al., 2022).

This paper aims to discuss the notion of silver entrepreneurship in the context of the silver economy. There are two primary research questions addressed in this study. Firstly it examines the definition of silver entrepreneurs focusing on whether there exists a distinction between older individuals who have been engaged in entrepreneurship throughout their careers and reach retirement as entrepreneurs, as opposed to those who commence entrepreneurial ventures later in life or following retirement. While acknowledgment of silver entrepreneurship exists both theoretically and practically the second question delves into the reasons behind the absence of specific policies catering to silver entrepreneurs. Although certain EU initiatives and policies indirectly support silver entrepreneurship by fostering entrepreneurship in general or tackling issues such as age discrimination in the labour market a comprehensive framework for supporting silver entrepreneurship is lacking. Policy-wise knowing who silver entrepreneurs are and what it takes to support them is essential to managing the population's ageing productively and promoting not only an age-ready but age-friendly approach to creating a sustainable economy and society in the new demographic reality. The paper attempts to provide answers to the previous research questions through a theoretical and empirical literature review of silver entrepreneurship to identify the current state of the art. It also identifies selected policies and strategies to foster silver entrepreneurship representing a more inclusive and age-diverse entrepreneurial landscape. The paper contributes to the establishment of a reference base for further research or/and formulating policy guidelines when promoting entrepreneurship as an engine of growth and development, particularly in the context of demographic transition.

After introductory remarks the rest of the paper is organised as follows. Section 1 reviews existing literature related to population ageing and its impact on the economy in terms of developing a silver economy. The next sections deal with the question of silver entrepreneurship. Section 5 discusses policies necessary for supporting silver entrepreneurship. The paper ends with the conclusion and proposals for further research.

1. The concept of silver economy

One of the greatest achievements in human history is population ageing (United Nations, 2019). People live longer and have healthier lives due to advancements in medicine, health and social care and technological advancements. Increased life expectancy, together with continued declines in fertility rates, is turning the demographic pyramid upside down with more older people than younger for the first time in history. Population ageing has long been stereotyped as a negative trend that adversely affects economic growth. The arguments have been related to the reduction of labour force participation and productivity (Gordon, 2016), the impact on public health support (Cristea et al., 2020), pressure on the health and social support system and national savings rates (Bloom et al., 2015). According to Prettner (2013), the support ratios are expected to decrease. This is because fewer workers will need to shoulder the responsibility of funding a larger population of retirees. Additionally, productivity levels are anticipated to shift due to age-specific productivity profiles and savings' behaviours will likely change as individuals expect longer lifespans. In their research Maestas et al. (2016) estimated that population ageing reduced the growth rate in GDP per capita by 0.3%age points per year during the 1980–2010 period. However, the impact of population ageing on economic growth and development is not as straightforward as it may seem. For example, Bloom et al. (2010) found that demographic changes in Asia from 1960 to 2005 had a noteworthy impact on economic growth. While a higher young-age dependency ratio positively influenced growth the old-age dependency ratio had a significantly negative effect on short-term growth but only a negligible impact on long-term growth. The study also identified behavioural responses to age structure shifts such as increased female labour force participation, higher savings and a greater emphasis on education. These responses when combined tended to counteract the negative effects of an ageing population resulting in an overall insignificant impact on economic performance. Aksoy et al. (2019) also offered empirical support for the connection between demographic composition and innovation engagement. They found that middle-aged (working-age) cohorts positively influenced patent applications but were negatively impacted by retirees. These innovation activities act as a crucial channel and are especially significant in generating mitigated long-term output growth in the light of ageing. The literature suggests that policy and institutional environment significantly mitigate the negative effects of population ageing on the economy and society (e.g., Gusmano & Okma, 2018).

Recently perceptions of older individuals and their impact on the economy and society have been changing. Not only is the elderly population increasing in number but the experience of ageing today is markedly distinct from that

of several decades ago. So-called "new elderly", i.e. new generations of older people, are healthier, better off and more active and positively engaged in the world than previous generations (Katz, 2000). They also tend to be more intelligent, physically fit, and happier than the people who turned 75 roughly two decades ago (Gerstorf et al., 2015).

The economic potential of older people has been recognised as they are beginning to play a more critical part in shaping economies worldwide and are forming a substantial and expanding consumer base in various sectors. According to Aacius and Suh (2019), people 50 and older represent approximately 34% of the worldwide GDP amounting to $45 trillion. Projections indicate that this demographic contribution is anticipated to increase to 39% of the global GDP, reaching $118 trillion by 2050. Global consumer spending will reach $96 trillion by 2050 compared to $35 trillion recorded in 2020. Spending on goods and services related to those age 50+ supported slightly over one billion world jobs in 2020, amounting to $23 trillion in labour income and it is expected to support 1.5 billion jobs, generating a global labour income of $53 trillion (Aacius & Suh, 2019). Business opportunities have appeared ever since the ageing markets have been growing in many sectors such as medical and long-term care goods and services, leisure and lifestyle, food and financial services, etc.

While demographers called this demographic transition a silver tsunami economists have found an equally vivid expression: *silver economy*. The concept of the silver economy has arisen to encompass the activities related to the needs and desires of older adults and their impact on various economic sectors. It signifies a noteworthy shift from the prior perception of older adults, specifically retired individuals, as merely a financial burden. Instead the negative demographic trend of ageing is now being regarded as an opportunity in the market leading to the creation of new jobs and workplaces (Barković Bojanić & Erceg, 2017). The silver economy refers to the economic possibilities that emerge from public and consumer spending linked to the ageing population and the distinct requirements of individuals aged 50 and above. This demographic can be categorised into three groups—active, fragile and dependent—each characterised by unique needs. Consequently the silver economy is a significant segment of the broader consumer economy, highlighting noteworthy differences in spending priorities and patterns. (European Commission, 2015, p. 2).

Klimczuk (2021) offers another valuable definition of the silver economy: the economic system that emphasises equilibrium in the realms of production, distribution, consumption and the trade of goods and services essential for both older adults and younger, yet ageing, generations. The core components of this system revolve around gerontechnology embedded in products and services specifically crafted to cater to the needs of an ageing population. Key players in this ecosystem include elderly employees, senior entrepreneurs,

senior consumers and senior investors. A similar definition is given by Leśna-Wierszołowicz (2018), who defines the silver economy as a strategic response to demographic shifts aiming to supply goods and services to the expanding demographic of elderly consumers. The core concept is that the elderly, if healthy and active, are not just recipients but active contributors—both socially and economically. By recognising older individuals as a productive and socially valuable group, the silver economy seeks to harness their potential to stimulate economic growth and foster the creation of new jobs (Leśna-Wierszołowicz, 2018). The silver economy encompasses a range of economic activities dedicated to meeting the needs of older adults. This encompasses various aspects such as leisure, well-being, transportation, housing, education, nutrition, health and potential employment, as illustrated in Figure 1.

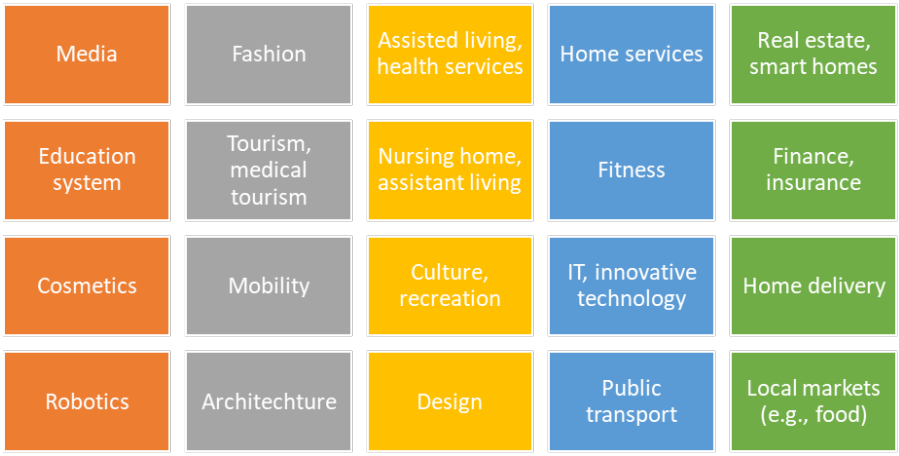

Figure 1. Economic segments affected by the silver economy

Source: adapted from (Zsarnoczky, 2018, p. 22).

Zsarnoczky (2018) highlighted in his study that the silver economy has the potential to influence and impact every sector of the economy. The World Economic Forum (2016, p. 7) stated core areas in which one can expect investments and innovations related to the ageing population:

- Investing in medical and long-term care services, including pharmaceuticals, is expected to yield significant returns especially in age-related diseases and functional impairments. This extends to markets for devices like home-based dialysis technology, IT-based care and smart homes with assisted living systems.
- In leisure, lifestyle and living support for those aged 60 and above substantial business opportunities lie in assisted living communities offering daily services. Age-adapted products and innovations such as driverless

vehicles, age-adjusted technology and specific holiday arrangements also present economic potential.
- The food industry anticipates growth in demand for dietary, allergy-friendly, flavourful and soft textured foods due to an ageing population. This opens avenues for lucrative investments in age-specific food markets.
- The financial services industry is poised for significant opportunities in serving ageing baby boomers, particularly in investments and insurance and including voluntary pensions. Addressing the substantial wealth older populations hold in advanced economies will be crucial.
- The construction and transport industry are gearing up for investments in age-friendly environments. Adapting workplaces, constructing homes considering age-related impairments and ensuring accessibility in public spaces are crucial areas with enormous investment potential.

Technology plays a vital role in creating a silver economy. As stated by Zsarnoczky (2018) the silver economy promotes strategies focused on unique technology services aiming to support the well-being of older people through, e.g., health monitoring, electrical mobility, web-based home care solutions. In line with that ageing-in-place is one of the concepts rapidly emerging due to the preference of older people to stay at home. However, they find it difficult since their physical, cognitive and social functional capacities are declining. Thus, the rising need for ageing-in-place services drives innovation in elderly healthcare, social support and home care sectors (Yang et al., 2015). Integrating technology in products and services tailored for older individuals enhances their well-being and opens new economic opportunities within the silver economy. Every facet of the silver economy calls upon diverse stakeholders, including governments, companies, NGOs and others to engage in innovative approaches for conducting business directed toward senior citizens.

The silver economy encompasses all economic activities related to the consumption, production and provision of goods and services including healthcare, financial services, housing, leisure and travel, targeted at older adults (Klimczuk, 2021). The silver entrepreneurship and the silver economy are mutually reinforcing. The growing demand in the silver economy creates opportunities for silver entrepreneurs while their innovative contributions further fuel the growth and development of the market (Matos et al., 2018). Therefore, it can be stated that this relationship holds significant potential for economic growth, social inclusion, and individual fulfilment.

The question of older people behaving entrepreneurially after their careers ended is fascinating. Namely there is more and more evidence that older people tend to behave in an entrepreneurial way, from being more active in social spheres (e.g., volunteering), getting back into the workforce, or even becoming self-employed using the money from retirement as a venture capital. The well-known example of Harland Sanders creating the famous

Kentucky Fried Chicken at age 62 is followed by numerous examples where older age was not an obstacle to becoming an entrepreneur (Patel, 2015). Older people do not seem to lose innovative capacities as suggested by Ruiu and Breschi (2019) thus entrepreneurship at an older age, or silver entrepreneurship may be a productive response to counterbalance the adverse effect of population ageing. Silver entrepreneurship refers to older individuals who start their new venture either after retirement or at late-state career transition (Greco, Tregua et al., 2022). Cornet (2014) stated that the silver market which targets older people presents opportunities for product development and innovation to meet the needs of this growing demographic while Cannon (2008) concluded that the silver economy concept seeks to capture the buying power of older consumers to support the innovation market for healthcare and autonomy services. Silver entrepreneurship is becoming an exciting and vital research area whereby various authors investigate the importance of silver entrepreneurship (e.g., Kautonen, 2013) as well as the motivations behind the choice of older people to become entrepreneurs despite older age (Greco, Tregua et al., 2022; Ilczuk et al., 2023).

2. Being self-employed as senior

Studies showed that a higher share of self-employed people remain working after retirement (over 65 years) than those who work as regular employees (OECD & European Commission, 2021). The importance of silver entrepreneurship and silver entrepreneurs can be seen in the share of working seniors who are self-employed increases to 39% for 65–69-year-olds and 52% for 70–74-year-olds (in 2020) (OECD & European Commission, 2021). The OECD and European Commission (2021) report further states that there is a higher likelihood of silver entrepreneurs having employees compared to the average numbers—one-third of silver entrepreneurs compared to 29% of other entrepreneurs. In some countries such as Germany almost 50% of the silver entrepreneurs have employees. Representatives of the silver economy are very active in self-employment and their share of being self-employed increases with age—i.e. in 2020, 18% of silver economy representatives (50–64 years) are self-employed, compared to 14% of the adults in the EU (OECD & European Commission, 2021). Although the number of self-employed is relatively high the representatives of the silver economy are not so active in starting new ventures. Figure 2 shows the number of self-employed persons in EU27 countries.

Figure 2 shows a stable number of people from 50–74 years who are self-employed within EU27 countries. However at the same time there is a sta-

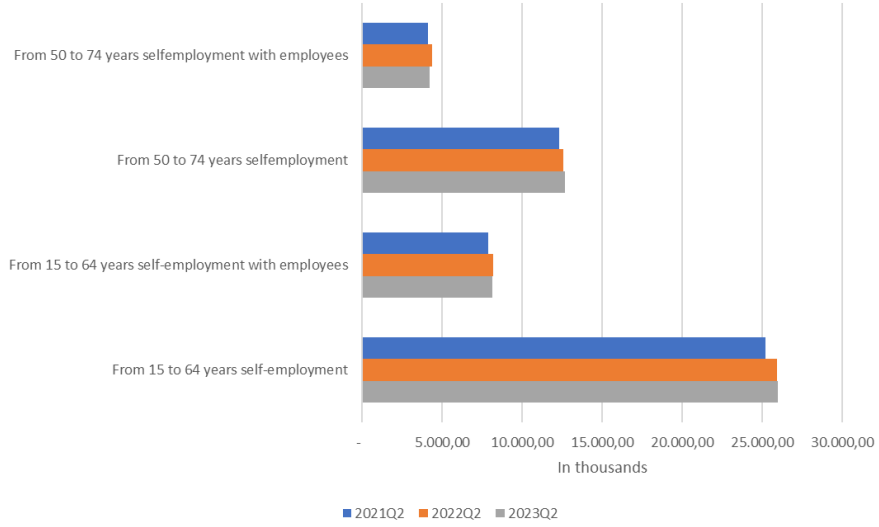

Figure 2. Number of self-employed persons in EU27 and self-employed persons with employees

Source: (Eurostat, 2023).

ble increase in the number of self-employed which shows that the number of silver entrepreneurs is growing. Additionally, they employ additional people in their ventures. The OECD and European Commission (2021) report found that the share of silver entrepreneurs who employed other people was lowest in Romania (6%) and highest in Germany (48%).

Only 2% of silver economy members started new ventures in 2016-2020, compared to 4% of the total population. However seniors were likelier to start their new ventures out of necessity. According to the Global Entrepreneurship Monitor (2023), almost 25% of companies founded by silver entrepreneurs were due to necessity while OECD and European Commission (2021) state that only 20% were founded due to necessity. In their report the OECD and European Commission (2021) found that almost a quarter of new EU silver entrepreneurs started new ventures between 2016 and 2020 compared to 18% of the total population because they could not find work. Other reasons for starting new ventures include not having enough savings, staying active and intending to socialise. Several studies found additional benefits not connected to money. Lallo and Raitano (2018) state that they significantly prolonged life compared to the total population while Stirzaker and Galloway (2017) found increased personal growth and overall life satisfaction. Wahrendorf et al. (2017) indicated that the reason could be personal preferences (e.g., personal identification with a company, having different work concepts) and less access to pension schemes. Fachinger and Frankus (2017) concluded that self-employed people did not save enough for their pensions which could be why people con-

tinue working after retirement age. Malek et al. (2011) found that silver entrepreneurs out of necessity are most likely driven by retirement savings and possible financial burdens from their family (i.e. children in post-secondary education, second families). Other studies (Lasen & Moreira, 2014) showed that older people continue their work since they physically and mentally can and no one is stopping them. OECD and European Commission (2021) state that older people interested in starting new ventures could spend their entire work life as employees which gives them experience. However they still lack the skills to be successful entrepreneurs. Although Figure 2 shows the self-employed persons in EU27 and self-employed persons with employees the main focus of the paper falls on silver entrepreneurs who have started their new ventures when they were older than 55 (as defined by Curan and Blackburn 2001; Kautonen, 2013).

3. Methodology

The global demographic trend of aging influences entrepreneurship on both the demand and supply sides. Innovations are being made in existing goods and services to cater to the needs and desires of older individuals while older people are increasingly inclined towards initiating entrepreneurial ventures. This paper focuses on silver entrepreneurs who have started an entrepreneurial venture at 55 and older. The age threshold to be considered a silver entrepreneur can vary depending on the context and definitions used in research and policy. Generally, silver entrepreneurship refers to entrepreneurial activities undertaken by individuals who are older and typically beyond traditional retirement age. This age threshold is often set at around 50 or 55 years old and above. However, there is no universally agreed-upon age threshold, and it can vary depending on cultural, economic and social factors as suggested by previous references.

The key distinction between entrepreneurs at older age still working lies in the timing and motivations behind their entrepreneurial endeavors One should differentiate between older individuals who continue to work as entrepreneurs and those who become silver entrepreneurs. Older (mature) entrepreneurs have likely been involved in entrepreneurship throughout their careers and continue their ventures beyond retirement age driven by, e.g., passion, purpose, need of achievement. Silver entrepreneurs on the other hand start their entrepreneurial journeys later in life, often as a means of transitioning into retirement or exploring new opportunities after leaving previous careers.

There are two primary research questions addressed in this study. Firstly, it examines the definition of silver entrepreneurs, focusing on whether there

exists a distinction between older individuals who have been engaged in entrepreneurship throughout their careers and reach retirement as entrepreneurs as opposed to those who commence entrepreneurial ventures later in life or following retirement. While acknowledgment of silver entrepreneurship exists both theoretically and practically the second question delves into the reasons behind the absence of specific policies catering to silver entrepreneurs. Although certain EU initiatives and policies indirectly support silver entrepreneurship by fostering entrepreneurship in general or tackling issues like age discrimination in the labour market, a comprehensive framework for supporting silver entrepreneurship is lacking.

This review paper endeavours to capture the nuanced complexities inherent in delineating silver entrepreneurship, i.e. silver entrepreneur. Despite the increasing body of literature consensus remains elusive on various aspects of this emerging trend within the field of entrepreneurship itself. These unresolved matters encompass delineating the age threshold and comprehending the underlying motivations driving older individuals to diverge from conventional retirement norms and reengage with the workforce. A more profound comprehension of silver entrepreneurship offers valuable insights for policymakers to foster a more conducive entrepreneurial environment for silver entrepreneurs including the establishment of age-specific regulatory frameworks, enhancing access to financial resources and promoting entrepreneurship education and training. Since silver entrepreneurship is a rather new area in the field of entrepreneurship a narrative literature review is used which tries to make a readable synthesis of current research. Narrative overviews serve as valuable educational pieces consolidating various pieces of information into a coherent and easily digested format. They offer a comprehensive perspective on a subject often detailing its history, development or management (Green et al., 2006).

4. Silver entrepreneurship

Many recent studies (e.g., Maâlaoui, 2019; Maritz, 2019; Martin & Omrani, 2019) explored silver entrepreneurship and silver entrepreneurs and different authors may use different terms to explain older peoples' entrepreneurial activities and silver entrepreneurs. Greco, Carignani et al. (2023) found that there are more than several different terms some of which include Mature or Mature-age entrepreneur, Second-career entrepreneur, Senior entrepreneur, Older or later-life entrepreneur, Third-age entrepreneur, Grey entrepreneur and Silver entrepreneur. Some researchers describe them as senior entrepreneurs (Linardi & Costa, 2021) or seniorpreneur (Maritz & Eager, 2017). The

main characteristics of the silver entrepreneurs are their use of their skills, experience and skills to start new businesses. Ahmad et al. (2014) confirmed this describing the silver entrepreneurs as people with more experience, better access to networks and resources and better qualifications in commerce, technology and science than other entrepreneurs. The authors note that some encouraging factors are related to entrepreneurial capital including extensive experience from previous employment, knowledge and a sound financial position. They also note that critical issues are professional qualifications, entrepreneurial capital, skills, experience and technical knowledge. A similar notion is that of the grey entrepreneur (Matricano, 2018; Weber & Schaper, 2004) who has the experience of accumulated practice, skills, knowledge and learning in relation to their younger colleagues. The authors note that technical knowledge about a specific product or service influences success in starting a new venture. This means personal skills, knowledge and intellectual agility—considered more pronounced in silver entrepreneurs—significantly influence entrepreneurial intentions. Minarcine and Shaw (2016) define second-career entrepreneurs as previously employed individuals who have decided to quit their jobs and pursue a dream. These are individuals who had no intention of starting a business but found that there was sufficient demand for their products or services. Second-career entrepreneurship encompasses the personal activities of these persons after their retirement (Lawal & Adeniran, 2022). The motivation for their involvement is usually to discuss the necessary shortfalls in the individual's income level after retirement or simply as a hobby to decrease unused time. Greco et al. (2022) found further studies discussing the numerous definitions and critical issues researchers have concentrated on when referring to this group of entrepreneurs (Table 1).

Table 1. Silver entrepreneurs' definitions and critical issues

Definition	Source	Critical issues
Later-life or older entrepreneur	Kautonen, 2013, p. 87	social capital, technical and managerial skills
Silver entrepreneur	Cannon, 2008, p. 32	experience, qualification in a field of study/work
Seniorpreneur	Maritz, 2019, p. 352	skills, attitudes
Grey entrepreneur	Matricano, 2018, p. 82	knowledge capabilities
Second-career entrepreneur	Minarcine and Shaw, 2016, p. C1	dream, demand
Mature or mature-age or third-age entrepreneur	Clarke and Holt, 2019, p. 77	motivation, possibility, financial risk

Source: adapted from (Greco et al., 2023, p. 127).

The previous table shows critical issues regarding silver entrepreneurs including motivation, finances, social capital and networks and the different skills people may have after their work life.

Many studies (e.g., Cannon, 2008; Kautonen, 2013) define silver entrepreneurs as individuals who start and operate small businesses later in their careers. Ahmad et al. (2014) characterise them as typically older professionals who have accumulated experience in commerce and have grown business networks and financial resources. The silver entrepreneurs according to Stypinska et al. (2019) do not perfectly follow the model of the ideal entrepreneur—i.e. a young white male. Stumbitz (2013) concluded that silver entrepreneurs can be innovative, dynamic and willing to find opportunities and take risks. The author further stated that silver entrepreneurs create innovative solutions to social problems (i.e. unemployment, social exclusion, poverty) and are more interested in social goals. Furthermore, they undeniably embody the entrepreneurial spirit of human nature which can be described as "active, innovative, creative, flexible, competitive, free and highly self-reliant" (Gross, 2016, p. 166). In another study (Weber & Schaper, 2004) the results showed that older people have greater success in launching and operating businesses than younger people.

Kolbacher et al. (2015) suggested that silver entrepreneurs managed companies have a longer lifespan and generally higher success than younger entrepreneurs. The authors provided insights on opportunity recognition, exploitation in the silver economy market, and innovation management for older users. Ahmad et al. (2014) stated various age-related advantages, such as greater commercial experience, personal networks and financial resources. The authors explored motivations and characteristics affecting the intentions of silver entrepreneurs in starting new ventures, categorising them as coherent entrepreneurs and highlighting the drivers for their entrepreneurial journey. Nasurdinet al. (2012) proposed a framework for productive ageing among silver entrepreneurs and addressed the profile, motivation and factors affecting their intentions to start new ventures (Figure 3).

This research confirmed that entrepreneurship could not be cast into a single mould. Therefore it is essential to further research silver entrepreneurship since many vital characteristics and factors can influence the decision to start a new venture within older generations. According to Kautonen (2013), silver entrepreneurs can possess advantages such as a more robust financial position, more industry and work experience, higher managerial and technical skill levels and what is sometimes the most important for the success of entrepreneurial venture—more developed networks to the younger entrepreneurs. Fachinger (2019) highlights four important characteristics when analysing silver entrepreneurship or self-employment among older people:

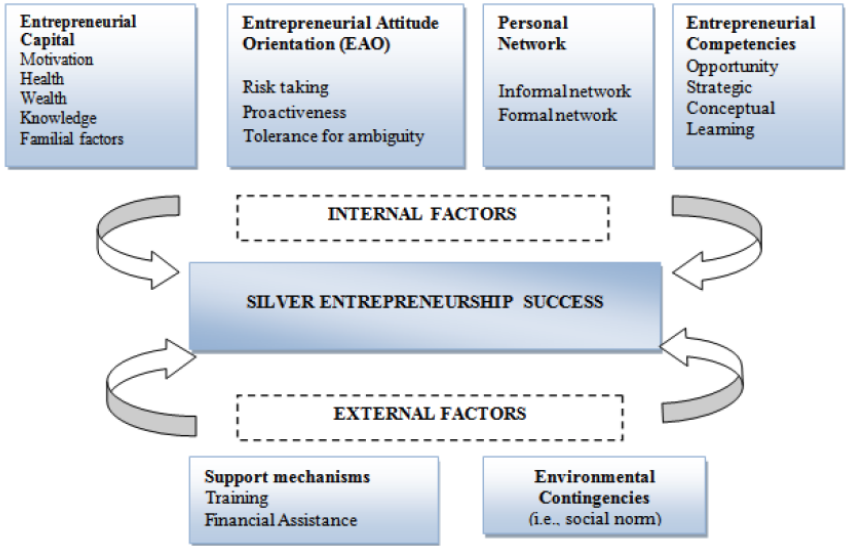

Figure 3. Conceptual framework

Source: (Nasurdin et al., 2012, p. 5).

- Income and wealth: monthly earnings are lower, while accumulated wealth is higher after retirement. According to the author, retirement means receiving money from different pension schemes (i.e. statutory, occupational, private), which is why the financial risks of self-employment and bankruptcy are lower for most retirees.
- Time sovereignty: older people are usually not bound by contractual obligations in terms of time. They have adult children who are usually not at home so they have more time for various activities such as leisure activities, volunteer work with fewer commitments, being a senior expert or starting their own business.
- Work experience and previous jobs: older people may have previous work experience in the sector in question providing them with the necessary background knowledge to facilitate self-employment. The network they have built up during their working life can also make the path to self-employment easier.
- Institutional framework: regulations such as the statutory retirement age can significantly impact the determination and represent age differences in the prospect of becoming self-employed.

Silver entrepreneurs' motivation drivers vary a lot. It ranges from financial motives (i.e. higher income) to age-specific motives (i.e. wanting to leave their mark on the world). Because seniors are guided by multiple motives and influenced by various environments, giving general guidelines for suc-

cessful senior entrepreneurship support programmes is difficult. Nasurdin et al. (2012) found that the motivators for silver entrepreneurs include personal wealth, family security, career progression and the pursuit of a more balanced life. Roxburgh (2019) stated four primary motives: necessity, the availability of capital, internet opportunity and success. Among different motivators, different push and pull factors (internal)can be found influencing silver entrepreneurs (Table 2).

Table 2. Push and pull factors of silver entrepreneurs

Pull factors	Push factors
Willingness to remain active (Kautonen, 2013)	Lack of prospects in the labour market (Stirzaker & Galloway, 2017)
Looking for new challenges (Stirzaker & Galloway, 2017)	Dissatisfaction with the previous job (Stirzaker et al., 2019)
Increasing income (Maâlaoui et al., 2019)	Providing adequate financial resources (Harms et al., 2014)

Source: adapted from (Ilczuk et al., 2023).

On the other side the external factors influencing entrepreneurial activity with older people include support from family and friends (Ahmad et al., 2014; Kautonen et al., 2011), having a business background in the family (Schröder et al., 2011), support from government and other institutions (Pilkova et al., 2016). Supporting silver entrepreneurship can remove older people's barriers to starting a business. Kibler et al. (2012, cited in Kautonen, 2013) found that silver entrepreneurs in the UK face barriers that can be assumed are probably similar worldwide:

1. Ageism: there is a stereotype that older people cannot serve the market, seize opportunities and become entrepreneurial, mainly because of their age.
2. Information and regulations: older people lack access to benefits (e.g., additional tax credits for their business startups), regulations are usually unclear and information relevant to the early stages of their business is insufficient and rarely understandable (most terms are more suited to the well-educated, media-savvy younger generations).
3. Resources: even if older entrepreneurs have financial security, financial resources are still the most critical missing resource when starting a business especially for those who start their business out of necessity (e.g., from unemployment). Acquiring resources such as the necessary social capital, is particularly difficult for those who have moved into a completely different industry and those who have been unemployed for some time. The lack of social capital could be replaced by mentors from various support agencies

which have the necessary business knowledge, understand the process of starting and growing a business and empathise with older workers.

4. Social environment: silver entrepreneurs whose family and friends already had experience in entrepreneurship received more support in starting a business than those whose family and friends had less entrepreneurial experience. The latter even discouraged older people from becoming entrepreneurs. Kautonen (2013) states that family and friends' negative opinions made the start-up process more difficult due to the following reasons: 1) different support forms (e.g., financial, emotional) from social contacts are essential in the primary stages of starting a business and 2) silver entrepreneurs become insecure when their social network keeps telling them that the idea of starting a business is uncertain.

Silver entrepreneurship and silver entrepreneurs are becoming necessary solutions to change attitudes toward ageing. Supporting older people to become silver entrepreneurs benefits their well-being and the quality of life in their communities. Therefore older people are increasingly seen less as a burden and more as a valuable human resource for sustainable social and economic development (Perić, 2020). Finally silver entrepreneurship is gaining recognition as a viable and successful option for older individuals to pursue their entrepreneurial aspirations. Silver entrepreneurs face unique challenges but research shows they have a higher chance of success (Birsyada & Paermana, 2020).

Although the impact of the silver economy on silver customers is recently part of the studies and research (e.g., Greco, Tregua et al., 2022; Zsarnoczky, 2018) the impact that silver entrepreneurship has on the silver customers is yet to be researched and defined. The number of studies on silver entrepreneurship (e.g., Fachinger, 2019; Ilczuk et al., 2023; Kautonen, 2013; Perić, 2020) is growing but currently the studies mainly refer to definition, motivation and barriers which potential silver entrepreneurs face. Matos et al. (2018) concluded that the impact of silver entrepreneurship should be based on economic, social, cultural and individual values and not only on financial or commercial ones. Therefore not explaining the impact of silver entrepreneurship on silver customers can be seen as this paper's limitation and a proposal for further research.

5. Policies for supporting silver entrepreneurship

Policies for encouraging and promoting silver entrepreneurship open opportunities for the extension of professional occupation, diminish unemployment concerns and enhance the social inclusion of the elderly. The studies

about silver entrepreneurship in many EU countries reveal that most people would like to remain economically active and start their businesses or be unretired (Lassen & Vrangbæk, 2021). Against the interest in engagement in entrepreneurship a limited number of older individuals are actively pursuing the establishment of businesses. Specifically between 2016 and 2021 approximately 7% of seniors in the European Union were engaged in early-stage entrepreneurship (OECD & European Commission, 2021). The theory identified some formal and informal institutions and issues influencing the engagement rate in silver entrepreneurship. Therefore informal institutions in cultural or social norms can affect entrepreneurship especially in certain groups such as the elderly (Pilkova et al., 2016). Underdeveloped institutions of this sort could lead to a decline of silver entrepreneurs throughout an entire generation (Estrin & Mickiewicz, 2011). Botham and Graves (2009) have studied the influence of formal institutions and their policies and discovered a positive correlation between well-implemented programs and the effective development of silver entrepreneurship.

The study by the OECD and the European Commission (2021) for policies for inclusive entrepreneurship has identified that silver entrepreneurs encounter less support in business startup activities. The lack of relevant silver entrepreneurship policies and strategies could be a significant barrier to pursuing the older startup business. Compared to other target groups for inclusive entrepreneurship very few programmes are tailored for seniors. Most initiatives within the European Union are characterised by their modest scale and are typically administered by local governmental or non-governmental organisations. Based on the policy assessment for the EU members the OECD has identified legs in training, coaching and mentoring in acquiring entrepreneurial skills. Small-scale support is identified in the financing of silver entrepreneurship, particularly in the grants for business creation, loan guarantees and microfinance loans. Very low formal support is identified in promoting entrepreneurial culture and regulatory tools relative to all other inclusive entrepreneurship groups (OECD & European Commission, 2021).

Creating a silver entrepreneurship support model is imperative and could be considered strategic thinking and investment in one of the essential resources of the silver economy. At the same time identifying and improving the policy measure will promote silver entrepreneurship as an integral and essential part of the active ageing policy. Matos et al. (2018) suggest that policies for silver entrepreneurship need to be in line with country's culture. Although the drivers behind silver entrepreneurship could range from financial benefit to social inclusion of older individuals, it could be realised in different environments. It is not easy to provide general blueprints for successful senior entrepreneurship support. The policy framework could encompass diversified support measures and policies for the older person customised based on the characteristics and environment in which one senior startup business

is launched. Observing silver entrepreneurship as a valuable resource of the silver economy policymakers encounter a challenge to create an appropriate entrepreneurship strategy and favourable entrepreneurial environment. The strategies of such categories should pay attention to the following:

- Creating positive awareness of senior entrepreneurship as a late-career option to remove negative age-biased as a potential barrier to silver entrepreneurship.
- Training activities and long-life learning. Development of programs intended for acquiring entrepreneurial skills and knowledge. They have to be customised to meet the needs of senior entrepreneurs and reflect the context in which they launch the business. Motivating especially older, experienced individuals to be engaged in mentoring.
- Financial support programmes. Develop and promote grants, low-interest loans and crowdfunding capital to support silver entrepreneurs.
- Regulation support. Promoting tax incentives for silver entrepreneurs starting businesses, including income tax. Promoting tax incentives for investing in senior startups.
- Customised support programmes. Provide grant schemes for launching entrepreneurial activities of seniors in rural areas.

The ageing population constitutes a challenge and opportunity simultaneously, so silver entrepreneurship has to be promoted as one of the main pillars of ageing policy support. The role of formal and informal organisations and policies are critical in shaping and supporting entrepreneurship (Lange & Johnston, 2020). For silver entrepreneurship an intentionally created entrepreneurial ecosystem should be set since the type of support may vary across different groups of entrepreneurs. Bohlmann et al. (2017) found that entrepreneurs of different ages need different types of support. Gielnik et al. (2012) suggest that policymakers should invest in maintaining or improving mental health and increasing learning and development opportunities targeting silver entrepreneurs. Proactive policies and strategies must be implemented to surpass bias and stereotyping against silver entrepreneurs. The policies and support for silver entrepreneurs should aim to establish a favourable and encouraging atmosphere enabling older individuals with entrepreneurial ambitions to prosper. Mikić et al. (2021) found that since seniors are influenced by diverse environments and steered by numerous motives it is not simple to present standard guidelines for positive silver entrepreneurship support programmes. The silver entrepreneurship support initiatives should include financial support, coaching, training programmes and business consultancy from the European perspective. The transition of individuals from unemployed to self-employed, or the extension of their working careers through self-employment could be considered an additional value for the silver economy.

Conclusions

This paper has tried to capture the essence of two concepts that describe the challenging nature of population ageing in terms of economic opportunity stemming from the global demographic transition the world is facing. Increasing life expectancy and reversal of the population pyramid, coupled with the fact that older people today seem to be better off than generations before in terms of healthy and active ageing opens a pathway to economic growth by untapping the potential of the older population on both supply and demand side of economics. These two concepts are related as silver entrepreneurship is a subset of the broader silver economy. Older entrepreneurs contribute to the growth and dynamics of the silver economy by creating businesses and services that cater to their age group's specific needs and preferences.

Silver entrepreneurship is a golden opportunity for an aging society. It contributes to economic growth and development by creating new businesses, generating employment opportunities and stimulating economies (e.g., Weber & Schaper, 2004). The experience and expertise of older people in various fields should be utilised as much as possible. They possess both knowledge and know-how of problems that ageing brings and can contribute to innovative solutions. Since older people frequently desire to continue working beyond official retirement entrepreneurship allows them to set up their ventures flexibly in terms of working arrangements and aligned with their interests. Remaining active and engaged in entrepreneurial pursuits can positively affect older people's mental and emotional well-being (e.g., Fachinger, 2019; Ilczuk et al., 2023; Kautonen, 2013; Perić, 2020). It provides a sense of purpose and fulfilment in their later years.

Silver entrepreneurs have a heightened awareness and deeper insight into their silver clientele enabling them to effectively address their needs. However, there is a lack of research or findings regarding the influence of silver entrepreneurship on silver customers. Last but not least is the social impact that silver entrepreneurship can have in creating a more inclusive community, promoting intergenerational collaboration and defying age-related stereotypes in the workplace and society in general.

Although there are policies present for supporting the silver entrepreneurs (Botham & Graves, 2009) it is important to state that they are very rare. Therefore creating a silver entrepreneurship support model is necessary, which can be seen as strategic thinking and investment in one of the significant silver economy resources. Policymakers encounter difficulties creating appropriate strategies and environments for silver entrepreneurship. Promoting a discourse on silver entrepreneurship is essential to raise individuals' awareness of entrepreneurship (by highlighting pros and cons and painting a realistic

picture of the entrepreneurial process) and indirectly, by increasing information about this option to family members and/or friends (Matos et al., 2018).

Researching silver entrepreneurship presents several challenges since entrepreneurship is a phenomenon without a universal definition. The lack of standardised definitions and classifications for silver entrepreneurship makes it attractive for studies to establish clear parameters for study. Older people are not a homogenous group. Individuals in the same age cohort may have different capabilities or status which makes them have different needs and wants (e.g., healthy vs. unhealthy individuals, working vs. already retired, educated vs non-educated). This heterogeneity can be recognised among older entrepreneurs reflecting the variations in motivations, business types, etc. The dynamics of technology and market changes are something that requires applied research. Also one should not neglect the interdisciplinary nature of silver entrepreneurship since it encompasses various methodological approaches from disciplines such as economics, sociology, psychology, technology, etc.

This study sheds light on the growing phenomenon of silver entrepreneurship. However significant opportunities exist to further understanding in this domain. Using an unsystematic narrative overview of the current literature on silver entrepreneurship represents a methodological research limitation that can be seen as a future research direction. Future research should be based on a quantitative systematic review of literature, i.e. a meta-analysis, where findings would be statistically synthesized and thus would provide a more comprehensive understanding of the topic. Future studies could delve deeper into the nuanced motivations of senior entrepreneurs by exploring how personal experiences, societal factors and economic conditions influence their entrepreneurial pursuits. Moreover, there is a pressing need to conduct longitudinal studies to assess the long-term effectiveness of policies and regulatory frameworks aimed at supporting senior entrepreneurship. By tracking the outcomes of these initiatives over time researchers can gain valuable insights into their impact and identify opportunities for refinement. Additionally, there is a burgeoning field of research exploring the intersection of senior entrepreneurship and technology particularly in the realm of artificial intelligence and digital platforms. Future studies could investigate innovative ways to harness technology to overcome barriers faced by senior entrepreneurs and promote their mental well-being and success. Furthermore cultural differences in the perception and practice of entrepreneurship among older individuals present a rich area for exploration. Comparative studies across diverse cultural contexts could shed light on the cultural factors shaping senior entrepreneurship and inform the development of culturally sensitive support strategies. Moreover, understanding the evolving needs and preferences of older consumers in the context of senior entrepreneurship calls for further investigation. Future research could explore consumer behaviour trends, preferences for products and services tailored to seniors and the impact of senior entrepreneurship on

the broader aging population. Lastly there is a need to engage in collaborative research efforts involving multiple stakeholders including governments, businesses, academia and support organizations.

By fostering interdisciplinary collaboration, researchers can gain holistic insights into the complex dynamics of senior entrepreneurship and develop comprehensive solutions to address its challenges and opportunities. By pursuing these research directions new theoretical insights and empirical evidence can be generated ultimately leading to more effective policies and support mechanisms for silver entrepreneurs to thrive. This will benefit older adults and contribute to the overall growth and dynamism of the global economy.

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sciendo Economics and Business Review https://www.ebr.edu.pl Vol. 10 (1), 2024: 179–198 https://doi.org/10.18559/ebr.2024.1.1082

Assessing the long-term asymmetric relationship between energy consumption and CO_2 emissions: Evidence from the Visegrad Group countries

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Abstract

This study investigates the impact of renewable (REW) and non-renewable (NREW) energy usage, along with economic growth (GDP), on carbon dioxide (CO_2) emissions in the Visegrad countries, which rely heavily on traditional energy sources. Using data from 1991 to 2021, the analysis employs a panel asymmetric regression with Driscoll-Kraay and FGLS standard errors. The latent cointegration test reveals long-term relationships with asymmetry among the variables. Real GDP fluctuations exhibit a negative impact on CO_2 emissions for both positive and negative shocks. A reduction in conventional energy source consumption leads to a greater CO_2 emission reduction, confirming asymmetry. Conversely, an increase in consumption positively impacts CO_2 reduction. However, non-conventional energy sources show no asymmetries. The OLS-based model proposed by Driscoll-Kraay showed reduced standard errors, but lower significance in the estimated parameters compared to the FGLS model. The findings recommend a sustainable energy transition for Visegrad countries by eliminating traditional sources and promoting renewable resources.

Keywords

- CO_2 emissions
- renewable energy
- asymmetric causality
- energy transition
- Visegrad Group
- asymmetric panel data

JEL codes: C32, C33, Q40, Q43

Article received 5 December 2023, accepted 15 March 2024.

This research was funded by the project within the framework of the Faculty of Economics, West Pomeranian University of Technology in Szczecin, Poland under the name "Green Lab. Research and Innovations". The 12th National Scientific Conference named after Professor Zbigniew Czerwiński "Mathematics and information technology at the service of economics".

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Suggested citation: Suproń, B. (2024). Assessing the long-term asymmetric relationship between energy consumption and CO_2 emissions: Evidence from the Visegrad Group countries. *Economics and Business Review*, *10*(1), 179–198. https://doi.org/10.18559/ebr.2024.1.1082

Introduction

At the 2015 Paris Conference, where climate change and global warming were discussed, the international community adopted the goal of concerted action to reduce greenhouse gases, including carbon dioxide. The main task emerging from the conference, as well as from subsequent events to lower global temperatures, was the need for an energy transition to low- and zero-emission sources (Flanker, 2016). Consequently, the energy transition has become a major challenge for both developed and developing countries in recent years (Pastukhova & Westphal, 2020). Meeting climate targets requires a change in the structure of energy production through significant financial investments. At the same time, this should be integrated into the pursuit of sustainable development, which will ensure existing or better economic living standards (Coy et al., 2021).

Many studies point to excessive CO_2 emissions from the burning of fossil fuels as a direct cause of global warming (Zoundi, 2017). Due to their large coal and lignite resources, a significant proportion of economies obtain their energy mainly from the combustion of these raw materials, thus contributing to environmental pollution (Antonakakis et al., 2017). Abandoning fossil fuels through the energy transition will therefore have a direct impact on economic development and pose a significant challenge for countries whose economies rely on cheap energy from coal combustion (Inglesi-Lotz & Dogan, 2018).

The 'Fit For 55' package adopted by the European Union in 2021, through which Europe aims to achieve climate neutrality by 2050, represents a further step in the fight against global warming. At the same time, this comprehensive package of reforms will have different social and economic impacts in different member states. The effects of Fit for 55 will differ from country to country, due to differences in energy mix and natural resources (LaBelle et al., 2022). Central European countries such as the Czech Republic, Hungary, Poland and Slovakia, which make up the Visegrad Group (V4) could experience very severe economic impacts of achieving climate neutrality due to their production structure and fossil fuel-based energy sector (Ambroziak et al., 2021).

This study aims to explore the relationship between renewable and non-renewable energy consumption, economic growth and CO_2 emissions in the

Visegrad countries using asymmetric panel econometric models. It also aims to determine whether there are any asymmetric effects of energy consumption and economic growth on CO_2 emissions. Additionally, the study investigates the impact of long-run shocks on CO_2 emissions in economies undergoing an energy transition. The text examines whether decreasing non-renewable energy usage and increasing renewable energy usage can lower CO_2 emissions while sustaining economic growth. It analyses the effects of positive and negative long-term economic shocks on CO_2 emissions in the countries under study.

The results can guide the harmonisation of climate and economic policies. The use of novel research methods can produce more accurate evidence. The study synthesises the methodology used in previous research on asymmetric relationships in environmental economics. Econometric techniques, including cointegration analysis for asymmetrical time series and data, modelling using the panel FGLS method, and testing for asymmetrical causality were employed.

Given these considerations, this study aims to fill the gap in the practical application of asymmetric panel econometric models by explaining how renewable and non-renewable energy consumption and economic growth affect CO_2 emissions in the Visegrad countries. In addition, the study synthesises the methodology used in previous research on asymmetric relationships in environmental economics. The research applied econometric techniques, including cointegration analysis for asymmetrical time series and data, modelling using the panel FGLS method, and testing for asymmetrical causality.

While there is extensive literature on the relationship between energy consumption, economic growth and CO_2 emissions, there is still a lack of research focusing specifically on the Visegrad countries, especially using asymmetric econometric models. The V4 countries are a particular example of a successful transition from centrally planned to market economies. They are also a model example of the economic success of European integration.

These countries are also playing an increasingly important economic role in Europe, becoming the site of many global economic investments (Brodny & Tutak, 2021)the issue of ensuring climate-neutral energy security is of great importance, especially in the "New" EU countries, where the energy transition began later than in the rest of the countries (the so-called Old EU. The Visegrad countries provide insights into the complex dynamics of energy transition. The example of the Visegrad countries can be used to draw conclusions about other countries that will one day embark on the path of economic integration, such as Ukraine and the Balkan countries, as well as countries pursuing a sustainable energy transition (Dzikuć et al., 2021).

The article is organised as follows: Section 1 reviews the recent empirical literature; Section 2 presents the range of data used and the methodology; Section 3 contains the results of the empirical analysis. The final part summarises the results of the study.

1. Literature review

The general basis for all considerations of the systematic and asymmetric determinants of CO_2 is the research on the Environmental Kuznets curve (EKC), which assumed a relationship between CO_2, energy production and economic growth (Apergis & Ozturk, 2015). In subsequent stages, other variables were added to the original model, such as renewable and non-renewable energy consumption (Adedoyin et al., 2021), urbanisation (Ahmad et al., 2021), industry (Rahman & Kashem, 2017), taxation and innovation (Sadiq et al., 2023), and the technical armament of labour (Alvarado et al., 2021). However, the vast majority of ECC-related studies in the European Union and other regions cite energy consumption as the main cause of environmental pollution (Al-mulali et al., 2014; Litavcová & Chovancová, 2021; Muço et al., 2021). The studies indicate that an increase in coal, electricity and oil usage leads to higher carbon dioxide emissions, while a reduction in coal, electricity, gas and oil usage results in lower carbon dioxide emissions in the long run (Abbasi et al., 2021; Adedoyin et al., 2021; Ito, 2017)among others. It is therefore essential to identify such factors that may play a constructive role in economic growth. In doing so, this study investigates the determinants of economic growth in Pakistan from 1972 to 2018. The dynamic autoregressive distributed lag (ARDL.

Additionally, the use of renewable energy has been found to reduce CO_2 emissions in the European Union region both in the short and long run (Azam et al., 2021; Deka et al., 2023; Grodzicki & Jankiewicz, 2022)panel unit root tests, panel heterogeneous co-integration method, panel Fully Modified Ordinary Least Square and the Granger causality method are employed. The primary outcomes of this study are as follows: (1. It is also observed that an increase in the share of renewable energy use leads to fewer CO_2 emissions (Rasheed et al., 2022). Most research indicated a negative, mostly U-shaped relationship between renewable energy consumption and CO_2 reduction, whether for Asian countries (Muhammad & Khan, 2019)energy use, CO_2 emissions and capital role in the economic growth. This study applies generalized method of moments (GMM, African (Inglesi-Lotz & Dogan, 2018), OECD (Bilgili et al., 2016), the European Union (Muço et al., 2021), United States (Ali et al., 2020), 150 countries of the world (Cialani, 2017), or all economies (Dissanayake et al., 2023).

The subject matter and scope of research conducted to date is so extensive that it has been the subject of numerous, comprehensive literature reviews (Haberl et al., 2020; Mardani et al., 2019). In the case of the Visegrad countries, which are the subject of this study, an overview of recent research and methods in the area of the EKC curve has so far been provided by Suproń and Myszczyszyn (2023) and Leitão et al. (2023). The symmetrical relationship be-

tween CO_2 emissions and energy consumption in the Visegrad countries was also analysed by Myszczyszyn and Suproń (2021). Previous studies of the relationship between CO_2 emissions and economic factors have used constantly improving methods, estimating symmetric single series models and panel data such as VECM, VAR, ARDL, NARDL, FMOLS, DOLS (Debone et al., 2021).

Recently, there have been a growing number of studies on the role of asymmetric effects of different factors on CO_2 emissions. Givens et al. (2019) analysed the theory of unequal ecological exchange. Recent advancements in econometric models and quantitative methods have sparked a surge of research into the asymmetric effects of various determinants on CO_2 emissions; Ullah et al. (2020) examined the asymmetric effect of deindustrialisation on pollution in Pakistan; Naseer et al. (2022) conducted a study of the asymmetric effect of education on CO_2 emissions in BRICS countries; Akram et al. (2020) using the asymmetric ARDL model, established the non-linear impact of energy efficiency and renewable energy on economic growth in the BRICS countries.

Mawejje (2023) also confirmed the asymmetric relationship between economic growth, CO_2 emissions and energy consumption in 19 Eastern and Southern African countries. Using an asymmetric model, Razzaq et al. (2023) provided new evidence that the development of international tourism drives economic growth and increases carbon emissions asymmetrically at different levels of economic growth and carbon emissions. McGee and York (2018), on the other hand, conducted a study of the asymmetric relationship between urbanisation and CO_2 emissions in less developed countries.

In conclusion, despite numerous studies on the subject, there is still a scarcity of research concerning the relationship between energy consumption, economic growth, and CO_2 emissions when using an asymmetric approach over a prolonged period. This is particularly the case for European countries, including the Visegrad countries. The literature review highlights a significant research gap in this field, particularly concerning the use of Feasible Generalized Least Squares (FGLS) models. So far, only sporadic research has been undertaken in this domain (Naqvi et al., 2022). Considering the foregoing, and given the current state of research, our study bridges the methodological gap.

2 Methodology and data

2.1. Methodology and econometric framework

Research on asymmetric time series estimation methods was initiated by Granger and Yoon (2002), who were the first to formulate the assumption of latent cointegration and to present a formula for partial cumulative sums for

positive and negative components. Subsequently, the concept of asymmetric causality and cointegration tests was further developed by Hatemi-J (2012). Moreover, Shin et al. (2014), following on from earlier work, proposed the NARDL model to test both long- and short-run asymmetric relationships between variables. York and Light (2017) presented a method for estimating asymmetric models for panel data based on the Ordinary least squares (OLS) method with fixed effect. In contrast, Allison (2019), referring to previous studies, pointed out in his paper that standard fixed effects regression methods assume that the effects of variables are symmetric. At the same time, he stated that a GLS model is optimal. Furthermore, the concept of methods for modelling and testing asymmetric relationships for time series was developed by Hatemi-J (2022) and Hatemi-J and El-Khatib (2016).

In the methodological area, this study draws on the work of Granger and Yoon (2002), Hatemi-J (2012), Shin et al. (2014), York and Light (2017), Alison (Allison, 2019) in examining asymmetric relationships in time series and panel data. A basic model form was adopted to demonstrate asymmetric relationships between CO_2 emissions and economic growth, renewable and non-renewable energy consumption:

$$CO2_t = \beta_0 + \beta_{1t} GDP_t + \beta_{2t} REW_t + \beta_{3t} NREW_t + \varepsilon_t \tag{1}$$

The above equation (1) is a long-run model and allows estimation of the model parameters for the long run. In order to capture asymmetric effects, all variables were transformed based on the method developed by Granger and Yoon (2002) and developed by Hatemi-J (2012):

$$\begin{aligned} \sum_{n=1}^{t} \Delta x_{it}^{-} &= \sum_{n=1}^{t} \min(\Delta x_{it}^{-}, 0) \\ \sum_{n=1}^{t} \Delta x_{it}^{+} &= \sum_{n=1}^{t} \max(\Delta x_{it}^{+}, 0) \end{aligned} \tag{2}$$

The variables under consideration were transformed into a natural logarithm form and were assigned symbols: lnREW for renewable energy consumption, lnNREW for non-renewable energy consumption, lnGDP for gross domestic product and lnCO_2 for carbon dioxide emissions. After transformation of the data to partial cumulative sums for positive and negative components and logarithmic transformation, the analytical form of the model under study was determined as follows:

$$\begin{aligned} \ln CO2_t = \beta_0 + \beta_{1t} \ln GDP_t^{+} + \beta_{2t} \ln GDP_t^{-} + \beta_{3t} \ln REW_t^{+} + \beta_{4t} \ln REW_t^{-} + \\ + \beta_{5t} \ln NREW_t^{+} + \beta_{3t} \ln NREW_t^{-} + \varepsilon_t \end{aligned} \tag{3}$$

Due to the fact that the study used panel data for 4 countries, the first step was to test for the presence of cross-sectional dependence (CSD) based on the Breusch-Pagan LM method (Baltagi et al., 2012). This method is applicable to panel data with a small number of cross-sectional units. In addition, multicollinearity tests were carried out (Daoud, 2017), along with serial correlation (Wooldridge, 2010) and heteroskedasticity (White, 1980), in order to determine the optimal estimation method. In the next stopper, the stationarity of the variables was tested at the level and for the first difference using the panel unit root test, second generation CIPS (Pesaran, 2007). To establish the asymmetric impact of energy consumption and economic growth, cointegration was examined using the Kao test (Hatemi-J, 2020; Kao, 1999).

In the present study, two models were estimated in line with previous research to compare their results. The Driscoll-Kraay model (Driscoll & Kraay, 1998), which is a modification of ordinary least squares (OLS) regression that is robust in terms of cross-sectional dependence and heteroskedasticity, and the FGLS model (Baum, 2001), which follows on from the findings presented by Allison (2019). The FGLS model itself is a regression model, appropriate for small panels with many observations over time ($T > N$), which is robust with regard to cross-sectional dependence and heteroskedasticity. The general form of the FGLS model is shown below:

$$\hat{\beta}_{FGLS} = (X'\hat{\Omega}^{-1}X)^{-1}X'\hat{\Omega}^{-1}y \tag{4}$$

In addition to model estimation, the study also conducted an asymmetric causality test to detect causal relationships between variables based on the Dumitrescu-Hurlin method (2012). This test considers the heterogeneity of the panel data, resulting in resilient outcomes. The null hypothesis posits that there is no causal relationship between the variables, whilst the alternative hypothesis proposes the existence of such a relationship.

2.2. Data and preliminary analysis

The proposed methodology was used to analyse the asymmetric, long-term relationship between renewable, non-renewable energy consumption (in tonnes of oil equivalent per capita) and economic growth (in constant 2015 USD per capita), and CO_2 emissions (in metric tonnes per capita) using the example of the Visegrad countries. All variables were extracted from the World Bank database and applied in a panel format. The data used in the study had an annual frequency and covered the period from 1991 to 2021 (t = 31). Table 1 presents the descriptive statistics for the variables CO2, GDP, NREW, and REW.

All four variables exhibit significant variability and deviations from normality. Skewness values indicate right-skewed distributions, while kurtosis values of 2 indicate moderate-to-strong leptokurtosis. The results of the Jarque-Bera test were significant for all four variables, further confirming that the data did not conform to a normal distribution. The variables under consideration are therefore asymmetric.

The correlation matrix is presented in Table 2, while Table 3 shows the results of the multicollinearity test for the time series studied. No multicollinearity problem was found for the variables tested, and the mean index for the Variance Inflation Factor (VIF) test was 1.68. Based on the descriptive statistics and preliminary analyses, non-parametric or robust econometric methods are necessary to achieve the research objectives.

Table 1. Descriptive statistics

Variable	CO_2	GDP	NREW	REW
Mean	125.24	11870.73	0.44	4.34
Median	82.57	11596.03	0.32	3.91
Maximum	362.71	20248.30	1.13	7.40
Minimum	23.38	4743.75	0.02	2.56
Standard deviation	107.97	3842.17	13.79	240.80
Skewness	0.94	0.20	0.71	2.23
Kurtosis	2.30	2.15	1.93	8.06
Jarque-Bera	20.92	4.54	16.26	234.77
Probability	0.00	0.03	0.00	0.00
Observations	124	124	124	124

Source: own calculations.

Table 2. Correlation matrix

Variables	$lnCO_2$	$lnGDP^+$	$lnGDP^-$	$lnNREW^+$	$lnNREW^-$	$lnREW^+$	$lnREW^-$
lnCO_2	1.000	–0.261	0.535	–0.369	0.543	–0.370	0.429
$lnGDP^+$	–0.261	1.000	–0.418	0.730	–0.690	0.657	–0.681
$lnGDP^-$	0.535	–0.418	1.000	–0.781	0.852	–0.702	0.793
$lnNREW^+$	–0.369	0.730	–0.781	1.000	–0.836	0.893	–0.948
$lnNREW^-$	0.543	–0.690	0.852	–0.836	1.000	–0.794	0.842
$lnREW^+$	–0.370	0.657	–0.702	0.893	–0.794	1.000	–0.843
$lnREW^-$	0.429	–0.681	0.793	–0.948	0.842	–0.843	1.000

Source: own calculations.

Table 3. Multicollinearity VIF Test

Variable	VIF	1/VIF
lnGDP+ –	1.94	0.515
lnNREW+ –	1.89	0.529

Source: own calculations.

3. Research results

Table 4 shows the results of the initial diagnostics for the asymmetric panel data. These results indicate that there is a problem with autocorrelation, heteroskedasticity and cross-sectional dependence in the series under investigation. The results are in line with expectations presented for asymmetric data by Allison (Allison, 2019). In view of the above, standard OLS models cannot be used in the estimation process.

Table 4. Asymmetric panel data tests

Test	Statistic	Value	*p*-value
Wooldridge test for autocorrelation	F	30.364	0.012
Heteroskedasticity White Test	$\chi 2$	33.560	0.001
Breusch-Pagan LM Residual Cross-Section Dependence Test	$\chi 2$	15.447	0.017

Source: own calculations.

In the initial stage of this study, the unit root tests were conducted using the second-generation CIPS test, which considers the issue of cross-sectional dependence and is known for its high statistical power. The results of the test are shown in Table 5. The test performed confirms that all variables are stationary at first difference I (1).

Building on previous work by Hatemi-J, a cointegration test procedure for asymmetric series was carried out in the next step by applying tests to Kao panel data. Cointegration analysis was applied in pairs and jointly. All tests confirmed the presence of cointegration in the asymmetric series, but not in the symmetrical pairs test. This indicates the presence of latent cointegration. The results of the cointegration tests are shown in Table 6.

Based on the obtained preliminary results, an OLS model with fixed effect and robust standard errors was estimated based on the Driscoll-Kraay method for panel data with heteroskedasticity and autocorrelation problems. The

Table 5. Panel data CIPS unit root tests

Variable	Level	First difference
$lnCO_2$	–2.294*	–5.210***
$lnCO_2^+$	2.042	–5.291***
$lnCO_2^-$	–2.025	–4.628***
lnGDP	–1.457	–3.490***
$lnGDP^+$	–1.316	–3.325***
$lnGDP^-$	–0.924	–4.902***
lnNREW	–2.060	–4.760***
$lnNREW^+$	–1.213	–4.178***
$lnNREW^-$	1.186	–4.204***
lnREW	–2.930***	–4.192***
$lnREW^+$	–3.354***	–4.368***
$lnREW^-$	–2.685***	–5.717***

Note: The significance of the coefficients is indicated by an asterisk in the tables, where *, **, *** denotes 10%, 5%, and 1% significance level, respectively.

Source: own calculations.

Table 6. The results of panel hidden cointegration tests

Variables	ADF	*p*-value
$lnCO_2$, lnREW	–0.026	0.490
$lnCO_2$, lnNREW	0.728	0.233
$lnCO_2$, lnGDP	–0.013	0.495
$lnCO_2^+$, $lnGDP^+$, $lnREW^+$, $lnNREW^+$	–1.761	0.039
$lnCO_2^-$, $lnGDP^-$, $lnREW^-$, $lnNREW^-$	–2.146	0.016
$lnCO_2$, $lnGDP^+$, $lnREW^+$, $lnNREW^+$	–1.284	0.009
$lnCO_2$, $lnGDP^-$, $lnREW^-$, $lnNREW^-$	–2.041	0.021
$lnCO_2^+$, $lnREW^-$, $lnREW^+$, $lnNREW^+$, $lnREW^-$, $lnGDP^+$, $lnGDP^-$	–2.761	0.003
$lnCO_2^-$, $lnREW^-$, $lnREW^+$, $lnNREW^+$, $lnREW^-$, $lnGDP^+$, $lnGDP^-$	–2.556	0.005
$lnCO_2$, $lnREW^-$, $lnREW^+$, $lnNREW^+$, $lnREW^-$, $lnGDP^+$, $lnGDP^-$	–3.023	0.001
$lnCO_2^+$, $lnCO^-$, lnREW, $lnREW^+$, $lnNREW^+$, $lnREW^-$, $lnGDP^+$, $lnGDP^-$	–3.245	0.001

Source: calculations.

estimation results are presented in Table 7. The lnREW variable and lnGDP had a statistically significant effect on the dependent variable. The model coefficients reveal that a 1% increase in renewable energy consumption causes

a 0.02% drop in CO_2 emissions in the countries under study. Conversely, if there is a negative change in lnGDP by 1%, CO_2 emissions decrease by 2.39%.

Table 7. Asymmetric Model Estimated with fixed effect (robust)

Variables	Coefficient	Standard error	*t*-statistics	*p*-value
$lnREW^+$	–0.024	0.003	–7.570	0.005
$lnREW^-$	–0.159	0.147	–1.080	0.359
$lnNREW^+$	0.272	0.313	0.870	0.448
$lnNREW^-$	0.109	0.063	1.740	0.181
$lnGDP^+$	0.057	0.146	0.390	0.721
$lnGDP^-$	2.390	0.866	2.760	0.070
Const.	2.173	0.033	65.090	0.000

Note: *F*-statistics of the model is 26.681 with *p*-value 0.000, R^2 of 0.723.

Source: own calculations.

In the next stage of the study, a long-term asymmetric model was estimated using the FGLS method. The estimation results are presented in Table 8. Based on the results obtained, it can be concluded that the GLS model showed a larger number of statistically significant variables and a different value of the estimated parameters. In contrast, the model estimated by the Driscoll-Kraay method has about ¼ smaller standard errors compared to the GLS model. At the same time, the standard errors of the GLS model are similar in their magnitude to those obtained by Şanlı et al. (2023)population density and sources of energy supply is critical in assessing environmental quality. Recent empirical studies paid limited attention to the role of renewable (RE for the NARDL model.

According to the results obtained for the FGLS model, an increase in renewable energy consumption in the countries studied contributes to a decrease in CO_2 of 0.23%. At the same time, the results of the Wald test for the joint significance of the coefficients did not confirm a significant asymmetry for renewable energy consumption. In the case of non-renewable energy consumption, the model tested indicates that a 1% increase in non-renewable energy consumption leads to a 0.34% increase in CO_2, while a decrease leads to a 0.71% reduction in CO_2. Wald tests simultaneously confirmed for these two variables a significant asymmetry at a significance level of 10%.

The final variable studied was GDP. The results showed statistically significant coefficients for both positive and negative changes. It should be noted that in the countries investigated, a 1% increase in GDP results in a 1.19% decline in CO_2 emissions, while a decrease leads to a long-term reduction of

Table 8. Asymmetric Model Estimated with generalized least squares

Variables	Coefficient	Standard error	*z*-statistics	*p*-value
lnREW$^+$	–0.233	0.054	–4.290	0.000
lnREW$^-$	–0.390	0.448	–0.870	0.383
lnNREW$^+$	0.339	0.299	–1.970	0.071
lnNREW$^-$	0.713	0.414	1.720	0.085
lnGDP$^+$	–1.186	0.234	–5.060	0.000
lnGDP$^-$	5.665	1.604	3.530	0.000
Const.	2.267	0.109	20.830	0.000
Wald asymmetry test results				
Variables		**Statistic**	**Value**	***p*–value**
lnGDP		$\chi 2$	8.30	0.004
lnNREW		$\chi 2$	2.58	0.098
lnREW		$\chi 2$	1.94	0.164
Diagnostics Wald $\chi 2$		$\chi 2$	189.64	0.002

Source: own calculations.

5.66% in CO_2 emissions. The asymmetry observed in this variable is also statistically significant.

To confirm whether changes in the structure of energy production can have a significant impact on CO_2 reduction, as well as to establish their asymmetric impact, a causality test was conducted in the final stage of the study. For this purpose, a paired test based on the Dumitrescu & Hurlin panel data test was applied (2012) in conjunction with the method discussed by Hatemi-J (2012). The results indicate that there is bidirectional causality between lnCO2 ↔ lnREW, lnREW$^-$ ↔ lnCO2$^-$, lnREW$^+$ ↔ lnCO2$^-$, lnNREW$^-$ ↔ lnCO2$^+$, lnGDP$^-$ ↔ lnCO2$^+$. Unidirectional causality, on the other hand, has been demonstrated for the variables: lnCO2$^-$ → lnREW$^-$, lnNREW$^-$ → lnCO2$^-$, lnGDP → lnCO2, lnCO2$^+$ → lnGDP$^+$, lnCO2$^-$ → lnGDP$^-$ (Table 9).

The findings suggest a feedback loop between positive and negative interactions of CO_2 and renewable energy consumption. Causality tests establish that a reduction in non-renewable energy leads to a decrease in CO_2 emissions. However, results imply that economic growth has a non-linear impact on CO_2 emissions in the countries studied. Emissions initially increase, but then decline after a certain point.

The presence of multiple bidirectional and unidirectional asymmetric causality suggests that the relationships between variables are intricate and necessitate a comprehensive approach. In determining energy production strat-

Table 9. Results of pairwise Dumitrescu-Hurlin panel causality tests

Causality	*Z*-bar statistics	*p*-value	Causality	*Z*-bar statistics	*p*-value
lnCO2 → lnREW	1.936	0.053	$lnCO2^{-} \rightarrow lnNREW^{-}$	–0.420	0.674
lnREW → lnCO2	2.870	0.004	$lnNREW^{-} \rightarrow lnCO2^{+}$	4.489	0.000
$lnREW^{+} \rightarrow lnCO2^{+}$	1.082	0.279	$lnCO2^{+} \rightarrow lnNREW^{-}$	23.575	0.000
$lnCO2^{+} \rightarrow lnREW^{+}$	16.156	0.000	$lnNREW^{-} \rightarrow lnCO2^{-}$	2.137	0.033
$lnREW^{-} \rightarrow lnCO2^{-}$	2.325	0.020	$lnCO2^{-} \rightarrow lnNREW^{+}$	0.908	0.364
$lnCO2^{-} \rightarrow lnREW^{-}$	12.417	0.000	lnGDP → lnCO2	2.111	0.035
$lnREW^{-} \rightarrow lnCO2^{+}$	–0.071	0.943	lnCO2 → lnGDP	–0.789	0.430
$lnCO2^{+} \rightarrow lnREW^{-}$	1.368	0.171	$lnGDP^{+} \rightarrow lnCO2^{+}$	0.571	0.568
$lnREW^{+} \rightarrow lnCO2^{-}$	2.567	0.010	$lnCO2^{+} \rightarrow lnGDP^{+}$	1.720	0.086
$lnCO2^{-} \rightarrow lnREW^{+}$	2.137	0.033	$lnGDP^{-} \rightarrow lnCO2^{-}$	–0.937	0.349
lnCO2 → lnNREW	0.785	0.433	$lnCO2^{-} \rightarrow lnGDP^{-}$	3.303	0.001
lnNREW → lnCO2	0.816	0.414	$lnGDP^{-} \rightarrow lnCO2^{+}$	3.912	0.000
$lnNREW^{+} \rightarrow lnCO2^{+}$	1.333	0.183	$lnCO2^{+} \rightarrow lnGDP^{-}$	4.432	0.000
$lnCO2^{+} \rightarrow lnNREW^{+}$	–0.482	0.630	$lnGDP^{+} \rightarrow lnCO2^{-}$	4.755	0.000
$lnNREW^{-} \rightarrow lnCO2^{-}$	8.843	0.000	$lnCO2^{-} \rightarrow lnGDP^{+}$	–0.063	0.950

Source: own calculations.

egies, a range of factors should be considered, including the energy source type, economic growth, and greenhouse gas emissions. Transforming the energy mix has the potential to affect CO_2 emissions, but it requires a balanced approach that considers various factors to tackle climate change effectively.

The results obtained for the asymmetric effect of economic growth on CO_2 emissions in the long term are consistent with those presented by Toumi & Toumi (2019). The results for GDP are at the same time different from those obtained by Iqbal et al. (2022), who showed no significant asymmetry in the long term. Both studies in question simultaneously confirm the long-term asymmetry for the relationship between renewable energy and CO_2 emissions, which could not be confirmed for the V4 countries. In contrast, the result obtained is consistent with the study by Şanlı et al. (2023), who only confirmed the positive impact of renewable energy on the decrease in CO_2 emissions, while indicating the presence of a statistically significant asymmetry in the relationship between non-renewable energy and CO_2 emissions.

Conclusions

The objective of this paper was to examine the enduring and uneven influence of renewable and non-renewable energy consumption, as well as economic growth, on CO_2 emissions, with a case study focussing on the Visegrad countries from 1991 to 2021. The study used the Driscoll-Kraay and FGLS models to address challenges arising from serial correlation, panel group heteroskedasticity, cross-sectional dependence, and the heterogeneity of asymmetrically modified data. The findings indicate the presence of cointegration for all variables, encompassing various combinations, in the asymmetrically transformed series. The OLS-based model proposed by Driscoll-Kraay showed reduced standard errors, but lower significance in the estimated parameters compared to the FGLS model.

These differences are due to different estimation rules, in particular the distribution of model residuals and the accuracy of these methods. However, the results tend to converge to some extent in terms of the strength and direction of the effects. It is important to emphasise the need for further research in this area, particularly on panels with more observations per unit of time, to develop optimal estimation techniques for an asymmetric effect.

Research also indicates that a rise in renewable energy consumption has a direct and proportional negative impact on CO_2 levels, thereby contributing to the mitigation of greenhouse gases. In contrast, a decrease in non-renewable energy consumption brings about a significant decrease in CO_2 emissions in the long term. Moreover, GDP was found to have an asymmetric effect on CO_2, where a decrease in GDP induces a greater decrease in GHG emissions than an increase in GDP. Thus, the research confirms that economic development, combined with increasing the share of renewable energy, is a source of stable and sustainable socio-economic development, while also being environmentally friendly. Furthermore, the application of asymmetric Dumitrescu-Hurlin causality tests confirms the existence of bidirectional causality between an increase in renewable energy consumption and a reduction in CO_2, a decrease in GDP and a decrease in CO_2, and a unidirectional relationship between a decrease in non-renewable energy consumption and a decrease in CO_2.

The study's findings may inform energy policy decisions. The estimation results obtained suggest that economic growth can be sustained during an energy transition. To achieve this, it is essential to develop renewable energy sources in a sustainable and well-considered manner. This goal can be achieved both through the involvement of domestic resources and foreign funds, including European funds and loans from institutions such as the World Bank.

The policy implications of the research suggest that the Visegrad governments should implement robust incentive programmes and subsidies to encourage investment in renewable energy projects. To fully realize the potential

of renewable energy, a two-pronged approach is essential: providing financial incentives to encourage its adoption, and modernizing the energy infrastructure to ensure efficient integration of different energy sources. To accelerate the transition to clean energy, policymakers should focus on two key areas: Firstly, investing in smart grid technologies to improve the flexibility and reliability of existing infrastructure, enabling efficient integration of renewable energy sources. Secondly, increasing government support for renewable energy research and development (R&D) to unlock the full potential of these technologies and pave the way for a sustainable energy future. Collaboration between academia, industry and research institutions can lead to breakthroughs that make renewable energy more accessible and cost-effective.

In line with the latest initiatives from the European Union aimed at reducing CO_2 emissions, it is essential to enhance human capital. Therefore, implementing training schemes and educational programmes is necessary to develop a skilled workforce capable of effectively managing, sustaining, and innovating within the renewable energy sector. Incorporating vocational training, academic programmes, and collaborations with industries can ensure a smooth transition in the labour market.

The Visegrad countries should actively participate in global collaboration, recognizing the interdependence of environmental concerns. Accelerating the transition and effectively tackling worldwide climate challenges can be achieved by exchanging best practices, technological advancements, and policy insights with other nations. It would be beneficial for the group to establish a collective fund and attract investors through a public-private partnership.

The study has some limitations that could be addressed in future research. For instance, the sample size is relatively small, with only four participants from Central and Eastern Europe (CEE), which may limit the generalizability of the findings to other regions. While economic growth and energy use are often seen as the primary drivers of CO_2 emissions, a singular focus on these factors overlooks potentially influential contributors such as green taxes, innovative climate solutions, population trends, and urban planning. To equip policymakers with deeper insights into effective plans for curbing CO_2 emissions and fostering sustainable economic growth in CEE economies, future research should expand its reach to encompass a broader range of countries and delve deeper into the influence of additional factors, along with examining potential interactions between them. Moreover, conducting research utilizing innovative estimation methods like Fourier ARDL or ARDL CS could yield compelling insights.

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