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Preface

Dear Readers,

Welcome to the eighth volume, first issue of *Research Papers in Economics and Finance*. In this edition, we present a collection of articles that address significant economic and financial issues from various perspectives. The contributions in this issue are diverse, covering topics from fiscal policy and financial fraud to digitalisation and income inequality. Each paper offers valuable insights and contributes to the ongoing academic discourse in its respective field.

Two papers in this issue of the journal are related to the VI scientific conference within the series entitled Institutions in Theory and Practice. The initiators of this series were three scientific centres, i.e. Poznań University of Economics and Business, Nicolaus Copernicus University in Toruń and Wroclaw University of Economics and Business. The conference meetings have become a place for the exchange of experience and cooperation among Polish institutionalists. The event presents the results of research in institutional economics and its relationship to other theories and economic practice. The scope of the event includes, among other things, the importance of institutions in economics and law, their role in economic development and the management of organisations, as well as methodological problems related to the study of institutions.

The first paper, titled **Assessment of Poland's fiscal position in the European Union in the face of crisis conditions** by Sławomir Zwierzchlewski, provides an in-depth analysis of Poland's fiscal condition within the European Union amid crisis conditions. The study highlights the extraordinary measures taken by economic authorities and their implications for fiscal stability, offering a timely exploration of this critical issue in the current economic landscape.

In **How institutions are related to agriculture? Systematic literature review**, Michał Barszczewski reviews the literature on the relationship between institutions and agricultural economics. Using the PRISMA method, the author systematically analyses 35 selected articles to clarify the definition of an institution and

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its relevance to agriculture. The study identifies gaps in existing research, particularly the lack of a precise definition of institutions and their historical context, and suggests a method for institution classification.

Marek Kot, in his paper **Financial frauds throughout the years – literature review**, examines the persistent issue of financial fraud across global markets. The paper analyses the correlation between the frequency of published papers on financial fraud and market events, underscoring the need for enhanced cooperation among regulators, law enforcement, academia and the private sector. The study calls for collaborative efforts to prevent and mitigate the effects of financial fraud.

Financial performance and cash flow: Evidence from the US banking industry by Gerasimos G. Rompotis investigates the relationship between cash flow and financial performance in the US banking sector using panel data analysis of 122 banks from 2019 to 2022. The findings reveal a complex relationship, highlighting both positive and negative correlations between different types of cash flows and financial performance metrics.

The research by Meryem-Nadjat Naas and Habib Zouaoui, titled **Forecasting foreign exchange rate volatility using deep learning: Case of US dollar/Algerian dinar during the COVID-19 pandemic**, explores the application of deep learning techniques to forecast foreign exchange rate volatility. The results demonstrate that machine learning methods, particularly linear regression, offer superior accuracy in predicting exchange rate volatility compared to traditional models.

The article **Institutional differences and threats to international tourists from the perspective of new institutional economics**, by Jakub Sukiennik, Sławomir Czetwertyński, Paula Przysada-Sukiennik and Agnieszka Mroczek-Czetwertyńska, examines the theoretical threats posed by institutional differences to international tourists. The authors utilise new institutional economics to analyse how these differences impact tourist security and the associated social costs. The paper highlights the changing preferences of post-pandemic tourists and the implications of institutional diversity for the global tourism industry.

In **Application of a single-equation SARIMA model for short-term conditional forecast (projection) of CPI price dynamics in Poland**, Patryk Kołbyko constructs an optimal SARIMA model for short-term forecasting of the Consumer Price Index (CPI) dynamics in Poland. Using data from 2010 to 2023, the author demonstrates the model's effectiveness in predicting CPI trends, offering a valuable tool for policymakers in managing inflation expectations and achieving monetary policy goals.

Sławomir Kuźmar and Dawid Piątek investigate the relationship between digitalisation and income inequality in Central and Eastern European countries from 2000 to 2020 in their paper **Digitalisation and income inequality in Central and Eastern European countries**. The authors perform empirical analysis on data from ten countries, finding a strong correlation between digitalisation indicators and income inequality measures. The study provides insights into how digitalisation

may exacerbate income disparities, informing policy discussions on mitigating its negative impacts.

Last but not least, the final paper entitled **Stock market return and merger and acquisition activity in Poland**, by Eliasz Czajkowski and Mateusz Mikutowski, explores the trends in mergers and acquisitions (M&A) in Poland from 2019 to 2022, analysing their correlation with stock market returns. The research offers strategic insights for investors and businesses, highlighting the sectors poised for growth and the implications of M&A trends in the Polish market.

We hope this volume provides valuable contributions to the field of economics and finance, offering readers fresh perspectives and rigorous analyses on pressing issues.

Yours faithfully,

Piotr Lis
Editor-in-Chief

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Assessment of Poland's fiscal position in the European Union in the face of crisis conditions

Sławomir Zwierzchlewski[1]

Abstract

Crisis conditions in the 21st century also reached the European Union countries, including Poland, and were reflected in the nominal and real economy. In particular, what suffered most was the fiscal condition of individual countries. To support the state of the economy, the economic authorities often took extraordinary, unconventional actions, which unfortunately resulted and still result in a deterioration of the state of public finances. It is therefore worth referring to this research and empirical problem from the perspective of the current and ongoing economic crisis.

Keywords

- fiscal position
- budget deficit
- public debt
- crisis conditions
- European Union

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Introduction

The 21st century has brought many unexpected phenomena to the global economy, including those originating from the non-economic sphere. In the first decade, a crisis emerged in the banking and financial sphere. At the turn of the second and third decades, another crisis occurred in the medical sphere. In the third decade, yet another crisis arose in the military sphere. The common feature

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of all these types of crises is the fact that they undergo transformation – firstly, objective, and secondly, subjective/spatial. No matter where a crisis originates, over time it has consequences in the socio-economic sphere and constitutes a challenge to the economic policy of state authorities. A crisis also has no geographical boundaries, because with globalisation it spreads on an international scale to most countries around the world.

Crisis conditions in the 21st century also reached the European Union countries, including Poland, and were reflected in the nominal and real economy. In particular, what suffered most was the fiscal condition of individual countries. To support the state of the economy, the economic authorities often took extraordinary, unconventional actions, which unfortunately resulted and still result in a deterioration of the state of public finances. It is therefore worth referring to this research and empirical problem from the perspective of the current and ongoing economic crisis. In this context, the basic aim of the study is to assess the fiscal situation of Poland, especially the level of budget deficit and public debt, against the background of the European Union in the face of crisis conditions in the 21st century. The three crises mentioned above have been taken into account. The research is based on the analysis of data, mainly regarding various measures of the deficit and debt of the public finance sector. In the empirical sphere, a ranking of the EU countries has been made and Poland's place in the ranking has been assessed.

The study consists of two main parts. The first part (point 1) is mainly theoretical and partly methodological in nature. It contains considerations on the essence of contemporary fiscal policy. It depicts how crisis conditions constitute challenges for fiscal authorities, in particular with regard to redistributive stabilisation policy. The second part (points 2 and 3) is mainly empirical in nature. It analyses data on Poland's fiscal situation compared to the EU. In the initial phase of the study, aggregated data and a broader period of 2000–2022 are taken into account (point 2). However, in the next phase of the study (point 3), three crises are directly referred to and individual EU member states are taken into account separately.

The article takes into account the author's theoretical knowledge based on many years of scientific experience, including various studies, conducted both by the author himself as well as other researchers. In turn, statistical data comes mainly from the Eurostat website, as well as the Central Statistical Office and the National Bank of Poland.

1. Theoretical and methodological foundations of fiscal phenomena in crisis conditions

The essence of fiscal policy is appropriate intervention in the market (economy) using the main tool, i.e. the budget, including income and expenditure. This intervention takes place in the context of the implementation of appropriate socio-economic functions and goals, both at the central and local government levels (Mortimer-Lee, 2001). The scale of interference depends on the degree of market defects (see micro- and macroeconomic defects of the market), as well as the accepted (formally or informally theory of social justice) (König, 2001). Therefore, there is no universal answer to the question whether a more liberal approach (less active redistributive fiscal policy) or a more social approach (more active redistributive fiscal policy) is better in conducting fiscal policy. One can logically accept a different degree of fiscal interventionism in time and geographical space, as long as it is adapted to the given conditions resulting from the current state of the economy and the efficiency of the market.

In conditions of economic stability, micro- and macroeconomic market defects are relatively small, and therefore fiscal intervention should be smaller. Its measure may be a lower rate of income redistribution, both on the income and expenditure sides (see the methodological notes on measuring the degree of fiscal policy activity below). In such conditions, a desirable phenomenon is a reduction of the budget deficit, or even its balance or surplus. Therefore, the prolonged state of relative economic stability will ultimately result in a reduction of the debt of the public finance sector, or at least its ratio to GDP. Looking from a long-term perspective, in the world's economic history, periods of economic stability favoured the domination of liberal, laissez-faire theories in economics, including A. Smith, D. Ricardo and later M. Friedman (Friedman et al., 2002).

In conditions of economic instability, micro- and macroeconomic market defects are relatively greater, and therefore fiscal intervention should be more active. Its measure may be the growing rate of income redistribution. An extreme situation requiring extraordinary fiscal intervention is a crisis, understood not as one of the phases of the "normal" business cycle, but as an extraordinary breakdown of the economy, manifested, among others, by a decrease in GDP. The economic history of the world, including modern times, shows that the sources of economic crises do not have to be strictly economic in nature, but also military, health, political or social. In such conditions, an increase in the budget deficit is a common phenomenon. A prolonged state of economic instability and/or crisis will result in an increase in the debt of the public finance sector, including its ratio to GDP. Looking from a long-term perspective, in the economic history of the

world, periods of economic stability favoured the dominance of social and interventionist theories in economics, such as J. M. Keynes.

From a theoretical point of view, fiscal policy should be flexible in relation to the conditions. Its level of activity (a more social versus liberal attitude) should depend on the state of the economy and the related scope of market defects. Exemplary, countercyclical, stabilising fiscal policy, implemented through an appropriate scale of redistribution, should contribute to achieving the goal of stable and lasting economic growth and social well-being (Süppel, 2003). In practice, however, such a model/exemplary image of economic policy is distorted by political and electoral factors. While expansionary policy is politically justified, restrictive policy is undesirable for the economic authorities seeking re-election. The redistributive policy becomes asymmetric (too expansive), resulting (as a side effect of taking care of macroeconomic goals) in a poor fiscal situation, including the long-term perspective.

Additionally, it should be noted that in the 21st century, in the face of crisis conditions, we often deal with this type of attitude in economic policy. The fiscal authorities must pursue an anti-crisis, active, unconventional budget policy to mitigate the occurrence of micro- and macroeconomic market defects, which became evident, among others, during the banking and financial crisis of the first decade, as well as the COVID-19 pandemic and the military crisis at the turn of the second and third decades of this century. However, these actions should be carried out skilfully and take into account fiscal side effects in the long term. It is recommended that when relatively stable economic conditions occur, there should be a return to anti-cyclical, more restrictive fiscal policy, including limiting the dynamics of the increase in the debt of the public finance sector. The policy cannot be permanently one-directional because it will make the economy "fragile" and susceptible to crisis situations, especially in the face of limited potential opportunities to conduct an expansive anti-crisis policy based on an increase in the deficit and public debt. During "better times", fiscal authorities should build a "protective cushion" in the event of worse economic conditions, including crises (Możdżeń & Zygmuntowski, 2022).

The above remarks show that measures of fiscal activity may include revenues, expenses and budget balance, as well as public debt. For the purposes of international comparisons, it seems better to take into account relative measures of the indicated values in relation to GDP (in %). In this way, we can compare countries of different sizes and with different currencies (Giżyński, 2013).

Bearing in mind that fiscal policy can be conducted at various territorial and geographical levels, both the central government (c.g.) and local government (l.g.) levels should be taken into account when assessing the country's fiscal situation. It is worth analysing the aggregate redistribution of income in relation to the overall public finances (general government, g.g.) (Sokołowski, 2003).

Such briefly presented methodological remarks have been used in the empirical part of the study to assess the fiscal situation in Poland against the background of the European Union in the 21st century, in particular in relation to crisis situations. Three "epicentres" of crises are included in this work, dated by the author to:

- 2009 – the financial crisis,
- 2020 – the COVID-19 pandemic,
- 2022 – the military crisis.

The research took into account mainly the Eurostat data and additionally data from the Central Statistical Office and the National Bank of Poland. The data was imported into the study in June 2023. The study methodology also included a ranking for the EU countries according to the indicated evaluation criteria.

2. Outline of Poland's fiscal situation in 2000–2022

The assessment of Poland's fiscal situation in the face of crisis conditions has been made against the background of data for a broader period. Due to the availability of statistical data, the starting date is the year 2000 and the end date is 2022. First of all, it is worth referring to absolute fiscal measures. In this way, it is possible to analyse the dynamics of changes in the fiscal situation. Figures 1 and 2 present data on the value of the deficit and debt of the entire public finance sec-

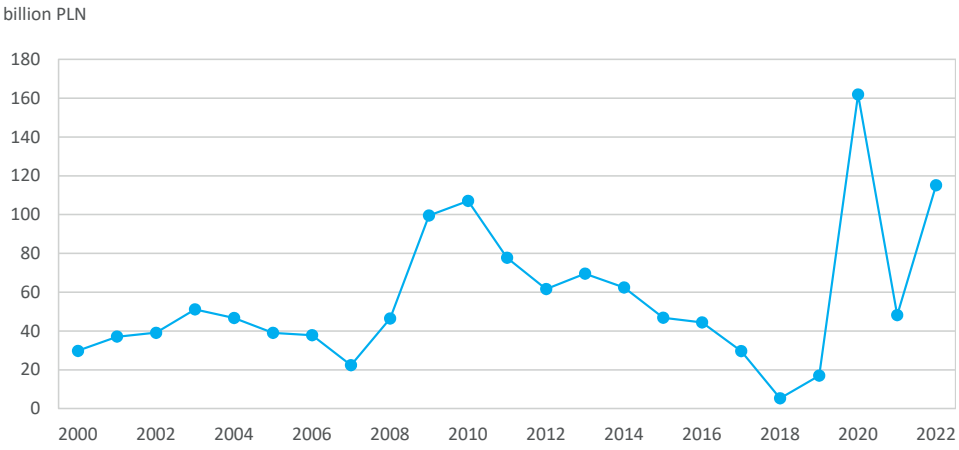

Figure 1. Budget deficit value of public finance sector in Poland in 2000–2022

Source: based on: (Eurostat, 2023a).

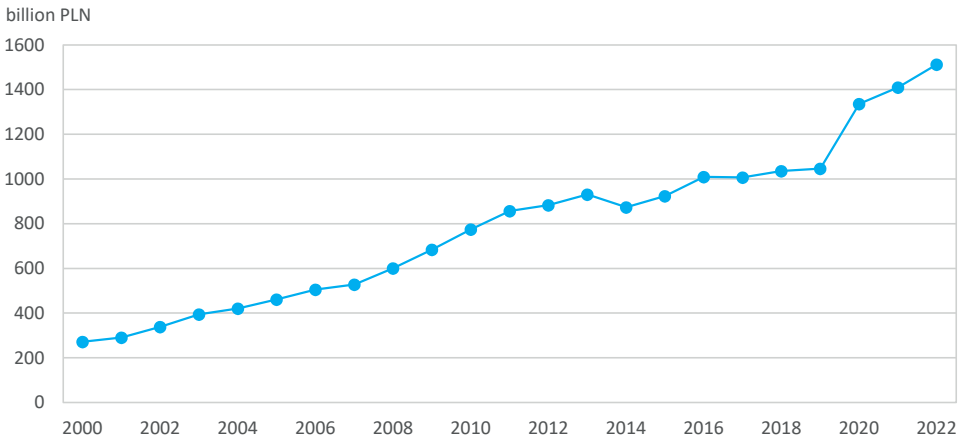

Figure 2. Debt value of public finance sector in Poland in 2000–2022

Source: based on: (Eurostat, 2023a).

tor for Poland for the period indicated above in the national currency (Polish zloty, in billions).

Even the basic data allow us to notice several important stages in the fiscal policy in Poland in the 21st century. We may observe a mild downward trend in the budget deficit after Poland's accession to the EU, which was disturbed by the global financial crisis. The deficit increased for three consecutive years starting from 2007. We may then observe a second, more significant downward trend in the deficit, which, in turn, was disturbed by the crisis related to the COVID-19 pandemic. While the deficit increased slightly in 2019, the following year saw its record increase in the 21st century. The year 2021 can be described as a post-COVID-19 "thaw", which, however, was "brutally" (also in the literal sense of the word) disturbed by Russia's invasion of Ukraine and the ensuing war. Currently, the war is the main cause of pressure to deteriorate the fiscal situation in the crisis conditions in Poland.

The dynamics of changes in the budget deficit is reflected in the values of public debt. We may observe its growth every year, except for 2014, when it decreased slightly in absolute terms compared to the previous year. Some debt stabilisation between the financial crisis and the COVID-19 pandemic should be assessed positively. At that time, its growth dynamics was relatively low.

Continuing the fiscal assessment of Poland, the ratio of the examined values (deficit and debt) to GDP (as a measure of the "economic size" of the country) should be used, especially in the context of the European Union. At this point in the study, we will also utilise aggregated data for the entire EU, and not just individual member states. Figures 3 and 4 show the percentage ratio of the deficit and debt of the public finance sector to GDP in Poland and the EU in the years 2000–2022.

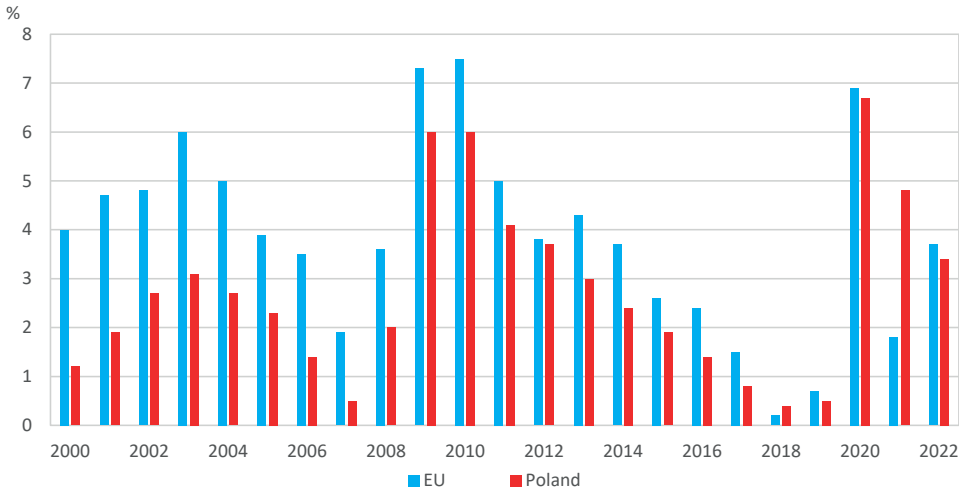

Figure 3. Ratio of public finance sector budget deficit to GDP in Poland and the European Union in 2000–2022

Source: based on: (Eurostat, 2023a).

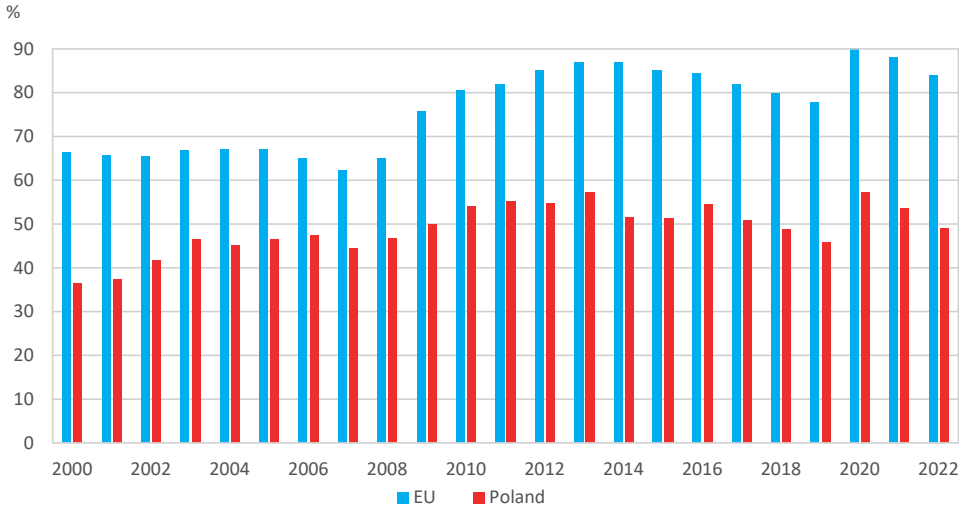

Figure 4. Ratio of public finance sector debt to GDP in Poland and the European Union in 2000–2022

Source: based on: (Eurostat, 2023a).

The data presented in this work confirm previous observations about a certain cyclicality of the fiscal situation, in particular about the impact of crisis conditions on the fiscal sphere in Poland and the entire EU in 2009, 2020 and 2022. Looking at both charts, Poland's fiscal situation against the EU background may already be positively assessed at this stage. As regards public debt (Figure 4), the situation is extremely clear. Its ratio to GDP is much lower in Poland in each year under analysis than the average for the entire EU. Additionally, in Poland this measure did not exceed the recommended EU limit of 60% in any year under analysis (including the threshold for accession to the euro area). For the EU, in turn, it exceeded this limit in every year under analysis.

The situation is similar when it comes to the deficit to GDP ratio. In this case, however, the differences between the values for Poland and the average values for the EU are not so large, and in 2018 and 2021 the relationship was reverse. Considering the deficit to GDP ratio, it can be seen that the COVID-19 crisis was most severe in Poland, and the financial crisis was most severe in the EU in general.

Additionally, it should be noted that for the entire research period starting from 2000, the recommended EU limit of 3% of the deficit to GDP ratio was exceeded many times, especially in the face of crisis conditions. On the one hand, it is a manifestation of the poor economic and fiscal situation in these years, and on the other hand, it is a manifestation of the response of the fiscal authorities to economic problems. The final assessment will be possible in the longer term, in conditions of economic stability. We will then see whether the effects of the expansive, anti-crisis fiscal policy will be long-term and whether they will be compensated during good economic times.

3. Fiscal ranking of Poland against the background of the European Union based on selected criteria

At the next stage of the fiscal assessment of Poland in the face of crisis conditions, a ranking of the EU countries was made based on appropriate criteria (see points 3.1–3.2). The three previously indicated "epicentres" of crises were taken into account, i.e. financial, health and military, and the place of Poland was indicated against this background. The main results of the study are presented in Tables 1 and 2. To better illustrate the ranking, each point is accompanied by a map showing the geographical distribution of countries, taking into account the criterion under analysis for the current period. It should also be noted that the ranking presented in this study is not considered in detail for all countries included in it. In fact, this will be the subject of separate research conducted by the author. In this work, the attention is focused on Poland and its place in the ranking.

3.1. Budget balance

The first ranking criterion is the ratio of the budget balance (usually the deficit) to GDP. Figure 5 shows the current situation in the EU for the appropriate ranges of values of the indicator used (see Legend). The darker the colour, the better the budget situation is. Several countries are currently recording budget surpluses: Denmark, Cyprus, Ireland, Sweden, Croatia and Luxembourg. At the other extreme are the countries with the highest deficit – above 5%: Italy, Hungary, Romania and Malta.

Poland is one of the countries with a higher deficit in relation to GDP. These data are confirmed in the last column of Table 1, where Poland ranks 19th among

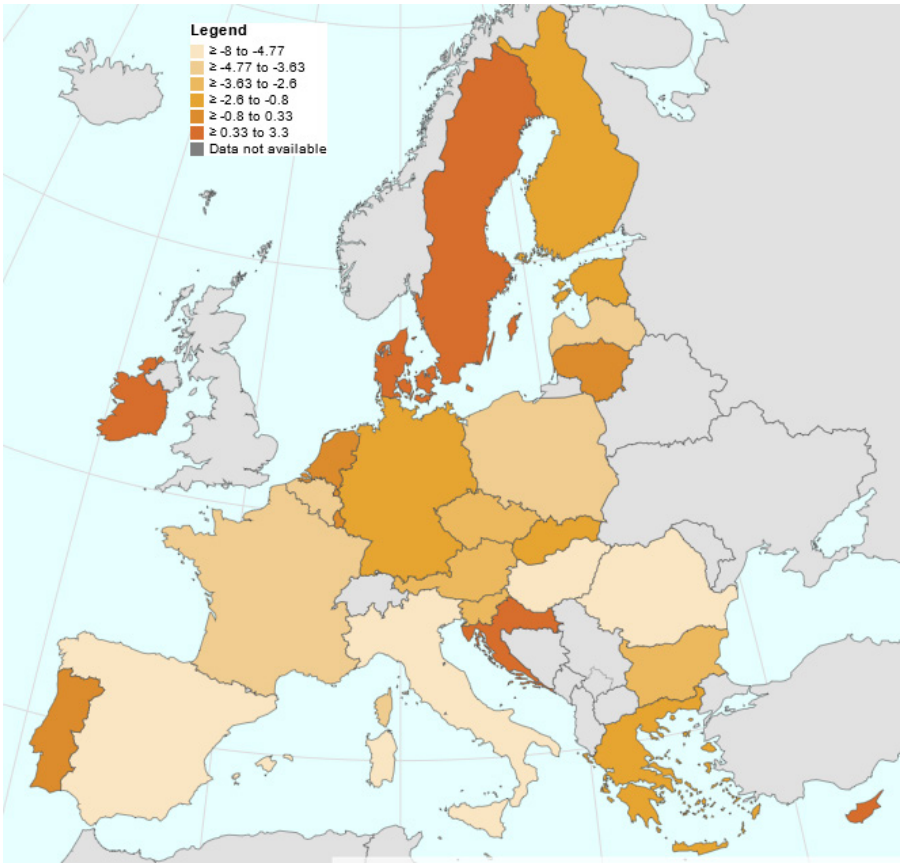

Figure 5. Map of the European Union – ratio of public finance sector budget deficit to GDP in 2022

Source: based on: (Eurostat, 2023b).

the EU countries in 2022. It is therefore among the countries that are strongly affected by the military crisis. Poland was in the same place in the 2009 ranking. However, it was three places higher in the case of the COVID-19 crisis in 2020.

Unfortunately, maintaining a relatively good situation in the macroeconomic sphere of the real economy (e.g. relatively high GDP dynamics and low unemploy-

Table 1. Ranking of EU countries according to the ratio of public finance sector budget deficit to GDP in crisis conditions

Country	2009 – financial crisis	2020 – health crisis	2022 – military crisis
Austria	12	20	17
Belgium	13	21	20
Bulgaria	8	5	15
Croatia	17	17	5
Cyprus	15	13	2
Czech Republic	14	12	18
Denmark	5	1	1
Estonia	3	10	10
Finland	4	11	11
France	18	22	22
Greece	27	26	13
Spain	25	27	23
Netherlands	11	4	7
Ireland	26	8	3
Lithuania	21	15	9
Luxemburg	1	3	6
Latvia	22	7	21
Malta	6	24	24
Germany	7	6	14
Poland	**19**	**16**	**19**
Portugal	24	14	8
Romania	23	23	26
Slovakia	20	9	12
Slovenia	16	19	16
Sweden	2	2	4
Hungary	9	18	25
Italy	10	25	27

Source: based on: (Eurostat, 2023b).

ment rate) results in a not very good current situation in the nominal sphere, including the fiscal sphere examined here, and, more recently, also the monetary sphere. Therefore, a classic theoretical interchangeability between nominal and real variables may be noticed here.

3.2. Public debt

The second ranking criterion is the size of public debt in relation to GDP. Figure 6 shows the current situation in the EU for the appropriate ranges of values of the indicator used (see Legend). The darker the colour, the worse the debt situation is.

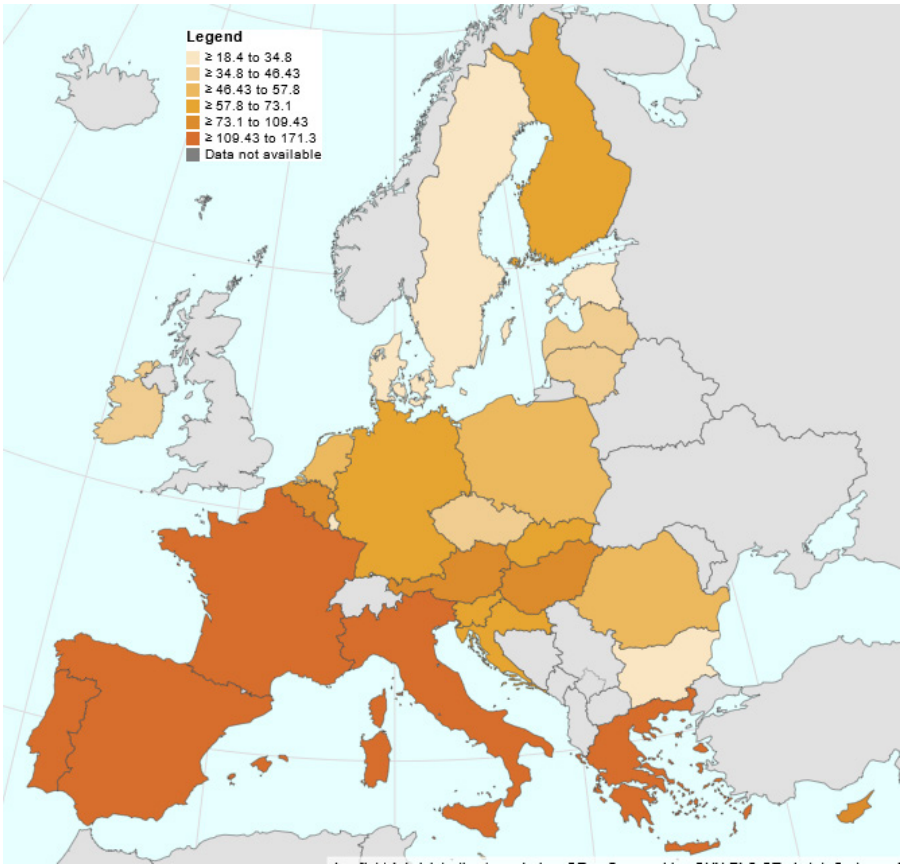

Figure 6. Map of the European Union – ratio of public finance sector debt to GDP in 2022

Source: (Eurostat 2023b).

Table 2. Ranking of EU countries according to the ratio of public finance sector debt to GDP in crisis conditions

Country	2009 – financial crisis	2020 – health crisis	2022 – military crisis
Austria	22	19	20
Belgium	25	21	22
Bulgaria	2	2	2
Croatia	13	20	16
Cyprus	16	22	21
Czech Republic	6	4	8
Denmark	10	7	4
Estonia	1	1	1
Finland	12	16	18
France	23	23	23
Greece	27	27	27
Spain	15	24	24
Netherlands	17	11	12
Ireland	18	13	9
Lithuania	5	8	6
Luxemburg	3	3	3
Latvia	9	6	7
Malta	19	10	13
Germany	20	15	15
Poland	**14**	**12**	**11**
Portugal	24	25	25
Romania	4	9	10
Slovakia	8	14	14
Slovenia	7	18	17
Sweden	11	5	5
Hungary	21	17	19
Italy	26	26	26

Source: own calculations based on (Eurostat 2023b).

Several countries with debt above 100% of GDP deserve a particularly negative assessment in this respect. They are mostly located in southern Europe: Greece, Italy, Portugal, Spain, as well as France and Belgium.

Poland ranks slightly higher in this ranking compared to the previous one. Currently, it is one of the countries with lower debt in relation to GDP. Moreover,

the ranking of the EU countries improved in the face of subsequent "epicentres" of crises. However, we still have to wait for the final assessment in this respect. Public debt is a cumulative amount that reflects, with some delay, budget deficits from subsequent periods. In particular, we still have to wait for the fiscal consequences of the military crisis, according to Table 2.

What is optimistic is the fact that the rather expansive anti-crisis fiscal policy of previous years is not yet reflected in the long-term fiscal measure. We can hope that countercyclical policy undertaken at the appropriate time, in post-crisis conditions, can alleviate the long-term effects of the 21st century crises. Additionally, Polish fiscal decision-makers have not yet "hit a wall" in the form of the possibility of greater fiscal expansion in the event of further crisis conditions.

Conclusions

The 21st century has been marked by turmoil in many spheres of life. The global economy is experiencing crisis situations, the sources of which are often not only economic and financial but also military or health-related. Crisis conditions spill over into many aspects of citizens' lives, causing micro- and macroeconomic market defects, and at the same time forcing intervention in the field of economic policy. In particular, fiscal authorities are forced to take unconventional, often ad hoc and unplanned actions, the effects of which are difficult to predict, especially in the long term.

Three successive crises (financial, health and military) have left their mark on the fiscal situation of the European Union. It has manifested itself in an increase in the size of deficits and debts of the public finance sector. Yet, some countries seem to have managed better (e.g. Scandinavian countries such as Sweden and Denmark) and some worse (e.g. southern European countries including Greece, Italy, Spain and Portugal). Nonetheless, it is probably too early to assess the final effects of the crisis conditions, especially regarding the military crisis. Given the experience of recent years, it would be worth considering formulating an emergency plan in the event of subsequent crises, and additionally rationalising the post-crisis policy. It should be countercyclical, i.e. it should also include a restrictive variant during good economic times.

Poland is one of the countries which experience subsequent crises (primarily financial) relatively mildly from the point of view of the macroeconomic results, including those relating to the real economy. In 2009, it was the only country with positive dynamics of changes in real GDP, and since then it has also been characterised by a low unemployment rate, not recorded since the systemic transfor-

mation at the turn of the 1980s and 1990s. In fact, Poland recorded a decline in real GDP only in 2020, with the following years bringing GDP growth. It has been shown in this work that achieving good macroeconomic parameters has side effects in the nominal sphere, including the fiscal one. Expansive budget policy at both the central and local government levels leads to an increase in budget deficits and debt. However, as of today the situation seems to be under control, even thought it is difficult to assess the final, long-term effects of crises, including the ongoing military crisis. It is still advisable to rationalise fiscal policy through, among other things, increasing its flexibility and striving to make it more countercyclical and stabilising in nature (and not ad hoc and pro-election). Of course, changes in this area must be spread over time and take into account, among others, such problems as the rigidity of budget expenditures, the crowding out effect or the Laffer curve.

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How institutions are related to agriculture? Systematic literature review

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Abstract

In this paper, the author reviews the literature on institutions and their relations with agricultural economics. The aims of the article are to clarify the definition of an institution, indicate its relevance from the perspective of agricultural economics and propose a method of institution classification. Using the PRISMA method, 35 articles were selected out of 238 articles from the Web of Science database that met the established requirements (i.e. they were simultaneously related to institutions, economic performance and the agricultural sector). Based on the identified articles as well as the preliminary literature review it can be concluded that there is a lack of research that precisely defines institutions and examines the historical context at the same time. There are not many papers in which authors assess relations between institutions. Furthermore, authors rarely associate directly with any theory, especially with institutionalism or new institutional economics. That may be a pragmatic approach, but at the same time results are less comparable with other papers written in the same manner. The contribution made by this article is a synthetic presentation of the issue of institutions in agricultural economics and a classification of institutions, with an indication of which type of institutions will be viable when assessing the relations of institutions with the farming sector.

Keywords

- institutions
- systematic review
- agriculture
- economic performance
- farms

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Introduction

Even though agriculture has become almost marginal, at least in terms of the statistical perspective in modern Europe, it is still important for diversity and European identity (Wilkin, 2016). For example, the important role of agriculture in counteracting poverty is noted (Mellor, 2018). Agriculture is a sector that has been present in the economy since the beginning. More productive agriculture is responsible for the development of a country. The agricultural sector provides key goods for the survival of the population, while also employing many people (especially in less developed countries). Due to the dependence of production on land, which is a scarce and specific good that requires appropriate management (Marks-Bielska et al., 2017, p. 15), a key factor in agricultural development is technology through which productivity can be increased. Knowledge makes it possible for farmers to utilise the most recent technology. At the same time, knowledge is strongly dependent of institutions (Wójcik et al., 2019).

The following article is largely based on the tenets of new institutional economics (NEI), which was founded on institutionalism (Ratajczak, 2012). The object of studies of representatives of both NEI and institutionalism is primarily the concept of "institution".

It is reasonable to point to specific types of institutions together with the conditions for which a particular way of stratifying them has been adopted. Thus, one can distinguish between formal and informal institutions, institutions concerning the economic, social or political sphere, as well as institutions of free and restricted access.

Institutions are changing and evolving. The speed with which change proceeds varies according to the type of institution. As a rule, informal institutions change slower than formal institutions (Williamson, 2000).

Arbitrary and systematic review have been conducted. Compared to an arbitrary expert review, a systematic review maintains its greatest advantage – the transparency of the procedure and its repeatability (Wolski, 2017). The systematic review used the PRISMA method (Page et al., 2021) where applicable. As the method was originally developed for meta-analysis in the medical sciences, some steps, such as assessing the risk of bias, were omitted. Even without these steps, however, PRISMA can be used as a tool for conducting a systematic review of the economic sciences (Staniszewski & Matuszczak, 2023).

Within the framework of the present study, the aim was to create a methodological workshop through which it would be possible to classify institutions based on the authority of the main representatives of new institutional economics, institutionalism and the latest research in the subject).

The following specific objectives served to realise the above-mentioned goals:

- indicating how institutions are defined in the economic sciences, with an emphasis on new institutional economics
- presenting studies that point to the relevance of institutions in the agricultural sector and evaluating the authors' positions
- presenting a coherent view of institutions and proposing their classification.

The contribution of the article is the identification of the research gap in the literature on institutions in agricultural economics as well as the classification and identification of institutions based on the conclusions of the literature review. This will allow the reader to better understand what an institution is in economic sciences and how to identify it in economic research studies, especially in agricultural economics. That, in turn, will further develop research on institutions in economics.

1. Methodology

The systematic review using the PRISMA method proceeded as follows: regarding the eligibility criteria for the review, only already published scientific articles were considered. It was decided not to impose any temporal or spatial restrictions. As agricultural economics is qualified as a social science, the Social Sciences Citation Index (SSCI) was used to select the database from which the articles would be selected. SSCI is an index which allows for the selection of social science articles, available in the Web of Science database. Due to the wider scope of the selection, there was lower risk of missing a valuable article (the process is shown in Figure 1).

The source of information for this review was a query retrieved on 11.03.2023 from the Web of Science database. The query was formulated as follows: ALL = (AK(institution* AND ("agricultur* sector" OR "agricultur*" OR "farm*"))) OR ALL = (AP(institution* AND ('agricultur* sector' OR 'agricultur*' OR 'farm*'))). It was also decided to limit the study to papers published in English, as these have the greatest impact on the international research agenda. It was decided to select articles from the collection in which:

- institutions are the object of study and are used to explain differences in economic performance;
- issues in economics and finance are addressed;
- the scope of the paper is the agricultural sector, provided that crop growing or animal husbandry is addressed in the context of the agricultural sector.

Articles selected for further review had to meet all of the above conditions simultaneously. In the selection process, all titles, abstracts and full texts were checked by one reviewer and analysed in English. The entire selection process is

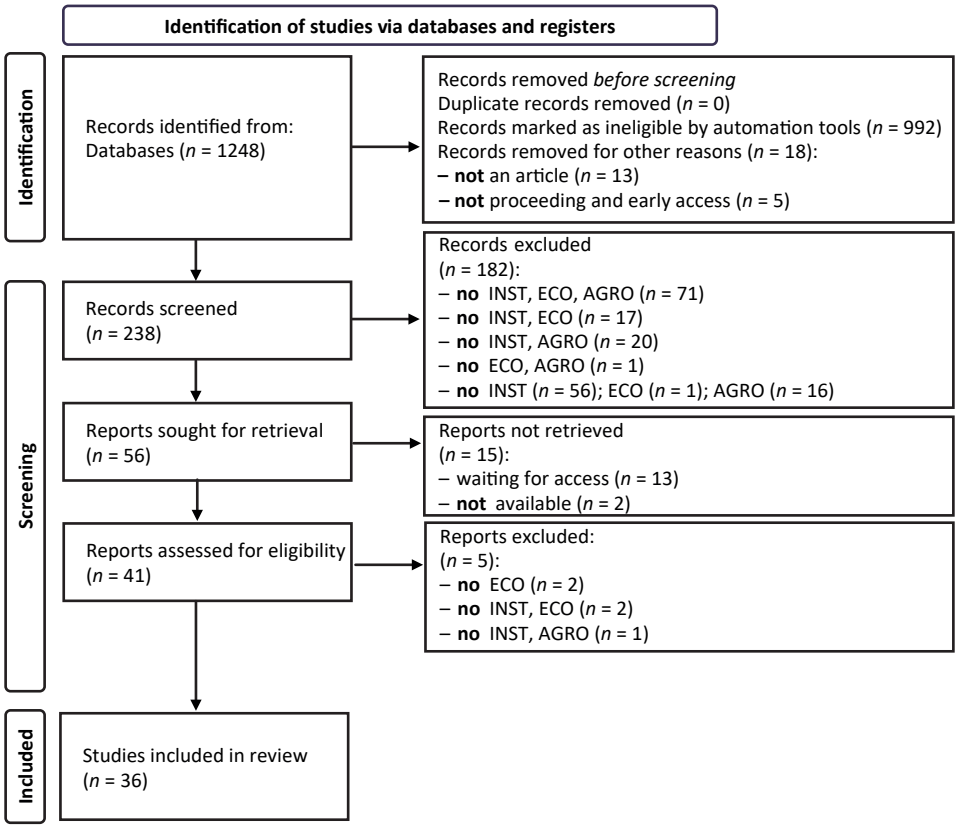

Figure 1. PRISMA flow diagram – selecting articles

Source: own elaboration based on the PRISMA systematic review of the Web of Science database.

shown in Figure 1. In the data collection process, the articles were categorised based on the expertise of the reviewer.

The first stage of the review conducted was the selection of the database from which the records would be extracted. Firstly, it was decided to rely on a single database due to potential technical difficulties in merging data (Kryszak et al., 2021). The Web of Science database was chosen, among other things, due to the prevalence of its use in systematic reviews of the literature on agricultural economics (Bathaei & Štreimikiene, 2023; Malapaneet al. 2022; Mizik, 2023; Poczta-Wajda & Sapa, 2021). As Malapane et al. (2022) point out, Web of Science is a highly reliable tool, giving access to a wide variety of scientific material, and is well suited to data-intensive, large-scale research.

After entering a query in the Web of Science database, 1248 records were obtained. Automatic article selection tools available in Web of Science were used. By considering only articles with the Social Sciences Citation Index (SSCI), 992 records

were eliminated. Subsequently, scientific papers that were not scientific articles (13 records) and articles that had not yet been officially published (5 records) were excluded from further study. As an outcome of the preliminary screening of abstracts (abstract screening) and the titles of the papers, 182 articles were rejected and 56 articles were provisionally accepted, if they met the requirements (i.e. they were about institutions, they fell within the subject matter of economics and finance, they were about the agricultural sector and agricultural production: crop cultivation, animal husbandry). Articles in which institutions were not the object of study and were not used to explain differences in economic performance (not INST), articles whose subject matter did not relate to economics and finance (not ECO), and those in which the agricultural sector was not the scope of the subject matter, including plant growing and animal husbandry (not AGRO), were rejected. Of the 238 articles, 71 did not meet any conditions, 17 were not about INST and ECO, 20 were not about INST and AGRO, and 1 was not about ECO and AGRO. In addition, 56 records were not including INST 1 did not consider ECO, and 16 neglected AGRO problematics.

After an initial review of the abstracts, the remaining articles were reviewed for full-text availability. It turned out that at the time of writing this paper, it was not possible to access 13 full texts. Steps were taken to access the full version of 13 out of 14 articles (for one record it was not possible to take these steps). As can be seen in Figure 1, 41 records were eventually included in the full-text analysis of the articles. After reviewing the full texts of the articles, it was decided to exclude 5 more articles, 2 of which did not address ECO, 2 did not address the issues of ECO and INST at the same time, and 1 article was not about INST and AGRO. Thus, the 36 selected articles are further analysed in this subsection.

As a supplement to the systematic literature review, a supporting literature review based on the Google Scholar and Scopus databases was conducted. Newer, frequently cited articles (published after 2010) and review articles (published after or before 2010) were selected to compare its conclusions with the systematic literature review. The conclusions from the supplementary literature review were coherent with the systematic literature review. Keywords for Google Scholar and Scopus were: agricultur* AND institution* OR farm*.

2. Literature review

Institutionalism took shape in the United States in the second half of the 19th century. Representatives of this economic school were the first to begin to study and define the institution and to recognise its crucial importance for the econom-

ic system. They relied on a holistic, interdisciplinary approach to economic issues (Stankiewicz, 2004, pp. 15–25). New institutional economics derives partly from institutionalism. It sets itself the task of answering the questions of what determines the emergence of specific institutions and what impact do they have on the economic performance of economic agents (Alston, 2018). Economic performance can be seen as the total labour input, the real income of factors in agriculture per annual labour unit, and the gross value added of the agricultural industry and animal production (Rađenović et al., 2022, p. 6).

An institution, according to Hodgson (2006), is a system of established and universal social rules that shape social interactions. Language, money, law, the system of weights and measures, as well as savoir vivre, are all institutions (Hodgson, 2006, p. 2). In this article, interpretation of the perception of institutions based primarily on the definitions proposed by representatives of the new institutional economics and by Hodgson, has been implemented. Thus, institutions are defined as established and widespread rules of conduct in a given community that shape interpersonal relations and social interactions (including organisations). Furthermore, institutions influence transaction costs, which may contribute to better or worse economic performance.

North (1991) points out the division of institutions into formal institutions, i.e. norms resulting from rules written in the law, and informal institutions, occurring as certain unwritten, community-established norms of behaviour (p. 97). Supplementing the conceptual apparatus regarding institutions in addition to the distinction between informal and formal ones (North, 1991; Ostrom, 2008), it is important to point out an additional division suggested, among others, by North together with Wallis and Weingast (2009, p. 56). They specify two types of institutions: institutions that restrict access to economic surplus and political life as well as inclusive institutions that provide actors with equal opportunities (North et al., 2009). Based on North's (1990) definition, three types of institutions can be further distinguished by their sphere of influence. These are economic, political and social institutions. For this paper, however, it was decided to include a third type of institutions, i.e. social institutions, as initially outlined by North (1990). Economic institutions determine the availability of community members to conduct business and take advantage of business opportunities (Mousseau, 2023, p. 119). Political institutions influence the "rules of the game" in which political decision-makers, those responsible for legislating and making policy, are participants (Besley & Persson, 2018). Social institutions are social practices established through norms that determine the status and conduct of actors who are part of a community (Tuomela, 2003). In this article, the author suggests viewing a social institution as the most general concept, which includes political and economic institutions. Furthermore, there may be purely social institutions, when they do not concern the economic or political sphere. Culture and social capital can also

be included in this set due to their specificity. Culture is a level of trust in others, a marker of status in society, beliefs about the appropriate trade-off between efficiency and fairness or established roles for men and women (Fernández, 2018). Social capital is a person's network of social ties (social bonds), providing access, mobilisation and use of the material and immaterial resources accumulated in the network, which enable and/or facilitate the realisation of specific economic goals (Sławecki, 2009, p. 59).

Very helpful in understanding the phenomenon of evolution and institutional change is the model proposed by Williamson (2000). Williamson presents four levels of analysis of social phenomena: at level one, change occurs very slowly (100 to 1000 years), at level two it occurs more rapidly (10 to 100 years), at levels three and four change occurs relatively rapidly (1 to 10 years) and continuously. At the same time, the first level is informal institutions, customs, traditions and religious norms. The second level is formal rules. Level three concerns governments and level four is about incentives for changes in the market and allocation of resources.

North (1991) indicates that economic change is path-dependent. He assesses that path persistence is more than an evolutionary process. He points out that the largest players may capture surpluses for themselves, with no incentive to do so to support development (North, 1991). In many publications regarding the topic of 'institutional change', Acemoglu (along with other researchers) developed North's insights. In their later work, Acemoglu et al. (2021) point to the continuing inability to explain the mechanisms involved in this phenomenon. Nevertheless, a situation of "institutional stagnation" has been recognised as an extreme, model example of institutional sustainability. This is a situation in which institutions do not change at all.

Agricultural economics emerged from a combination of company theory as well as marketing and organisation theory in the 19th century. In the 20th century, it developed into an empirical branch of economics. From the 1960s onwards, agricultural economics also began to address issues such as the development of poor countries, trade and the effects of government-led macroeconomic policies in wealthy countries. In later years, issues of production, consumption, environmental protection or natural resources also began to be studied within agricultural economics (Runge, 2018).

In the supporting literature review, the authors present which components of the agricultural sector institutions affect the factors of production.

In the supporting (non-systematic) review of the Scopus database, 22 articles on the relevance of institutions in agricultural economics were analysed. Three articles dealt with the impact of institutions on economic performance, and the content of 2 articles dealt with the relevance of institutions in trade. The link between institutions and economic performance was seen in the largest number of articles, 6 out of 22 examined. In 2 articles, the occurrence of specific institutions

was linked to the amount of transaction costs, also in 2 articles the role of institutions in stimulating innovation in the agricultural sector was highlighted. The relevance of institutions from an agricultural policy perspective was demonstrated in 4 articles. A potential relationship between institutions and the availability of capital was noted in 3 articles. Given that the articles from the Scopus database review largely focused on developing countries, the contribution of productivity, agricultural policy effectiveness, economic performance or capital availability as important characteristics of the agricultural sector that should be influenced by institutions was not surprising. Developing countries are in the early stages of economic transition and base their system primarily on the agricultural sector (Mellor, 2018). At the same time, the agricultural sector absorbs a significant share of the means of production in these countries. By increasing productivity/efficiency, it is possible to achieve economic results at a lower cost and free up the means of production with the possibility to develop other sectors of the economy.

Both articles from Google Scholar and the Scopus supporting literature review recognise the relevance of state policy and its effectiveness, as well as the importance of innovation. Summing up, the topic of institutions as an important factor influencing the agricultural system remains topical, which is reflected in scientific literature. Depending on the specifics of the studied region, researchers are interested in other spheres of influence of institutions. At the same time, however, it is possible to notice serious problems in articles which deal with institutions: often the institution is not defined, and the definitions presented in various articles differ significantly. In the following section, the aim is to conduct a systematic literature review to further investigate this problem.

3. Results and discussion

In the systematic review of literature, thirty-six articles were examined. The topic of institutions in the context of their impact on farm economic performance appeared to be the most widely used in developing countries. The largest number of records comes from the Middle East and India (12): these are largely case studies, evaluating the effectiveness of policies in place and forecasting the effectiveness of solutions planned for the future. There are also a number of articles on Africa (9). A few articles were devoted to Europe (4). Same number were considereing South America continent (4).. In addition, 3 articles covered the Far East and China region. The fewest articles were either not related to any specific country or region (2) or concerned North America (1). Thus, as can be seen, only 5 articles out of 33 (not counting articles of a general nature) relate to regions

where developed countries predominate. The final selected set of articles was used to create a list of institutions influencing economic performance (Figure 2) in the agricultural sector and allowed comparison with the typology of institutions suggested in the preliminary literature review.

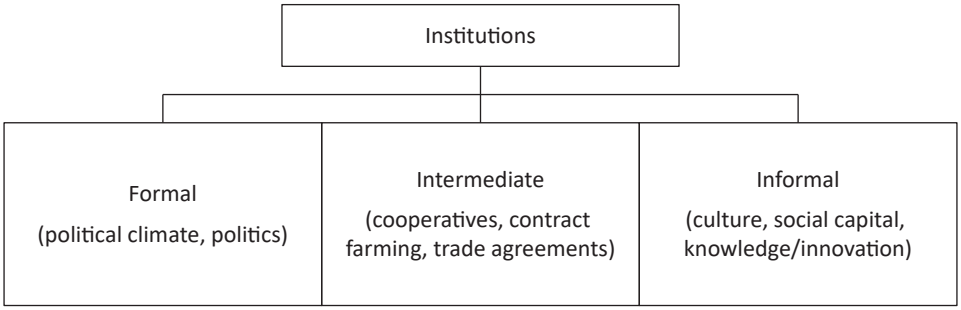

Figure 2. Proposed classification of institutions

Source: own compilation based on a comprehensive literature review.

Due to the emergence of institutions whose classification did not fully correspond either to formal or informal institutions (for example, producer organisations or formally concluded contracts), it was decided to create a cluster called "intermediate institutions". Intermediate institutions are characterised by being under state regulation, but at the same time free to contract. For instance, a producer group can be seen as a formal as well as an informal institution at the same time (Dal Belo Leite et al., 2014).

While a large proportion of articles focus on only one category (about 77%), there is also a noticeable proportion of articles that examine both formal and informal institutions or institutions of an intermediate nature (about 23%).

When comparing the institutions examined in the systematic review with the typology of institutions from the supporting review, it was noted that the manner of classification coincides with the conclusions of the PRISMA review to a large extent. Nevertheless, after a synthesis of conclusions of both reviews, doubts were raised in the context of formal institutions, in particular concerning active state interventions in the economic sector. The term "economic policy" has been suggested for such state activities, which would allow similar formal institutions to be harmonised. It is also more specific than just "policy". Another term that, in the author's opinion, better reflects the political reality along with the changes taking place in the system is the concept of "political climate". This term combines certain cyclical changes in the context of the power system. In the end, it was decided to simplify and at the same time complete the division of institutions. It was decided to have a maximum of 3 levels, simultaneously limiting the examples to the key ones. Figure 2 shows the categories of institutions distinguished by the authors.

The potential impact of the system of government in which the community operates on the agricultural sector was widely indicated in the works used in the review. Reference was made to how elections are conducted (Klomp & de Haan, 2013), as well as to political stability (Ebanyat et al., 2010), democracy and institutional quality (Fosu, 2013). The problem has also been looked at from a regional perspective, examining the local governance habits of the population (Ng'ang'a et al., 2016). The established legal system and functioning organisations of the state were identified as important for the sustainability of aquaculture food production (Manlosa et al., 2021). The important role of the power system was also pointed out by Baker et al. (2018). The paper notes that it is crucial to reconcile local institutions with those of the state; government programs can assist in this.

The papers also attempted to distinguish explanatory variables in terms of variously understood farm characteristics and to test a separate model in each case. In their study, Falconnier et al. (2015) separated farms in terms of how resource-rich they were (poor, moderate, rich), but also separated farms that were rich in resources and at the same time had large animal herds. A similar division that took into account only the attractiveness of the resources held was made by Kumar et al. (2017). The authors separated the following classes under the land class category: marginal, small, medium and large. In terms of their role in the market, Manjunatha et al. (2016) identified sellers, buyers and farmers who do not participate in the groundwater trading market. Another interesting breakdown is the identification of farms that entered into varying numbers of trading arrangements with foreign companies (Rambe & Agbotame, 2018). Among cacao farmers, Hernández-Núñez et al. (2022) distinguished between those who have been primarily engaged in it for years (cacao farmers), those who treat cacao cultivation as one of their sources of income (diversified farmers with cacao), and those who are entering the market and looking for opportunities to invest in cacao cultivation (new cacao farmers). Due to their different motivations and business practices, these farmers were characterised by different economic outcomes. Sinha et al. (2021) indicate business size in terms of land ownership. They list the following groups of farms: marginal, small, medium, medium-large and large.

Local traditions, culture or religion are among the potentially important factors influencing the agricultural sector. This issue is addressed in the work of Kumar et al. (2017), among others, where they serve as control variables. Ng'ang'a et al. (2016) point to the local governance system known as the "Gada system", where its quality and how much it protects property rights, among others, are important. Mishra et al. (2018a) address the distinctive Indian cultural problem of castes and tribes and their impact on economic performance. Informal institutions such as culture, social roles and tradition are key to explaining water savings in a sociological paper by Oberkircher and Hornidge (2011). Gil et al. (2016) point out that the ability to adopt an innovative cropping system is influenced by culture as well as

historically established norms of behaviour, a certain enduring pattern. Tradition is also appealed to by the proponents of often dysfunctional farming systems (Pinto-Correia et al., 2019). The customs of local people can hinder policy-making if it is inconsistent with such traditions (Baker et al., 2018).

It is also worth pointing out the important role attributed to intervention and state policy in the articles indicated. A beneficial effect of state intervention with a distress relief effect (COVID-19) on farm inputs is observed (Varshney et al., 2021). State programs such as the Farmer FIRST Programme can also contribute to increased productivity and better economic performance (Venkatesan et al., 2023). Programs that allow purchases with subsidies lead to both higher inputs and economic performance (Oldekop et al., 2015). Institutional reforms of market price controls, properly carried out, allow the price of a product (in this case cocoa) to stabilise as a result of changes in its production. The authors point out that this is not absolutely to the advantage in every case (Quarmine et al., 2014). In his theoretical reflections, Barnes (2016) notes that state interventions like food policy can allow for a shift in "production frontiers", i.e. increase production potential. Technical support to farmers offered by the state (extension services) is commonly identified as one of the important factors influencing the agricultural sector (Ayuya et al., 2015; Ebanyat et al., 2010; Manjunatha et al., 2016; Mishra et al., 2018a, 2018b). In addition, Ayuya et al. (2015) point to the potential of certified organic agricultural production to counter poverty, which can be facilitated by state intervention.

Ownership issues have also been highlighted as a potentially important explanatory variable for differences in the characteristics of the agricultural sector. Oldekop et al. (2015) made a distinction between landlords, tenants and renters and indicated that there are important differences in the characteristics of these three types of tenure, which may translate into, for example, economic performance. Security of land tenure has been identified as one of the potential explanatory variables for crop productivity (Ebanyat et al., 2010) but also potential for adaptation (Ng'ang'a et al., 2016). Similarly, land tenure status may influence the potential to adapt innovative solutions (Gil et al., 2016). The very fact of land ownership was considered in Barnes et al.'s (2015) research on long-term and short-term efficiency.

Another important aspect explored in the work was the interconnectedness between actors, the motivation to cooperate, and mutual trust, which can be collectively referred to as "social capital". Different ways of contracting with each other can lead to higher or lower transaction costs (Dissa et al., 2022). Again, the work of Ng'ang'a et al. (2016) points to social capital as a driver of adaptation. Participation in social networks itself has a similar impact (Gil et al., 2016). Dependence on society, but also the possibility of receiving help from loved ones, can have a positive impact on farm profit (Kiani et al., 2021). Social capital, in addition to synergies with other capitals (e.g. cultural, human or political), can positively affect cocoa

production levels (Hernández-Núñez et al., 2022). Trust plays important role for the emergence of beneficial organic farms (Deka & Goswami, 2022). Ayuya et al. (2015) further add to this claim the important role of social capital. In the context of government policy effectiveness, as indicated earlier, it is worth pointing out the synergies: a trusted source of information for the farmer, the convergence of recognised norms of behaviour and social pressure – participation in the government program (Daxini et al., 2019).

Cooperatives are the result of "good" social capital and high trust, so the risks of cooperation are minimal and the benefits are high. A concept at the intersection of the two is "civic society" seen as in the article by Manlos et al. (2021). It consists of farmers' self-organisation and sharing of capital, but also inter-organisational and social connections (networks). They include resource and factor sharing as a control variable (e.g. Kumar et al., 2017; Mishra et al., 2018a). Cooperatives can have a significant impact on transaction costs (Dissa et al., 2022). Value creation on small farms can be significantly influenced by cooperatives (Prosperi et al., 2023). When we consider forms of goal-oriented organisations of farmers, their self-organisation, e.g. in the form of cooperatives, will maximise the benefits of such activities (Sinha et al., 2021).

The relevance of access to capital in the agricultural sector was also widely discussed (Chandio et al., 2020; Gil et al., 2016; Kumar et al., 2017; Mishra et al., 2018a). Contractual arrangements between the farmer and the institution were identified as a potentially beneficial way of entering into commercial arrangements for the agricultural sector (Mishra et al., 2018a, 2018b; Sinha et al., 2021).

Conclusions

An important conclusion of the review is that these classifications do not contradict each other but complement one another's information about the institution. By categorising them in this way, it is not only possible to forecast in what time frame real institutional change will be possible, but also to diagnose in which social aspect the institution is embedded.

When appraising a particular institution, the author suggests the following approach:

1. Classification of institutions based on the criterion of formality (formal/informal/intermediate) (cf. Dal Belo Leite et al., 2014; North, 1991; Ostrom, 2008).
2. Classification of institutions on the basis of the criterion of the sphere of impact (social/economic/political) (cf. Besley & Persson, 2018; Mousseau, 2023, p. 119; North, 1990; Tuomela, 2003).

3. Classification of institutions based on the criterion of the level of analysis of social phenomena (level 1, 2, 3, 4) (cf. Williamson, 2000).
4. Classification of institutions according to the criterion of restricting access (restrictive, inclusive) (cf. North et al., 2009, p. 56). Informal and formal institutions are not independent arrangements from each other, they co-exist and interact with each other. This finding is in line with the literature on the subject, which furthermore points to the greater relevance of informal institutions to which, among other things, policies (formal institutions) should be aligned (Baker et al., 2018; Kiani et al., 2021; Uzuegbunam & Geringer, 2021; van Hecken et al., 2019). In turn, this justifies considering them in a single model when examining their potential impact on the agricultural sector. This allows for taking into account the relationship between informal and formal institutions. It also reduces the risk of omitting important variables from the model. Moreover, it should be taken into account that institutions exist in a certain configuration (van Hecken et al., 2019), which depends on historical factors (Manlosa et al., 2021; Ünal, 2018).

The issue of digitalisation and virtual functioning of institutions has not been mentioned directly in the analysed articles. It may have been an issue of keywords and topic restrictions in the systematic review. Nonetheless, the issue has been indirectly included by some of the authors. For example, Ayuya et al. (2015), Ng'ang'a et al. (2016), Mishra et al. (2018b) included phones as an important factor in acquiring information, thus – knowledge. Deka and Goswami (2022) pointed out that online global retailers offer better control over marketing than the conventional method of selling tea; social media makes it easier to exchange knowledge and share information with other tea smallholders. The importance of mass media (radio, television, newspapers and the Internet) has appeared as the most important source of information in case of credit borrowers – agricultural households in India (Kumar et al., 2017). Thus, the issue of digitalisation and virtual functioning of institutions may be a promising area of future research as it appears to be relevant in modern agriculture.

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Financial frauds throughout the years – literature review

Marek Kot[1]

Abstract

Financial frauds have been a growing problem across the global financial markets. Losses generated by such illegal activities affect both the global economy and individual entities, especially those operating in the financial market. Perpetrators of such frauds seem to always be one step ahead of the law enforcement, regulators as well as private sector entities such as banks and scientists. This review examines publishing actions taken throughout the years. It also shows whether there has been any correlation spotted between the number of papers published in a particular year and the events on the financial markets. Finally, the article summarises all types of financial frauds which have been identified in the literature and assesses whether the selection of those types is original or had already been identified in the past years. The study involved a systematic literature review to achieve the set goals. Following the final results of the article, it is clear that the issue of financial frauds has been a growing global concern. It is crucial to strengthen the collaboration between the regulators, law enforcement, academic environment and private sector. Cooperation across the sectors should include research on how to prevent and mitigate the consequences of this kind of frauds.

Keywords

- financial fraud
- bank fraud
- financial crimes
- negative impact

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Introduction

The phenomenon of financial crime has reached enormous proportions all around the world. Its scope includes many illegal activities. Numerous units, both private and public, deal with that issue on a daily basis. Every year, preventing and mitigating the effects caused by criminals, as well as prosecuting them, requires significant financial, material and human resources (Lou & Wang, 2009, pp. 61–62). And yet, this phenomenon seems to be vaguely underestimated from the perspective of scientific literature. This is evidenced by the lack of a uniform definition of the financial crime and the small number of publications in this field.

The problem of the missing definition can be explained to some extent by the fact that the concept of crime is derived directly from the criminal law, which can be different in each legal system. As such, the perception of financial crime will differ from country to country. However, this does not explain the fact that even in the Polish literature it has not been possible to develop a single, coherent definition of financial crime. The subject of this article, however, will not be the construction of the definition, but a review of the literature that directly or indirectly addresses the problem of financial crime. The lack of a standardised definition may lead to discrepancies in identifying the catalogue of activities that may fall into the category of financial crimes. A concept broader than financial crime is financial fraud. Due to the frequent use of these terms as synonyms, especially in the foreign literature, and lack of the consistent definition of financial crime, this publication will focus on financial frauds. Such an approach will prevent an excessive limitation of its subject, and at the same time will ensure that its scope is still relevant.

In order to further standardise the criteria serving as a starting point for further research, key words from the English language related to frauds have been adopted. That will enable the analysis of the widest possible spectrum of literature, not including unrelated publications in the review, and at the same time not excluding those that raise the problem of financial frauds at least to some extent. According to the most recent literature, the catalogue of such frauds includes credit fraud, corruption, money laundering, terrorist financing, securities and commodities fraud, sanctions evasion, cyber-crime, counterfeiting of means of payment, pyramid schemes, accounting frauds, as well as digital currency crimes (FATF, 2012, pp. 123–124; Matakovic, 2022, pp. 1–5; Price & Norris, 2009, pp. 539–540; Reurink, 2016, pp. 36–45; Segal, 2016, p. 48). The aforementioned list of activities contains the most common ones found in financial markets, but it is not exhaustive. In the further part of the paper, financial frauds which are described in the publications selected in the process of literature review will be collected and compared with

the above list. The results of that analysis will either extend or maintain the existing financial frauds catalogue.

The purpose of this paper is to analyse the scope of literature and the frequency of its publication over the past 18 years, and then to find the trend, if any, in which the publication curve moves. Data such as dates or periods of financial crises and turmoil in the financial markets with be superimposed on the trend curve. Such comparison will allow us to determine whether there is a connection between the need to publish and the events in global financial markets. Other possible conclusions may be whether the problem of financial crime increases in times of market volatility, whether criminals take advantage of the fact that the attention of authorities, law enforcement, market surveillance and the private sector is turned to other problems, or whether these issues are not related at all. However, if they appear to be related to some extent, the research results can be used to predict the movements of the trend, periods of increased criminal activity or problems with the stability in the economy in the future.

In Section One, the methodology used for the literature review is described, and publications on similar topics and methodology are cited. In the next step, databases, keywords as well as inclusion and exclusion criteria are defined. In Section Two, the author analyses the obtained results and presents tables and graphs showing the development of the number of publications over the years. Additionally, events from financial markets, and the banking sector in particular, which could have determined the changes under analysis, are assigned to each of the turning points in the chart. Section Three analyses and briefly describes selected publications in terms of identified types of financial frauds and their negative effects. Furthermore, the paper's limitations, which biased the results, are identified and briefly discussed. Finally, the author presents the conclusions of the research in last section and formulates the need for further research in the field of financial frauds. Future studies should especially focus on detection, prevention and identification of bad actors involved in the illicit activities.

1. Methodology

This literature review is based on the method of a systematic literature review. The analysis will pave the way for further research in this area, which, in turn, will allow us to observe the problem on an ongoing basis, draw conclusions in a reactive manner and prepare for future events. The process of determining the subject of the research is conducted in three steps, leading from the entire available collection of literature to a reliably selected database. Each step includes selections

according to a separate criterion: basic database, keywords, as well as inclusion and exclusion criteria (Czakon, 2011, p. 58).

There are a number of existing publications on this topic, the authors of which also conducted the literature review in a similar manner. One of such publications uses the PRISMA-ScR protocol (*Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews*). The authors performed an extensive review of both academic and grey literature in the field of cryptocurrency frauds. They identified 29 different types of frauds in the academic literature and 47 in the grey literature (14 of which were not identified by the academic sources). The conclusions that the authors came up with, besides a unique list of financial fraud types, were that illegal activity in the field of cryptocurrencies is growing rapidly and cross-sectoral cooperation is necessary to combat financial frauds (Trozze et al., 2022). Another publication which raises the issue of frauds was published by Mangala & Soni in 2023. The authors conducted a systematic literature review on frauds in the banking sector. The paper was based on 70 articles published in four databases between 2000 and 2021. It reveals that bank frauds have become a great problem, causing both financial and non-financial damage to banks, their stakeholders and the economy. The study states that banks should undertake strong measures in the area of risk management in order to prevent, detect and respond to frauds (Mangala & Soni, 2023, pp. 285–287). The current research aims to completement and extend the existing studies and their results to some extent.

1.1. Databases, keywords, inclusion and exclusion criteria

Several steps have been taken in this literature review to explore the issue as thoroughly as possible. The first step was the selection of searching tools. Scopus and Web of Science databases were used as search engines. Then, multiple inclusion criteria for the found items were adopted. The first criterion was the language of publication. Bearing in mind the few, or most often no publications in Polish, it was decided to include only those written in English. Due to the discrepancies in the definitions, markets and academic practices, as well as the multitude of synonyms in English, a wide range of key phrases had to be adopted in order to make the literature review as credible as possible. Many various configurations of key phrases were tested, plenty of which were general and gave an overly wide range of search results (e.g. “fraud” or “crime”). On the other hand, when those phrases were specified too precisely, the results were very limited or nil (e.g. “financial crimes in banking sector”). The final result of testing numerous key phrase configurations provided two phrases that, after an initial review, seemed to give satis-

factory search results. These phrases were as follows: "financial fraud" and "bank fraud". Both were subsequently adopted as the inclusion criterion.

Due to the very dynamic environment and the development of the phenomenon of financial frauds, it was decided that only the latest publications should be subjected to further analysis. At the same time, a large enough range of dates had to be selected to make the obtained sample reliable. Therefore, publications issued in the years 2005–2022 were analysed. The year 2023 was not taken into consideration because it did not end while writing this paper, and hence data would be incomplete and could distort the results and their interpretation. The review included academic publications, i.e. articles, conference materials and books. The study did not include the following types of grey literature (defined as materials not controlled by commercial publishers) (Mazur & Orłowska, 2018, p. 242): reports and publications provided by entities other than universities. In addition to the above, publications as blog posts, presentations, newsletters and marketing materials were also excluded from the research.

In the next steps, the publications identified in the review process, which described the problem of financial frauds and their impact on the economy were quoted and analysed. Due to the high volume of search results, not all publications could be included in this step. With that in mind, it was decided that only publications with the highest number of citations would be analysed. In addition to that, they should be available in the PDF format. Then, the full text would be searched using key words to confirm that it addressed the mentioned issue. For that purpose, the author used the following key words: "impact", "economy" and "fraud".

Despite strict inclusion criteria, numerous publications were found from fields and categories that were recognised as out of scope. To ensure the most accurate selection of publications, works in the following categories and fields were excluded: Medicine, Physics and Astronomy, Energy, Environmental Science, Biochemistry, Materials Science, Chemistry, Earth and Planetary Sciences, Ethics, Robotics, Optics, Infectious Diseases. On the other hand, the following categories and fields were included: Business Finance, Economics, Computer Science, Law, Criminology, Mathematics, Interdisciplinary Social Sciences, Psychology. Although the problem of frauds is certainly a significant in these sectors, this paper focuses on frauds in the financial sector. Table 1 summarizes the main fields and categories that have been excluded and included.

The initial search found 12894 results. With the above "filters", 1670 publications were rejected and ultimately 11224 items remained for further analysis. Table 2 shows the results for both phrases gathered into individual databases. At first glance, it can be said that the number of items found using the phrase "financial fraud" was over three times higher than the "bank fraud". Additionally, the number of publications found in Scopus is similar to the one in Web of Science. This may suggest that the majority of them are duplicates. Unfortunately, due to

Table 1. Excluded and included subject fields/categories

Fields/categories excluded	Medicine, Physics and Astronomy, Energy, Environmental Science, Biochemistry, Genetics and Molecular Biology, Agricultural and Biological Sciences, Nursing, Chemical Engineering, Materials Science, Pharmacology, Toxicology and Pharmaceutics, Health Professions, Chemistry, Earth and Planetary Sciences, Neuroscience, Immunology and Microbiology, Dentistry, Veterinary, Food Science Technology, Ethics, Gerontology, Green Sustainable Science Technology, Nutrition Dietetics, Environmental Sciences, Social Work, Sociology, Robotics, Optics, Energy Fuels, History of Philosophy of Science, Biochemical Research Methods, Physics Multidisciplinary, Anthropology, Clinical Neurology, Linguistics, Electrochemistry, Infectious Diseases, Behavioural Sciences, Arts and Humanities.
Fields/categories included	Business Finance, Economics, Computer Science, Business, Management, Engineering, Law, Criminology, Telecommunications, Operations Research Management Science, Decision Sciences, Multidisciplinary Sciences, Public Administration, Political Science, Information Science, Mathematics, International Relations, Education Scientific Disciplines, Social Sciences Interdisciplinary, Psychology.

Source: own study.

Table 2. Quantitative summary of the literature review

Phrase	Database	Number of identified items	Number of items found with inclusion and exclusion criteria applied
financial fraud	Scopus	5141	4689
bank fraud	Scopus	1537	1441
	Scopus Total	**6678**	**6130**
financial fraud	Web of Science	4783	3846
bank fraud	Web of Science	1433	1248
	WoS Total	**6216**	**5094**
Total		**12894**	**11224**

Source: own study.

the differences in the exported data from both databases and its overall population, it would take too many manual efforts to properly filter and remove the duplicates. Nevertheless, it is highly possible, that if the research was to be conducted using only one database, the results would also be reliable.

2. Results and discussion

As was noted in the previous section, the number of publications found using the phrase "bank fraud" was smaller than that associated with the phrase "financial fraud". Such a trend can also be observed in each of the analysed years (see Table 3). This seems to be a natural dependence, considering the fact that the financial sector covers the banking sector as well as many others. Another interesting dependency, yet also predictable, is the growing number of publications year over year. There were only few cases where the number of publications was lower than in the previous year. Such deviations were observed in 2012, 2013 and 2016. Interestingly, after both 2013 and 2016 the number of those publications increased even faster than in the preceding years.

Table 3. Number of publications in each year (including databases and phrases)

	Scopus		Web of Science		Sum		Overall sum
Year of publication	*financial fraud*	*bank fraud*	*financial fraud*	*bank fraud*	*financial fraud*	*bank fraud*	
2022	688	193	456	116	1144	309	1453
2021	565	174	442	151	1007	325	1332
2020	502	140	393	111	895	251	1146
2019	450	153	350	113	800	266	1066
2018	315	102	325	120	640	222	862
2017	268	91	301	94	569	185	754
2016	248	64	229	79	477	143	620
2015	229	76	245	86	474	162	636
2014	194	67	200	94	394	161	555
2013	180	41	142	48	322	89	411
2012	181	59	148	36	329	95	424
2011	194	56	150	46	344	102	446
2010	156	57	118	41	274	98	372
2009	143	53	103	37	246	90	336
2008	116	26	93	26	209	52	261
2007	102	29	55	24	157	53	210
2006	85	32	53	17	138	49	187
2005	73	28	43	9	116	37	153
Total	**4689**	**1441**	**3846**	**1248**	**8535**	**2689**	**11224**

Source: own study.

As has been already mentioned, there are more and more publications in the field of financial and bank frauds every year (Figure 1). Apart from the three deviations mentioned above, the graph is moving in one direction, confirming earlier observations. Figure 1 shows two points when the trend line reverses, indicating that the number of publications in the following years began to increase at a rapid pace after decreasing over one or more years. The first point was 2013 when after a two-year decline in the total number of publications, their number increased by over 32% year over year. At the same time, 2013 was considered rather a boom year on the financial markets. The question to be asked is what caused the trend to reverse? Among many events of those years, it may have been the delayed aftermath of the debt crisis in Europe in 2009–2010, and then the collapse of financial markets in August 2011 caused by the fear of the crisis spreading to Spain and Italy (Jayech, 2016, pp. 632–634), as well as the fear of downgrading the ratings of France and the United Kingdom, which at that time faced such a threat (Bremer, & Dmitracova, 2011). Another event that could have drawn the attention of researchers to the problem of financial frauds was the speculative bubble on Bitcoin in 2014. In the fourth quarter, the value of that cryptocurrency increased from $130 to $1.200 and then fell to $500 within only a few days (Li et al., 2019, pp. 92–93; Monamo et al., 2016, p. 129).

The next turning point on the trend line was the year 2016. Similarly to 2013, there are no clear reasons for such a change. The intensity of the publishing action, and thus reversal of the trend, could have resulted from growing inflation and the increase in market interest rates. It could also have been determined by the delayed reaction to the announcement of the quantitative easing policy adopted by the European Central Bank in March 2015 and its impact on the market, which was most felt just in 2016 (Hohberger et al., 2019, pp. 1–3). Perturbations in the European banking sector in 2016 could have been another trigger for the publishing action. These issues mainly concerned the Italian and German banking sectors (Hodson, 2017, pp. 118–122; Miglionico, 2019, pp. 469–471). Although these events were scheduled to be brought up in Figure 2, it seems appropriate to mention them here.

The growing number of publications addressing the issue of financial frauds indicates that the significance of this matter is becoming more and more serious. With that in mind, one can conclude that in the years 2012, 2013 and 2016 researchers' attention was turned away from this issue, and afterwards efforts put into researching this matter were even greater than in the preceding years where an upward trend could be observed. Interestingly, the global financial crisis of 2008 is practically invisible in Figure 1, as if it was insignificant. This is an unexpected conclusion, as the author's initial belief was that the events of that year would leave the biggest mark, which they may have done, but not in the immediate years.

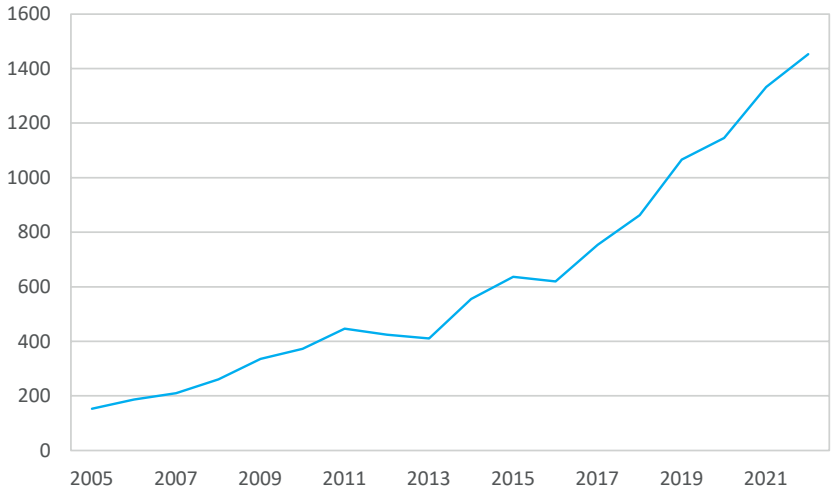

Figure 1. Total number of publications in particular years

Source: own study.

It is worth elaborating briefly on Figure 2, which relates to the search results using the phrase "bank fraud" only. While cumulative data shown in Figure 1 was not as clear-cut as it might initially seem, Figure 2 shows four distinct points in the history when the number of publications increased dramatically. As was done for Figure 1, similar analysis will be performed to identify events that could have influenced such a shape of the trend curve in Figure 2.

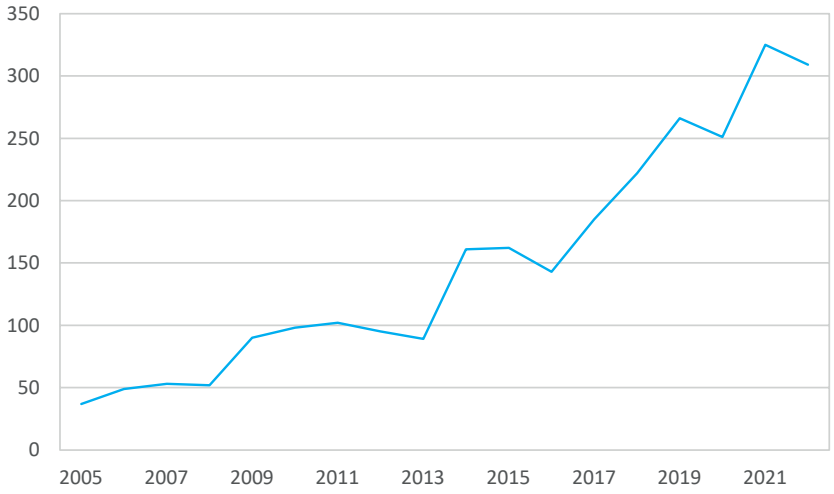

Figure 2. Number of publications found using the phrase "bank fraud" only

Source: own study.

The first moment defined on the chart is the year 2009, when within one year from 2008 the number of identified publications increased by 76% (from 52 to 90). This year is mainly associated with the global financial crisis, and the greater dynamics of publications dealing with the issue of bank frauds seems to be a natural result in the face of what had happened. Moreover, that crisis has had a significant impact on how the financial market is functioning (Tomasic, 2011, pp. 8–10). It is worth mentioning that one of the famous fraud types at that time was fraud in the mortgage securitisation industry (Fligstein & Roehrkasse, 2016, p. 620).

The year 2009 was followed by 4 years of relative stagnation, only for the annual number of publications to increase from 89 to 161 between 2013 and 2014, which stands for an increase of 81% y/y. It was the year when banks responsible for the LIBOR scandal suffered from financial penalties. The official estimates were that the value of contracts based on LIBOR was $300 trillion, while unofficially it was said to be up to $800 trillion (Ashton & Christophers, 2015, p. 189). In the same year, JPMorgan Chase entered into a settlement with the authorities, which consisted of a payment of $13 billion, in exchange for being released from the liability for its activities in offering mortgage-backed bonds in 2007-2009. The sum of all penalties that were imposed on JPMorgan Chase bank in 2013 for many of its actions, including the London Whale scandal, oscillates around $20 billion (Passas, 2016, pp. 76–77). Finally, the last event identified for this period was the financial crisis in Cyprus. The banking sector was particularly vulnerable to the perturbations of that time. To some extent, it was a consequence of the 2007–2008 events, but also many other factors (Stavárek, 2013, pp. 312–313). Although all the cited events are certainly not exhaustive, and there were several more significant ones, there is no doubt that the described few were crucial for the condition of financial markets. The year 2013 was undoubtedly dramatic for the banking sector in many countries. Hence, it should not be a surprise that the focus of researchers on frauds, especially the bank ones, has risen rapidly.

The next point in Figure 2 is the year 2016, which was followed by 3 years of an almost steady increase in the number of published items. During these three years, the annual number of publications increased from 143 to 266 in 2019. This means an average annual increase of 41 items. Some of the events that could have influenced such an increase were cited in the analysis of Figure 1. They seem to be the reason for the increase in the amount of research on both financial and bank frauds. Another event, different from the already mentioned ones, which could have affected the banking industry was the imposition of a fine of EUR585 million on Deutsche Bank (DB) in 2013. The fine was related to money laundering allegedly committed by DB and its related companies. Moreover, similar suspicions fell on many other European banks (Yeoh, 2020, pp. 127–128). Another significant case within the banking industry was The Wells Fargo cross-selling scandal. In September 2016, Wells Fargo announced that it would pay $185 million to settle

a lawsuit filed by the regulators and the county of Los Angeles. At the same time, the bank admitted that its employees had opened as many as 2 million accounts without customer authorisation over a five-year period (Tayan, 2019, p. 2). There is no doubt that in the described cases that the perpetrators of those frauds were the banks themselves. It should be obvious, however, that not only banks are to be blamed. Nonetheless, it seems reasonable to conclude that their illegal or unethical activity led to the biggest crises in the sector, and subsequently attracted more attention to the issue of frauds.

The last point on the chart with a significant increase was the year 2021. The number of published items increased from 251 to 325 during the year. Although it was an increase by "just" 29%, the difference is as many as 74 publications (the most among all the analysed periods). That was the time of the COVID-19 pandemic, and the global economy had gone into the lockdown. During that time, the economy worldwide experienced a massive slowdown and, in some places, recession. In the Polish banking sector, 2020 was the first year in the past 27 years in which banks recorded a loss. It was mainly caused by the forced increase of reserves for franc credits (Wilkowicz, 2021). Another factor affecting the banking sector was the reduction of interest rates by the Monetary Policy Council to record low levels. What is more, the US FED also drastically reduced the level of interest rates, and in the Euro area, they had been low for several years at that time (Ampudia & Van den Heuvel, 2022, pp. 49–51). Low interest rates forced market participants to look for profits in other places than those that could be profitable in the higher interest rates environment. This may have been a driver for some to undertake unethical or even illegal activities just to generate higher revenue. It was not until 2021 that interest rates began to increase around the world. In addition to the above, one of the events that could have sped up the publication process in the area of financial frauds was bankruptcy of the German FinTech Wirecard in 2020. The company provided electronic payment processing services globally. It filed for insolvency after discovering missing EUR1.9 billion in its assets. This was the result of more than 10 years of systematic book falsification and frauds (Chen, 2022, pp. 68–70).

It is worth noting that the average increase in the number of publications in the analysed period (2005–2022) is 16. Clearly, each period is distinguished by the several times higher average annual growth. However, in 2022 there was a noticeable decrease in the number of published items. Figure 2 shows that a year before each significant increase in the number of publications, a smaller number was recorded. Has the trend continued, and the same thing happened in 2023? Certainly, it is worth conducting further research in this area in order to answer the question in the coming year. The above examples of events in relation to Figures 1 and 2 are intended to show that the number of publications is not unrelated to events on financial markets, and at the same time does not constitute an exhaustive list of all events that could have affected the formation of charts and trends.

3. Review of selected literature

For this section of the paper, the author selected publications that had the highest number of citations and were available in the PDF format. The initial number of selected publications was 23, 6 of which were not available in the PDF format. Therefore, the full text of 17 publications was analysed. The number of citations of those items ranged from 223 to 838 (on average 419 per paper). Their content was subjected to a key word search using the following key words: "impact", "economy", "fraud". In this way, it was determined whether the publication covered the correct problem as well as contained types of financial frauds and their effects. Below are the brief considerations contained in the selected publications regarding the negative impact of the financial fraud on both the financial and banking sectors as well as the entire economy. The purpose of this section is to gather the types of financial frauds and their impact on the economy in one place. This was a secondary objective in this paper and should be treated as such, as it does not exhaust the subject but shed more light on it and opens the door to further study and discussion.

One of the negative effects of financial fraud on individual entities is the loss of reputation (Karpoff et al., 2008a, p. 601). Moreover, the director of such an entity may also lose their reputation (Fich & Shivdasani, 2007, p. 324; Hoffmann & Birnbrich, 2012, p. 391). One of the frauds described in the analysed literature was management fraud, which can be defined as the deliberate fraud committed by the company's management. It may cause damage to investors and creditors through materially misleading financial statements (Kirkos et al., 2007, p. 995). According to Abdallah et al. (2016, p. 91), frauds in general have a dramatic impact on the economy, law and human moral values. One of the frauds they mentioned was cyber-crime, the seriousness of which lies in the fact that almost all technological systems which involve money and services can be compromised by fraudulent acts, e.g. credit card, telecommunication, health care insurance and online auction systems. Another frauds impacting countries' economy are corruption, illicit transfer of dirty money and tax evasion. It is estimated that $500 billion are transferred from developing and transitional economies to Western accounts every year. That causes a significant damage to the economic condition of such countries, at the same time affecting mostly the poor. Such processes result from the use of tax havens around the globe, where stashed assets are estimated at $11.5 trillion (Dobers & Halme, 2009, p. 243).

Moro et al. (2015, p. 1315) stated that banks focus primarily on prevention and detection of the following types of frauds: credit fraud, communication channels frauds, cyber-crimes. Cohn et al. (2014, p. 86) identifies frauds such as market manipulations, market index manipulations and tax evasion as particularly harm-

ful to the banking sector, which along with the financial markets make up a fundamental pillar of every advanced economy. Additionally, the authors stated that banking services are the key requirement for economic growth. Therefore, the above-mentioned frauds committed by banks and their employees had a great impact on the whole economy, leading to dramatic loss of reputation and a crisis of trust in the financial sector.

The negative effects of financial frauds mentioned above have a very wide scope. Starting from the effects on individuals, to institutions, to the economy of the entire country, region or even the global economy. Table 4 summarises information about the analysed publications, including data such as the number of citations, types of financial frauds and whether their impact was described in the publication. Several types of names were inconsistent, so the names were standardised for the sake of more efficient analysis, i.e. *the management fraud/misleading financial statements* category was used for a number of similarly named types, e.g. *falsification of financial information*. Table 5 summarises the number of financial fraud types identified in the full text review process and a percentage share in the total number of reviewed publications. Due to a large number of items, the summary was prepared in the form of a table rather than a chart, which allowed us to provide a clearer presentation of data.

There were 21 financial frauds identified in total. The most often quoted fraud was management fraud/misleading financial statements, which appeared in 7 out of 17 publications (41.2%). Interestingly, this fraud was mainly present in the publications published between 2005–2010. The newer studies examined financial frauds which had not been known so well in the past. At this point, it can be stated that there might be a correlation between the types of the most frequently described frauds and the events taking place on the financial markets. This matter, however, should be researched further to confirm or deny this correlation.

The above financial frauds differ from the ones listed in the Introduction and will certainly complement the initial list of frauds. Without a doubt, there are more types of financial frauds and, given the perpetrators' imagination, it is rather impossible to gather a complete and final catalogue of such activities. That is also the reason for which detection, prevention and identification of bad actors is so difficult.

It is worth mentioning that the majority of the literature selected for the final step of the review was published over 10 years ago. Given the fact that this phenomenon has been changing dynamically, the approach to this problem has also evolved. Thanks to developing studies within this area, the contemporary literature describes and approaches this matter slightly differently. It is safe to say that the current approach has improved. With that in mind, it can be concluded that future studies should be based on the most recent literature, not limited to the one with the highest citation index. One of the ways of such an approach would

be to keep using the index itself, but at the same time narrow down the analysed period to a few years only, so that only the most recent publications will be researched. Such an approach has not been the aim of this paper, as the main purpose was to show how and why the number of publications changed throughout the years, which could not be achieved without a properly long period.

Limitations

Despite a thoroughly conducted literature review, a few limitations still occurred, which affected the final results. Their impact does not seem to be significant, yet future studies should certainly keep them in mind. Not all the limitations can be removed, but perhaps there are ways of working around them. Firstly, given the fact that the total population of found publications was large, duplicates were not removed. It was caused by the differences between the bulk data extracted from Scopus and Web of Science databases. Due the inconsistent file format it could not be done using, e.g. the vlookup feature in MS Excel. Given the volume of the records, it would require too much manual effort to filter the data and get rid of the duplicates properly. Secondly, this (and any) review was limited by the eligibility criteria. This study did not include the grey literature which was not indexed in both databases but created and published by private entities representing the business sector. Such literature contains numerous most recent solutions, data and ideas which would certainly be useful for the academic papers. What is more, only two databases were used for the review, which narrowed down the number of generally available publications indexed in the other databases.

The next criterion used for the study was the key phrase. Several combinations were tested and only two were selected as the ultimate ones. There could be dozens or more combinations and numbers of key phrases/words used. Therefore, the population of found publications would be completely different. Another criterion was the analysed period, which for the purpose of the research was 18 years, and which could be different depending on the needs and approach. Unfortunately, it seems that any set of limitations will always be present in the research work, and despite the fact that it is hardly avoidable, researchers should undertake all available tools to mitigate the impact of the limitations on the final result of their work. Hopefully, it was accomplished in this study.

Table 4. Summary of the selected literature review

Paper	Authors	Year	Citations	Financial fraud types	Impact described
Graph based anomaly detection and description: a survey.	Akoglu, L., Tong, H. & Koutra, D.	2015	838	credit card fraud, insurance fraud, accounting frauds, tax evasion, securities fraud, cyber-crimes, insider trading	no
The application of data mining techniques in financial fraud detection: A classification framework and an academic review of literature.	Ngai, E.W.T., Hu, Y., Wong, Y.H., Chen, Y., & Sun, X.	2011	670	credit card fraud, money laundering, insurance fraud, corporate fraud, securities and commodities fraud, management fraud/misleading financial statements	no
Restoring trust after fraud: does corporate governance matter?	Farber, D. B.	2005	613	management fraud/misleading financial statements	no
The cost to firms of cooking the books	Karpoff, J., Lee, D., & Martin, G.	2008	602	accounting frauds, IPO frauds, corporate fraud	yes
Corporate misreporting and bank loan contracting	Graham, J. R., & Jiaping Qiu, S.L.	2008	527	fraudulent restating, management fraud/misleading financial statements	no
Financial fraud, director reputation, and shareholder wealth	Fich, E. M., & Shivdasani, A.	2007	462	corruption, accounting fraud	yes
Data mining techniques for the detection of fraudulent financial statements	Kirkos, E., Spathis, C., & Manolopoulos, Y.	2007	413	management fraud/misleading financial statements	yes
The consequences to managers for financial misrepresentation	Karpoff, J., Lee, D., & Martin, G.	2008	396	management fraud/misleading financial statements	no
Business culture and dishonesty in the banking industry	Cohn, A., Fehr, E., & Marechal, M.A.	2014	351	market manipulation, interest rate manipulation, tax evasion	yes
Corporate social responsibility, investor protection, and earnings management: Some international evidence.	Chih, H.-L., Shen, C.-H., & Kang, F.-C.	2008	325	accounting frauds	no

Table 4—cont.

Paper	Authors	Year	Citations	Financial fraud types	Impact described
Fraud detection system: A survey	Abdallah, A., Maarof, M.A., & Zainal, A.	2016	311	credit card fraud, telecommunication fraud, insurance fraud, online auction fraud	yes
The antecedents and consequences of top management fraud	Zahra, S.A., Priem, R.L., & Rasheed, A.A.	2005	303	management fraud/misleading financial statements	yes
Detection of financial statement fraud and feature selection using data mining techniques	Ravisankar, P., Ravi, V., Raghava Rao, G., & Bose, I.	2011	300	management fraud/misleading financial statements	yes
Corporate social responsibility and developing countries.	Dobers, P., & Halme, M.	2009	271	tax evasion, other tax frauds, corruption, illicit transfer of dirty money	yes
Credit card fraud detection using machine learning techniques: A comparative analysis.	Awoyemi, J.O., Adetunmbi, A.O., & Oluwadare, S.A.	2017	264	credit card fraud	yes
A survey of anomaly detection techniques in financial domain	Ahmed, M., Mahmood, A.N., & Islam, M.R.	2016	253	credit card fraud, telecommunication fraud, insurance fraud, insider trading	yes
Business intelligence in banking: A literature analysis from 2002 to 2013 using text mining and latent Dirichlet allocation	Moro, S., Cortez, P., & Rita, P.	2015	223	credit fraud, communication channels frauds, cyber-crimes, money laundering, securities and commodities fraud, mortgage fraud	yes

Source: own study.

Table 5. Share of financial fraud types in the analysed population

No.	Financial fraud types	Amount	% share	No.	Financial fraud types	Amount	% share
1.	management fraud/misleading financial statements	7	41.2	12.	telecommunication fraud	2	11.8
2.	credit card fraud	5	29.4	13.	other tax frauds	1	5.9
3.	accounting fraud	4	23.5	14.	credit fraud	1	5.9
4.	insurance fraud	4	23.5	15.	fraudulent restating	1	5.9
5.	securities and commodities fraud	3	17.6	16.	illicit transfer of dirty money	1	5.9
6.	tax evasion	3	17.6	17.	interest rate manipulation	1	5.9
7.	corporate fraud	2	11.8	18.	IPO frauds	1	5.9
8.	corruption	2	11.8	19.	market manipulation	1	5.9
9.	cyber-crimes	2	11.8	20.	mortgage fraud	1	5.9
10.	insider trading	2	11.8	21.	online auction fraud	1	5.9
11.	money laundering	2	11.8				

Source: own study.

Conclusions

The number of publications increases every year, which may suggest that the scale of the problem is growing. This also proves that researchers put greater focus on this issue. Overall, within the period of 18 years, 11224 search results were identified in both databases, despite the strict inclusion criteria applied. As Figures 1 and 2 show, the number of published items is moving in an upward trend. There were, however, a few points on the charts where the trend was broken. Deviations from the trend can be observed and their causes seem to be obvious, especially when it comes to the "bank frauds" search results. It would seem that the relationship between the number of publications in a given year and the events on the markets will be clearly visible for the entire comprehensive search results, but it was more noticeable and definitive for bank frauds.

Though the upward trend in the number of publications is certain, a decrease is noticeable in 2022. It should not last long, however, as the charts show that a year before each significant increase in the number of published items, a smaller number was recorded. Has the trend continued, and the same thing happened in 2023? The current situation in the financial markets may indicate an affirmative answer. The year 2023 was not easy for the global economy. Conditions were particularly difficult in the banking sector. This sector has experienced major global turbulences, i.e. the Credit Suisse buy-out by UBS bank due to the former's liquidity problems, the collapse of Silicon Valley Bank and Signature Bank in the United States. The analysed historical examples showed that after such serious turmoil on the market, the number of publications in the field of financial frauds increased. With that in mind, it is safe to say that we will observe an increase in published items in the upcoming months/years.

Despite the identification of many consequences and types of financial frauds in Section 3, more research is required on this problem. Ways of preventing them and mitigating their effects should be researched specifically. More attention needs to be paid to detecting and punishing perpetrators, as they very often seem to be one step ahead of law enforcement, legislators, regulators, researchers and the private sector, e.g. banks. The above study also indicates the need for better cooperation between entities from the private and public sectors, and especially between the law enforcement authorities, business, supervisory authorities and the academic community.

According to Snyder (2019, p. 337–338), a quality literature review must have both depth and rigor, which means that it needs to demonstrate an appropriate strategy for selecting articles and capturing data and insights, and to offer something beyond a recitation of previous research. In addition, a quality literature review needs to be replicable, which means that the method must be described in

such a way that an external reader could replicate the study and obtain similar findings. Lastly, Snyder states that a literature review must be useful for scholars and practitioners. All these requirements seem to be met in this paper.

Having in mind the numerous limitations that were listed above, this paper manages to deliver an original insight into the subject. Perhaps further studies could prove that there were significant events on the financial market which did not determine the increase in the number of publications in the years that were not analysed in this paper. This could allow us to make a more holistic evaluation of the dependency between market events and the publications curve, and, in turn, help predicting the future to some extent. The author invites researchers of further studies to analyse this matter in more depth. Since developments in this field are fast paced, it is also recommended to perform regular updates to this scoping review to maintain an accurate view thereof.

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Financial performance and cash flow: Evidence from the US banking industry

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Abstract

This study examines the relationship between cash flow and financial performance with a sample of 122 American banks covering the period from 2019 to 2022. Panel data analysis is applied in the work. Financial performance is computed as the Return on Assets (ROA) and Return on Equity (ROE). The explanatory variables used are the net cash flow, free cash flow, cash flow from operating activities, cash flow from investing activities, cash flow from financing activities, size of banks, leverage ratio (total liabilities to total assets), liquidity ratio (current assets to current liabilities) and efficiency ratio (total revenue to total assets). The results provide evidence of a negative relationship between financial performance and net cash flow. This is also the case for cash flow from investment and financing activities. On the other hand, the relationship of free cash flow with financial performance is positive. As regards the other explanatory variables, leverage and efficiency are positively related to financial performance.

Keywords

- financial performance
- cash flow
- leverage
- liquidity
- efficiency
- banks

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Introduction

Investors who seek promising investment opportunities in the market tend to assess various micro of macro factors concerning the targeted corporations. This is also the case for lenders and other creditors who aim at cooperating with companies of high financial stability and creditworthiness. Cash flow is among the important factors considered by investors and creditors. Positive and strong cash flow means that a company is able to repay its debts and maintain some cash to undertake future investments or cover other needs. Ongoing positive cash flow indicates that a company is on a strong footing, whereas continued negative cash flow indicates that a company is probably in financial trouble. In other words, sufficient cash flow relates to a company's liquidity, which is vital for its success and longevity.

Analysing cash flow is not only important to investors and creditors but also for the companies themselves. A company has to understand the sources from which its cash comes from as well as the areas in which it is spent. Along with helping the management to maintain a high level of liquidity, efficient cash flow analysis can help managers take corrective actions when necessary. Ultimately, efficient cash flow management can contribute to improving business planning and investment decision making, which in turn can lead to higher profitability and growth.

Based on the above, the cash flow figures reported in a relevant financial statement of a company can be strong indicators or predictors of the company's future performance. However, maintaining a high cash flow level might not always be the best choice for a company. According to Jensen (1986), firms with substantial free cash flow frequently face potential conflicts of interest between shareholders and managers. Free cash flow refers to the cash generated by a company after all the capital expenditure has been accounted for and can be used in various ways such as paying dividends, financing new projects or repaying a debt.

Based on the theory of Jensen (1986), free cash flow is an important tool available to the managers of modern corporations, in which the ownership and management are usually separated to each other. Managers are likely to use free cash flow to projects that are not necessarily to the benefit of shareholders. On the other hand, managers may be reluctant to channel free cash flow to investments of higher risk that could increase the shareholders' value. The fear of losing their jobs upon the failure of such projects withhold managers from undertaking such risky endeavours. Overall, in the context of cash flow management, the fulfilment of own goals or the avoidance of promising investments due to personal fears constitute the agency costs that can affect the financial performance of a company in a negative fashion.

In this study, we assess the relationship between the financial performance and cash flow of 122 American banks over the period of 2019–2022. In our analysis, financial performance is measured as the Return on Assets (ROA) and Return on Equity (ROE), respectively. Five cash flow variables are considered, namely, the cash flow from operating activities, cash flow from investing activities, cash flow from financing activities, net cash flow and free cash flow. Along with cash flow, we use four control variables, which are the size of banks, the leverage ratio, i.e. total liabilities to total assets, the liquidity (current) ratio, i.e. current assets to current liabilities, and the efficiency ratio, i.e. total revenue to total assets.

Our results reveal that net cash flow is negatively related to performance. By contrast, the relationship of free cash flow with performance is positive. As far as the other three cash flow figures are concerned, cash flow from operating activities has no significant relationship with financial performance, while the impact of investing and financing cash flows on performance is significantly negative, especially in the case of ROE. Going further, the size of banks bears no influence on their financial performance. The leverage ratio is important in explaining return on equity but not return on assets. The liquidity ratio has no significant relationship with performance. Finally, the efficiency ratio is positively related both to ROA and ROE.

The main contribution of our study is the fact that it provides new insights into the relationship between the financial performance and cash flow for a large sample of American banks with the most recent data that are publicly available. In addition, to the best of our knowledge, most studies dealing with cash flow management in the banking industry of the United States focus on the information value of the cash flow statements of banks compared to the relevant value for the manufacturing and other non-financial companies (e.g. Mulford and Comiskey, 2009; Gao et al., 2019).[2] Therefore, our study is quite novel because it deals with the relationship of financial performance with cash flow in the banking industry of the United States, an issue that is under-researched.

Furthermore, our results can form a useful practical selection tool for investors trying to detect banks with the strongest indicators of financial performance, which may reward them with more generous dividend payouts and, possibly, higher stock returns. Finally, our study can be relevant when assessing the causes of the recent collapses in the banking industry of the United States, that is, the failures

[2] In fact, as reported by Gao et al. (2019), banks argue that, unlike the cash flow statements of industrial companies, the relevant statements of banks provide little additional information because banks deem that cash flow is not a useful measure of the operating performance or the financial condition for them. Banks also argue that the distinction between cash flow from operating, investing and financing activities is not as meaningful for them as it is for industrial companies. Such a stance of banks may explain the relevant lack of studies on the relationship between performance and cash flow for the American banks.

of the Silicon Valley Bank – SVB, the Signature Bank – SB, and the First Republic Bank – FRB.

In particular, SVB's failure can be explained in several ways including limited diversification and a classic bank run, where many customers withdrew their deposits simultaneously due to the bank's solvency issues reflected in poor financial ratios. In regard to diversification, SVB invested large amounts of customers' deposits in long-term US treasuries and agency mortgage-backed securities, whose value is negatively related to interest rates. When the Federal Reserve Bank increased interest rates in 2022 trying to combat the galloping inflation, SVB's bond portfolio started to drop. When economic factors hit the tech sector, many bank customers withdrew money. At this point, SVB did not have sufficient liquidity to meet these deposits because its assets were tied up in long-term investments. As a corollary, the bank started selling its bonds at a significant loss, which caused distress to customers and investors. Within 48 hours after disclosing the sale of assets, the bank collapsed.[3]

As noted in a report by the Federal Deposit Insurance Corporation released in April 2023, the collapse of the Signature Bank was due to poor management, especially of the risks associated with accepting crypto deposits, which comprised more than 20% of the bank's total deposits. When the crypto industry started to turn and interest rates started to rise, those deposits started leaving the bank. In addition, the failure of the SVB, which happened just days before the SB was forced to close, helped ignite the run on the SB's deposits.[4] The collapse of the FRB is connected to the rise in interest rates by the Federal Reserve Bank as well, which led depositors to seek better returns elsewhere. In this respect, the FRB suffered a 41% outflow in deposits during the first quarter of 2023.[5]

More or less the three recent bank failures in the United States referred to above reflect poor cash flow management and mistaken investment decisions. That said, we deem that our study could be a useful basis for improving decision making and cash flow management policies, which would contribute to ensuring the stability of the banking institutions in the United States.

This paper is structured as follows: the next section discusses the main findings of the literature on the relationship between financial performance and cash flow. Section 3 concerns the methodological approach and the sample of our study. Section 4 presents the empirical findings of our study. Finally, Section 5 summarises the conclusions of our study and offers some suggestions for future research on the subject.

[3] Information on the SVB's collapse has been found on: Hetler (2024).

[4] Information on the SB's collapse has been found on: Buchwald (2023).

[5] Information on the FRB's collapse has been found on: Saul (2023).

1. Literature review

Several studies have examined the relationship between financial performance and cash flow. Brush et al. (2000) investigate the argument in the agency theory that the sales growth in firms with free cash flow and without strong governance is less profitable compared to sales growth in firms without free cash flow. The empirical findings verify this hypothesis. The authors suggest that having substantial management stock ownership mitigates the influence of free cash flow on performance, despite allowing higher sales growth.

Kroes and Manikas (2014) examine the impact of cash flow management, that is, changes in cash flow measures, on company financial performance, as well as the sign of this impact. The authors use quarterly data from 1233 manufacturing companies in the United States. The results show that changes in the cash conversion cycle (CCC) metric do not affect firm performance. However, changes in the operating cash cycle are significantly associated with changes in Tobin's Q.

Wang (2010) uses data from publicly listed companies in Taiwan to examine the association between free cash flow and agency costs and how these two factors influence firm performance. The results show that free cash flow can induce agency costs. However, the achievement of free cash flow resulting from internal operating efficiency could lead to better firm performance despite the existence of agency costs.

For Taiwan as well, Ni et al. (2019) study the impact of cash flows from operating, investing and financing activities on firm value for a total of 7,598 firm-year observations during the period 2005–2014. Tobin's Q is the firm value proxy, also being the dependent variable of the applied panel data analysis. The results show that inflows from financing activities and outflows to investing activities can enhance firm value, whereas cash inflows from operating activities probably cannot contribute to firm value.

Heydari et al. (2014) assess the relationship between free cash flow and the performance of 63 companies listed on the Tehran Stock Exchange. The study covers the period 2006–2012. Panel analysis is applied with four alternative measures of performance, i.e. return on assets, return on equity, Tobin's Q and stock return. The findings show that there is a significantly negative relationship between free cash flow and all performance measures. For Iran as well, Gheshlaghi et al. (2014) report that there is a significantly negative relationship between performance and investing cash flow but there is no relationship between cash flow from operational and financing activities.

Frank and James (2014) examine the relationship between cash flow and firm performance in the food and beverages sector of Nigeria using a sample of six companies listed on the Nigerian Stock Exchange. The results show that cash

flows from operating and financing activities are positively related to corporate performance, whereas cash flows from investing activities are negatively related to financial performance.

Nwanyanwu (2015) also focuses on Nigeria. In particular, the author examines the relationship between cash flow and corporate performance of 45 small and medium enterprises from the hospitality and media sectors of the country. The data of the study are collected through 135 questionnaires and correlation analysis is applied. The results indicate a significantly strong positive relationship between cash flow position and financial performance expressed in net profit terms.

Next, Amah et al. (2016) focuses on the banking sector of Nigeria. The authors examine the relationship between cash flow and financial performance of four banks listed on the Nigerian Stock Exchange. The results indicate that operating cash flow has a significant and strong positive impact on performance, while investing and financing cash flows have a negative but weak relationship with the banks' performance.

In Turkey, Kadioglu et al. (2017) investigate whether free cash flow affects the performance of companies. The authors apply panel regression analysis with data consisting of 2,175 observations belonging to 370 companies listed on the Borsa Istanbul Stock Exchange. The study period spans from 2009 to 2015. A significantly negative relationship is found between free cash flow and firm performance, with the latter measured as Tobin's Q. Overall, the results on the Turkish companies support the free cash flow hypothesis of Jensen (1986).

In the insurance sector of Jordan, Alslehat and Al-Nimer (2017) evaluate the impact of cash flow management, that is, cash flow from operating, investing and financing activities, on the financial performance of 23 local companies. The study covers the period 2009–2013. The results reveal that cash flow from operating activities is the highest among the three cash flow components. With respect to performance, the study provides evidence of a significant relationship between cash flows from operating and investing activities and return on assets. By contrast, the relationship between financing cash flow and performance is not significant.

Furthermore, Hau (2017) tests the validity of the Jensen's (1986) theory using data of the Vietnamese companies listed on the Hochiminh Stock Exchange. The focus is on manufacturing, trade and real estate companies. The empirical findings show that free cash flow has a positive effect on firm performance for all the examined sectors.

Joshi (2019) investigates the relationship between free cash flow and firm performance with data of non-financial companies included in the S&P BSE 500 Index, which covers all major industries in the economy of India. The study period spans from 2006 to 2016. Financial performance is measured as return on equity. The independent variable of the analysis is the free cash flow, which is found to have a significant and strong positive relationship with corporate performance.

Next, Rahman and Sharma (2020) examine whether a firm with proper cash flow management can increase its financial performance. More specifically, the effect of cash flow from operations on the financial performance of the insurance and manufacturing companies in Saudi Arabia is examined. The performance measures considered here are return on assets and return on equity. The results show a positive and significant association between financial performance and operating cash flow.

Rasheed and Shahzad (2020) focus on the association between free cash flow and financial performance of 126 companies from the textile sector in Pakistan during the period 2010–2014. The results indicate that free cash flow is positively related to corporate performance.

Finally, Abughniem et al. (2020) assess the impact of free cash flow on the performance of 100 firms listed on the Amman Stock Exchange, with data covering the period 2010–2015. Several elements of cash flows are taken into consideration, while performance is computed as return on assets, market value per share and Tobin's Q. The empirical results obtained from the panel data regression analysis show that free cash flow affects the return on assets and market value per share in a positive way.

2. Research methodology

In this section, we describe the research methodology applied to assess the relationship between cash flow and financial performance of the American banks.

2.1. Correlation analysis

First, we apply correlation analysis of the key variables considered in our study using the correlation coefficient. The variables analysed are financial performance, i.e. return on assets calculated as the fraction of earnings before tax to total assets, and return on equity, computed as the ratio of earnings before tax to total equity, cash flow from operating activities, cash flow from investing activities, cash flow from financing activities, net cash flow, free cash flow, banks' size, computed as the natural logarithm of total assets, leverage ratio, that is, total liabilities to total assets, liquidity ratio, calculated as the ratio of current assets to current liabilities, and efficiency ratio, which is computed as the fraction of total revenue for each year under study to total assets at the balance sheet date, i.e. as at December 31 of each year of the study period.

The main benefit of correlation analysis is that it helps identify which variables we should investigate further and it allows for rapid hypothesis testing. This analysis is primarily concerned with finding out whether a relationship exists between variables, and then determining the magnitude and sign of that relationship. However, correlation does not entail causation. That means that correlation analysis identities and evaluates a relationship between two variables, but a positive correlation does not automatically mean that one variable affects the other. This type of correlation only reflects a linear correlation of variables and ignores non-linear types of relationships or correlations.

2.2. Regression analysis of financial performance

2.2.1. Single-factor regression analysis

In the first step, we run the following single-factor panel regression model on the relationship between financial performance and cash flow:

$$Pnce = \beta_0 + \beta_1 CF + u \quad (1)$$

where $Pnce$ stands for ROA or ROE and CF stands for cash flow. ROA is calculated as the fraction of earnings before tax to total assets, and ROE is computed as the ratio of earnings before tax to total equity, u refers to the residuals of the model.

Two alternative versions of model (1) are applied. The first one uses net cash flow as an independent variable. Net cash flow is the sum of cash flow from operating activities, cash flow from investing activities and cash flow from financing activities and is found in the published financial statements of the examined US banks.[6] Farris and Hutchison (2002) find that a shorter cash conversion cycle leads to higher present value of net cash flow generated by assets, which contributes to higher firm value. If this is true for our sample as well, the coefficient of the net cash flow variable in model (1) will be positive and significant.

The second version of model (1) uses free cash flow as an explanatory variable of financial performance. The calculation of free cash flow is based on publicly available data and is conducted with the following formula:

[6] The published financial statements of the banks under analysis have been collected manually from Nasdaq.com

Factor:	Found in:
+ Cash Flow from Operating Activities	Statement of Cash Flows
+ Interest Expense	Income Statement
– Tax Shield on Interest Expense	Calculable
– Capital Expenditures	Statement of Cash Flows (Cash Flow from Investing Activities)
= Free Cash Flow (2)	

The Tax Shield on Interest Expense concerns tax savings resulting from the deduction of interest expense for taxation purposes. The payment of interest expense reduces the amount of taxable income, as well as the amount of taxes payable by an enterprise. To compute the interest tax shield, we use the following formula:

$$Tax\ Shield\ on\ Interest\ Expense = Interest\ Expense \times Effective\ Tax\ Rate \quad (3)$$

The effective tax rate refers to the percent of income a company owes or pays in taxes. We chose to use this tax rate to achieve consistency among the examined banks, given that corporate taxation in the United States is somehow complex as taxes are imposed at the federal, most state and some local levels. State and local taxes may vary among different states or local jurisdictions. The effective tax rate is easily computed as follows:

$$Effective\ Tax\ Rate = \frac{Income\ Tax}{Earnings\ Before\ Tax} \quad (4)$$

If Jensen's (1986) theory applies to the examined sample of American banks, the coefficient of free cash flow in model (1) will be significantly negative.

2.2.2. Multi-factor regression analysis

In the second step, along with the cash flow factors in model (1), we consider four additional control variables. The first variable is the size of banks. The second control variable is the leverage ratio. Next is the liquidity ratio and the fourth variable is the efficiency ratio. The five-factor panel model we run is shown in the following equation:

$$Pnce = \beta_0 + \beta_1 CF + \beta_2 Size + \beta_3 Leverage + \beta_4 Liguidity + \beta_5 Efficiency + u \quad (5)$$

where $Pnce$ and CF are defined as in model (1). Banks' size is computed as the natural logarithm of total assets. $Leverage$ ratio is the fraction of total liabilities to

total assets. Liquidity ratio is calculated by dividing current assets by current liabilities. *Efficiency* ratio is computed as the fraction of total revenue for each year under analysis to total assets at the balance sheet date, i.e. as at December 31 of each year of the study period; u refers to the residuals of the model. Similar to model (1), we run two versions of model (2): one with net cash flow in the explanatory variables and one with free cash flow.

Size is frequently considered to be positively related to firm performance. If this is true in our case, the coefficient of size will be positive and significant. With respect to leverage, there are studies that report a negative impact of this factor on firm performance (e.g. Yameen et al., 2019). If this is also the case for our sample, the coefficient of leverage must be negative. According to Zygmunt (2013), the importance of liquidity for the financial performance of a company might determine its level of profitability and, consequently, its financial performance. Based on this analysis, the coefficient of the liquidity ratio in model (5) should be positive. Efficiency is positively related to corporate financial performance (Khan et al., 2021). If this is the case for our sample too, the estimate of the efficiency ratio in model (5) is expected to be positive.

In the next step, we examine the impact of the three main components of cash flows (i.e. cash flow from operating activities, cash flow from investing activities and cash flow from financing activities) on financial performance. The relevant model is shown in the following equation:

$$Pnce = \beta_0 + \beta_1 OpCF + \beta_2 InvCF + \beta_3 FinCF + u \tag{6}$$

where performance is defined as ROA or ROE, $OpCF$ stands for cash flow from operating activities, $InvCF$ refers to cash flow from investing activities and $FinCF$ concerns cash flow from financing activities. Based on the findings from the literature, the coefficient of operating cash flow is expected to be positive. However, based on the empirical results of several studies, the coefficient of cash flow from investing activities is expected to be negative, which is also the case for the cash flow from financing activities.

In the last step, we add to model (6) the four control variables considered in model (5), thus obtaining the following model (7):

$$\begin{aligned} Pnce = {} & \beta_0 + \beta_1 OpCF + \beta_2 InvCF + \beta_3 FinCF + \beta_2 Size + \beta_3 Leverage + \\ & + \beta_4 Liguidity + \beta_5 Efficiency + u \end{aligned} \tag{7}$$

where all variables are defined as in the previous models, while the expectations about the sign of coefficients are as above.

2.3. Sample

The study focuses on US listed banks and covers a four-year period between 2019 and 2022. The main selection criterion applied for the preparation of the sample was the size of the banks at the end of the study period, i.e. the magnitude of their assets at the end of 2022. Another criterion applied concerned the financial reporting period of each bank. In particular, for consistency purposes, we only considered banks whose fiscal year spans from the January 1 to December 31 each year. Based on this requirement, banks with year-end other than December 31 have been excluded from the sample. This process resulted in 122 of the biggest banks operating in the US being included in our sample, the names of which are presented in Appendix.[7]

Total assets of these 122 banks at the end of 2022 amounted to 16.7 trillion USD. At the same date, total assets of the entire banking industry in the United States amounted to 23.6 trillion USD.[8] Based on assets, our sample covers 71% of the entire banking industry. Therefore, we deem our sample as quite representative of the whole banking market in the US.

Table 1 provides basic accounting figures of the examined banks over the period 2019–2022. The data are presented in average terms over the entire period under analysis and include total assets, current assets, equity, total liabilities, current liabilities, total revenue, earnings before tax (EBT), income tax, and net income, i.e. earnings after tax.[9] An equity to assets ratio is reported as well. The data for the entire sample are presented in five clusters, which have been prepared by descending the assets of banks. Based on this technique, cluster 1 reports the accounting of the 25 biggest banks over the study period, cluster 2 presents the accounting data of the second group of the biggest banks over the study period and so on.[10]

At the balance sheet level, average assets amount to 127 billion USD, with the largest bank in the sample presenting assets of 3.4 trillion USD. This is the banking giant JPMorgan Chase Bank. On the other hand, the smallest bank in the sample is the Regions Bank, which is headquartered in the Regions Center in Birmingham,

[7] Refer to: "Largest U.S. Banks by Asset Size" (2023), for a report on the assets of the 250 largest listed banks in the US at the end of 2022.

[8] Refer to: "US Banks Total Assets (I:USBTA)" (2023).

[9] Average terms over the entire period under analysis means that the reported values of the financial statements figures at the end of each of the four years under study have been summed. Afterwards, the sum has been divided by number 4 to obtain the average annual term of each figure. The same process has been applied for the calculation of the average financial ratios reported in Table 2 and the average cash flow figures provided in Table 3.

[10] The data reported in Table 1 have been collected manually from Nasdaq.com

Table 1. Accounting data

Stats	Total assets	Current assets	Equity	Equity to assets	Total liabilities	Current liabilities	Total revenue	EBT	Income tax	NetiIncome
Cluster 1: top size companies										
Average	561,986,797,140	224,782,158,000	51,193,443,280	9.14	509,867,623,860	435,497,879,400	25,445,543,333	7,402,170,875	1,327,883,469	6,049,870,740
Min	42,293,288,500	8,032,300,000	0	0.00	37,809,062,000	2,363,250,000	1,679,740,000	524,626,000	110,503,250	414,122,750
Max	3,370,361,500,000	1,619,944,250,000	281,785,750,000	13.70	3,088,575,750,000	2,623,336,000,000	116,454,250,000	46,602,250,000	8,709,250,000	37,893,000,000
Count	25	25	25	25	25	25	25	25	25	25
Cluster 2: second top size companies										
Average	31,073,520,948	8,782,235,833	3,450,272,635	11.26	27,623,248,313	26,862,276,302	1,356,026,396	426,554,698	90,832,250	335,487,688
Min	18,437,987,750	2,792,250,750	1,397,486,250	6.57	15,711,401,000	15,315,655,000	657,168,250	163,970,000	35,905,000	128,065,000
Max	54,911,511,250	19,685,643,750	6,307,028,500	17.80	49,942,605,000	46,639,346,750	4,054,404,500	800,804,250	190,506,000	613,961,000
Count	24	24	24	24	24	24	24	24	24	24
Cluster 3: medium size companies										
Average	13,607,148,323	3,316,503,490	1,596,825,417	11.70	12,010,322,906	11,660,261,156	560,579,552	184,712,656	39,920,573	143,990,219
Min	9,120,494,750	1,468,619,250	877,002,250	7.01	8,060,886,500	7,882,705,500	339,714,250	–36,551,250	13,563,000	–56,092,500
Max	19,429,343,250	6,509,274,750	2,610,985,750	14.06	16,853,243,250	16,757,862,250	778,552,500	283,883,750	72,958,500	212,545,750
Count	24	24	24	24	24	24	24	24	24	24
Cluster 4: second bottom size companies										
Average	7,707,744,896	1,486,349,604	841,253,365	11.02	6,866,491,531	6,635,970,563	349,441,771	99,459,271	20,194,219	79,054,875
Min	4,431,425,000	754,133,500	524,665,500	8.00	3,521,701,500	2,481,002,500	234,388,750	–11,756,750	–34,266,000	22,495,500
Max	9,520,844,750	2,743,517,500	1,239,989,250	20.53	8,280,855,500	8,103,356,000	668,257,250	162,027,500	32,612,500	133,229,750
Count	24	24	24	24	24	24	24	24	24	24
Cluster 5: bottom size companies										
Average	5,560,401,980	1,573,829,800	588,844,260	10.90	4,971,557,720	4,808,225,230	264,305,840	82,569,620	17,258,620	65,143,030
Min	1,361,761,250	474,271,500	268,681,250	7.60	1,070,192,500	38,009,500	94,554,250	29,485,000	5,858,250	23,626,750
Max	7,459,615,500	5,252,404,000	834,511,500	21.41	6,779,259,000	6,665,578,500	560,917,500	139,177,750	31,323,000	124,954,500
Count	25	25	25	25	25	25	25	25	25	25
Total sample										
Average	126,606,573,098	49,056,900,240	11,769,488,709	10.79	114,647,385,619	99,110,301,707	5,522,956,936	1,621,091,875	296,000,836	1,320,008,068
Min	1,361,761,250	474,271,500	0	0.00	1,070,192,500	38,009,500	94,554,250	–36,551,250	–34,266,000	–56,092,500
Max	3,370,361,500,000	1,619,944,250,000	281,785,750,000	21.41	3,088,575,750,000	2,623,336,000,000	116,454,250,000	46,602,250,000	8,709,250,000	37,893,000,000
Skewness	2.71	3.20	3.49	0.35	2.73	1.70	2.91	4.08	3.51	3.07
Kurtosis	4.71	3.16	3.90	2.20	3.03	3.65	2.63	4.52	2.78	4.59
Count	122	122	122	122	122	122	122	122	122	122

Source: own calculation based on data found on www.nasdaq.com

Alabama. Its average current assets amount to 49 billion USD, which captures 39% of total assets.

The average equity in the sample approximates 12 billion USD. The minimum and maximum equity figures amount to 0 and 282 billion USD, respectively. Compared to the total assets, the equity figures are rather low. In fact, the average equity to assets ratio in the sample is just 10.79%. This percentage shows that an average American bank relies heavily on external resources for financing its operations. Going further, average total liabilities amount to 115 billion USD with the maximum total liabilities figure exceeding 3 trillion USD. Average current liabilities amount to 99 billion USD or 86% of total liabilities. Such a high portion of current relative to total liabilities could trigger liquidity issues for the American banks.[11]

At the profit and loss statement level, the average total revenue amounts to 5.5 billion USD. The maximum total revenue figure is 116.4 billion USD and has been achieved by the JPMorgan Chase Bank. The lowest revenue of 94.6 million USD is presented by the Farmers and Merchants Bank of Long Beach in California. When it comes to profitability, the average EBT in the sample amounts to 1.6 billion USD. The worst profitability measure is –36.6 million USD (achieved by Berkshire Bank in Boston, Massachusetts). On the other hand, the maximum EBT of the sample is 46.6 billion USD. JPMorgan Chase Bank reached this maximum profitability level.

Table 2 presents key financial ratios of the banks in the sample, that is, the leverage liquidity and efficiency ratios, along with the return on assets and the return on equity. The average leverage ratio is 88.96%. The minimum and maximum leverage ratios of the sample are 74.75% and 96.76%, respectively. These leverage ratios verify our conclusion above concerning the strong dependence of banks in the United States on external financing. The average liquidity ratio is 66.60%, that is below 100%. This means that the current assets of banks are not enough to repay their current liabilities. This is another indicator of possible liquidity issues for the American banks, as a liquidity ratio that is higher than unity is usually considered in the accounting literature to be a good liquidity ratio.[12] The average effi-

[11] Current liabilities are what an enterprise needs to pay within the next 12 months from the financial reporting period or within its normal operating cycle. Knowing current liabilities is important because it enables the company to plan its finances. If the amount of current liabilities is too high, it can be a sign that the business is not effectively using its current assets or short-term liabilities and, consequently, it may face difficulties in repaying all of its short-term obligations. If a company fails to satisfy short-term creditors, unpleasant negative consequences could be triggered for it. Refer to: Moula (2021) for the significance of managing short-term liabilities.

[12] A liquidity ratio exceeding unity indicates that the company is in good financial condition and is less likely to face financial hardships. The higher the ratio, the higher the safety margin that the business possesses to meet its current liabilities (source: "What is a good liquidity ratio?" (2023).

Table 2. Financial ratios

Stats	Leverage	Liquidity	Efficiency	Return on Assets	Return on Equity
Cluster 1: Top size companies					
Average	90.29	79.22	5.73	1.52	16.51
Min	85.77	20.57	3.08	0.94	0.00
Max	96.76	854.91	22.79	4.09	53.66
Count	25	25	25	25	25
Cluster 2: second top size companies					
Average	88.63	32.66	4.40	1.39	12.64
Min	82.17	14.70	3.29	0.92	6.97
Max	93.39	52.81	13.35	2.60	19.56
Count	24	24	24	24	24
Cluster 3: medium size companies					
Average	88.17	28.06	4.19	1.37	11.78
Min	85.60	16.37	3.72	–0.24	–3.32
Max	92.78	55.41	5.18	2.22	20.07
Count	24	24	24	24	24
Cluster 4: second bottom size companies					
Average	88.71	30.29	4.85	1.18	12.02
Min	74.75	12.37	3.33	–2.20	–3.51
Max	91.87	208.11	16.93	1.84	20.33
Count	24	24	24	24	24
Cluster 5: bottom size companies					
Average	88.98	158.41	5.60	1.58	14.40
Min	77.99	16.00	3.39	0.91	8.41
Max	92.33	3,220.31	30.83	4.96	23.41
Count	25	25	25	25	25
Total sample					
Average	88.96	66.60	4.97	1.41	13.50
Min	74.75	12.37	3.08	–2.20	–3.51
Max	96.76	3,220.31	30.83	4.96	53.66
Skewness	1.77	1.09	2.36	0.58	2.82
Kurtosis	3.60	5.99	3.07	1.05	2.77
Count	122	122	122	122	122

Note: Leverage Ratio: total liabilities/total assets
Liquidity Ratio: current assets/current liabilities
Efficiency Ratio: total revenue/total assets
Return on Assets = earnings before tax/total assets
Return on Equity = earnings before tax/total equity

Source: own calculation based on data found on www.nasdaq.com

ciency ratio is rather low at 4.97%. The minimum efficiency is 3.08% (achieved by Charles Schwab Bank, SSB) and the maximum efficiency ratio is equal to 30.83% (presented by the Regions Bank).

As far as the financial performance of the examined banks is concerned, the average ROA in the sample is 1.41%. The minimum ROA is equal to –2.20% and the maximum ROA is equal to 4.96% (achieved by the Regions Bank). The average ROE is 13.50%, with extreme ROE scores amounting to –3.51% and 53.66%. These minimum and maximum ROE ratios are presented by the LendingClub Bank and the Ameriprise Bank (FSB), respectively.

Table 3 provides information on the five cash flow factors considered in our analysis, namely operating cash flow, investing cash flow, financing cash flow, net cash flow and free cash flow. The data are presented in average terms over the period 2019–2022. The average cash flow from operating activities in the sample amounts to 1.4 billion USD. The average cash flow from investing activities is negative at –5.3 billion USD. The corresponding average cash flow from financing activities is equal to 5.2 billion USD.

Going further, the average net cash flow is equal to 1.2 billion USD. This average amount is not equal to the sum of the cash flows from operating, investing and financing activities. The difference is due to the effect of exchange rate differences.[13] Finally, the average free cash flow figure in the sample amounts to 7 billion USD. For all cash flow figures reported in Table 3, there is a wide gap between the minimum and maximum figures (amounting to an average of 133 billion USD for the five factors combined).

3. Empirical results

The results of our empirical analysis are reported in this section. We first discuss the correlation coefficients among the key variables considered in our study and then we present the results of the regression analysis on the financial performance of the American banks.

One significant regulatory requirement that must be met by banks in the United States concerns the Liquidity Coverage Ratio (LCR), which refers to the proportion of highly liquid assets that must be held by financial institutions; it must be enough to fund cash outflows for 30 days and ensure their ongoing ability to meet short-term obligations. This ratio is actually a generic stress test that aims to foresee market-wide shocks and ensure that financial institutions have sufficient capital preservation to ride out any short-term liquidity disruptions, that may plague the entire system. For a detailed discussion on the LCR ratio refer to: Murhy (2022).

[13] The cash flow of 14 out of 122 banks in our sample are affected by exchange rate differences.

Table 3. Cash flows

Stats	OpCF	InvCF	FinCF	NetCF	FreeCF
Cluster 1: top size companies					
Average	5,903,676,760	–22,496,588,500	22,584,612,940	5,636,442,510	29,814,332,589
Min	244,825,000	–145,283,500,000	–20,315,500,000	–3,532,500,000	–1,912,880,454
Max	27,346,250,000	10,707,000,000	194,842,000,000	72,110,250,000	186,334,944,238
Count	25	25	25	25	25
Cluster 2: second top size companies					
Average	482,627,781	–1,880,168,406	1,460,025,813	63,144,688	2,399,005,429
Min	134,939,500	–5,155,250,250	–150,662,500	–119,253,250	720,679,672
Max	1,079,546,500	–167,530,000	4,616,591,750	483,048,750	5,764,317,192
Count	24	24	24	24	24
Cluster 3: medium size companies					
Average	191,566,542	–861,974,990	730,174,854	59,891,010	1,065,317,951
Min	81,467,000	–2,592,204,250	–309,142,250	–7,283,500	–134,495,911
Max	292,119,250	292,714,750	2,575,276,000	436,163,750	2,731,112,197
Count	24	24	24	24	24
Cluster 4: second bottom size companies					
Average	110,687,141	–430,560,250	341,314,870	21,441,761	546,906,446
Min	–184,687,250	–1,224,044,250	–807,982,250	–40,674,000	–565,483,576
Max	402,248,250	668,063,750	1,433,062,750	120,106,500	1,230,943,986
Count	24	24	24	24	24
Cluster 5: bottom size companies					
Average	98,837,980	–394,932,630	306,221,400	10,111,920	498,586,506
Min	31,680,750	–1,009,042,750	82,933,500	–31,512,000	279,366,708
Max	377,171,500	–201,294,750	952,811,250	72,015,250	1,073,026,938
Count	25	25	25	25	25
Total sample					
Average	1,384,271,389	–5,318,398,244	5,192,065,963	1,185,291,408	7,003,950,671
Min	–184,687,250	–145,283,500,000	–20,315,500,000	–3,532,500,000	–1,912,880,454
Max	27,346,250,000	10,707,000,000	194,842,000,000	72,110,250,000	186,334,944,238
Skewness	4.73	–2.47	3.83	4.79	5.28
Kurtosis	2.22	4.65	4.75	4.28	4.85
Count	122	122	122	122	122

Note: Free Cash Flows = Cash from Operating Activities + Interest Expense – Tax Shield on Interest Expense + Cash Flow from Investing Activities

Source: own calculation based on data found on www.nasdaq.com

3.1. Correlation analysis

In this section we discuss the correlation among the average ROA and ROE, which are the two types of financial performance considered in our analysis,[14] cash flow from operating activities, cash flow from investing activities, cash flow from financing activities, net cash flow, free cash flow, banks' size, as well as the leverage, liquidity and efficiency ratios over the period 2019–2022. The relevant calculations are presented in Table 5.[15]

However, before analysing correlation coefficients, we examine the stationarity of the financial data series used in our analysis. Stationarity is examined with the Augmented Dickey-Fuller (ADF) Unit Root Test. The null hypothesis of this test is that a data series has a unit root, that is, the series is not stationary. The null hypothesis is rejected when the test value is more negative than the critical values. The results of ADF testing, i.e. t-statistics and probabilities along with critical values at 1%, 5% and 10%, are provided in Table 4. As shown in the table, the eleven variables that are used in our correlation and regression analysis have no unit roots and are stationary, with no exceptions.

After verifying that our data series are stationary, we focus on the correlations among the variables. As shown in Table 5, ROA is positively related to the cash

Table 4. Stationarity testing

Variable	Test critical values			ADF test outcomes	
	1%	5%	10%	*t*-statistic	probability
ROA	–3.44	–2.87	–2.57	–20.77	0.00
ROE	–3.44	–2.87	–2.57	–4.52	0.00
Oper. cash flow	–3.44	–2.87	–2.57	–21.34	0.00
Inv. cash flow	–3.44	–2.87	–2.57	–9.32	0.00
Fin. cash flow	–3.44	–2.87	–2.57	–8.30	0.00
Net cash flow	–3.44	–2.87	–2.57	–10.23	0.00
Free cash flow	–3.44	–2.87	–2.57	–9.56	0.00
Size	–3.44	–2.87	–2.57	–5.54	0.00
Leverage	–3.44	–2.87	–2.57	–19.89	0.00
Liquidity	–3.44	–2.87	–2.57	–17.26	0.00
Efficiency	–3.44	–2.87	–2.57	–22.11	0.00

Source: own calculation.

[14] We note that other studies, such as those by Kroes and Manikas (2014), Ni et al. (2019), Heydari et al. (2014), Kadioglu et al. (2017) and Abughniem et al. (2020), examine financial performance by using Tobin's Q. We do not take this financial performance measure into consideration in our analysis.

[15] We note that the cash flow figures have been scaled by total assets at the end of each year under analysis.

Table 5. Correlations

Variable	ROA	ROE	Oper. cash flow	Inv. cash flow	Fin. cash flow	Net cash flow	Free cash flow	Size	Leverage	Liquidity	Efficiency
ROA	1.00	0.68	0.11	–0.26	0.14	–0.11	0.26	0.00	0.08	0.29	0.37
ROE	0.68	1.00	0.12	–0.18	0.04	–0.15	0.20	0.11	0.38	0.21	0.24
Oper. cash flow	0.11	0.12	1.00	–0.06	–0.18	0.06	0.39	–0.09	–0.33	0.50	0.55
Inv. cash flow	–0.26	–0.18	–0.06	1.00	–0.79	0.12	–0.93	0.09	–0.19	–0.15	–0.04
Fin. cash flow	0.14	0.04	–0.18	–0.79	1.00	0.46	0.66	–0.05	0.20	0.01	–0.10
Net cash flow	–0.11	–0.15	0.06	0.12	0.46	1.00	–0.08	0.00	–0.10	0.02	0.03
Free cash flow	0.26	0.20	0.39	–0.93	0.66	–0.08	1.00	–0.09	0.11	0.27	0.16
Size	0.00	0.11	–0.09	0.09	–0.05	0.00	–0.09	1.00	0.26	–0.10	–0.07
Leverage	0.08	0.38	–0.33	–0.19	0.20	–0.10	0.11	0.26	1.00	–0.28	–0.47
Liquidity	0.29	0.21	0.50	–0.15	0.01	0.02	0.27	–0.10	–0.28	1.00	0.66
Efficiency	0.37	0.24	0.55	–0.04	–0.10	0.03	0.16	–0.07	–0.47	0.66	1.00

Source: own calculation.

flows from operating and financing activities, but it is negatively correlated to the cash flow from investing activities. The correlation of ROA with net cash flow is negative. The opposite is the case for free cash flow. The correlation of ROA with the size of banks is nil. Finally, the correlations of ROA with leverage, liquidity and efficiency ratios are all positive. The direction of ROE's correlation with the examined variables is exactly equal to that of ROA. However, the magnitude of ROE's correlation coefficients differ from that of ROA's correlations.

The correlation coefficients prove that the variables we have chosen to use in our analysis have some sort of relationship with the financial performance of the American banks. However, the question of whether these linear relationships can be interpreted as if the selected variables could explain or influence financial performance will be answered by the results of the regression analysis presented in the next section.

3.2. Regression analysis of financial performance

3.2.1. Single-factor regression analysis

The results of the single-factor model (1) on banks' financial performance are provided in Table 6, which has two panels: Panel A concerns the results on ROA and Panel B reports the results on ROE. The table presents the coefficients of the variables, the t-statistic regarding their statistical significance and the R-squared coefficient along with the results of the heteroscedasticity and autocorrelation tests.

In the case of ROA, the single-factor model (1) produces a slightly negative but significant estimate for the net cash flow factor (–0.02). The corresponding slope for free cash flow is slightly positive (0.03) and significant. The sign of slopes obtained when ROE is a dependent variable of the regression model is similar to that of ROA's results. However, the economic validity of slopes is more material compared to that of ROA. More specifically, the coefficients of net cash flow and free cash flow are –0.24 and 0.19, respectively, implying that an increase in net cash flow by 1% can reduce firm performance by 0.24%, whereas an increase in free cash flow by 1% may result in an increase in firm performance by 0.19%. With respect to the statistical validity of the reported results, it shall be noted that the relevant testing has shown no heteroskedasticity and autocorrelation issues.

Overall, the empirical results of the single-factor regression analysis contradict our expectations about a positive impact of net cash flow on financial performance and a negative effect of free cash flow on the performance. In addition, the accentuated positive relationship between performance and free cash flow is

Table 6. Single-factor regression analysis of performance

Variable	Coefficient	*t*-statistic	Coefficient	*t*-statistic
Panel A: Return on Assets (ROA)				
Constant	1.42*	35.84	1.19*	22.14
Net cash flow/free cash flow	–0.02**	–2.35	0.03*	5.91
R-squared	0.11	–	0.17	–
Heteroskedasticity testing: *F*-statistic (*P*-value)	4.49 (0.16)	–	0.16 (0.69)	–
Autocorrelation Testing: *F*-statistic (*P*-value)	0.60 (0.55)	–	1.47 (0.11)	–
Panel B: Return on Equity (ROE)				
Constant	13.62*	39.64	12.02*	25.32
Net cash flow/free cash flow	–0.24*	–3.30	0.19*	4.44
Heteroskedasticity testing: *F*-statistic (*P*-value)	0.48 (0.49)	–	0.00 (0.99)	–
Autocorrelation testing: *F*-statistic (*P*-value)	1.42 (0.12)	–	1.09 (0.22)	–
R-squared	0.12	–	0.14	–

Note: * statistically significant at 1%; ** statistically significant at 5%.

Source: own estimation.

in contrast to Jensen's (1986 theory about the negative impact of free cash flow on corporate performance.

3.2.2. Multi-factor regression analysis

The results of the five-factor model (5) are presented in Table 7. The coefficients of the cash flow factors are quite similar to those obtained from the single-factor model. In the case of ROA, net cash flow and free cash flow estimates are slightly negative and positive, respectively, being statistically significant at 5%.

When it comes to the size of banks, the relevant estimates in Table 7 are statistically insignificant. Based on these results, the size of the examined banks cannot affect their financial performance, whether the performance is ROA or ROE. This is also the case for the liquidity ratio.

When ROA is taken into consideration, the coefficient of the leverage factor is positive but statistically insignificant. However, the corresponding leverage estimate in the case of ROE shows a strong positive and statistically significant influence, amounting to 1.60 and 1.61 in the first and the second version of the applied model, respectively.

Table 7. Five-factor regression analysis of performance

Variable	Coefficient	*t*-statistic	Coefficient	*t*-statistic
Panel A: Return on Assets (ROA)				
Constant	–7.02	–1.13	–6.64	–1.05
Net cash flow/free cash flow	–0.02**	–2.35	0.02**	2.33
Size	–0.03	–1.02	–0.02	–0.64
Leverage	0.10	1.32	0.09	1.18
Liquidity	0.00	0.64	0.00	0.25
Efficiency	0.12*	4.87	0.12*	5.31
R-squared	0.23	–	0.24	–
Heteroskedasticity testing: *F*-statistic (*P*-value)	4.33 (0.00)	–	12.10 (0.00)	–
Autocorrelation testing: *F*-statistic (*P*-value)	1.11 (0.19)	–	1.53 (0.13)	–
Panel B: Return on Equity (ROE)				
Constant	–133.42*	–6.99	–134.53*	–6.68
Net cash flow/free cash flow	–0.16*	–2.83	0.13***	1.71
Size	–0.04	–0.18	–0.03	–0.14
Leverage	1.60*	7.89	1.61*	7.32
Liquidity	0.00	0.60	0.00	0.47
Efficiency	1.08*	7.28	1.08*	7.36
R-squared	0.39	–	0.38	–
Heteroskedasticity testing: *F*-statistic (*P*-value)	5.21 (0.00)	–	5.82 (0.00)	–
Autocorrelation testing: *F*-statistic (*P*-value)	1.05 (0.14)	–	1.18 (0.17)	–

Note: * statistically significant at 1%; ** statistically significant at 5%; *** statistically significant at 10%.

Source: own estimation.

Finally, with respect to efficiency, the relevant estimate in the case of ROA is significantly positive, being equal to 0.12 in both versions of the model. This significant estimate indicates that an increase by 1% in the total revenue per assets achieved by an American bank may boost its ROA by 12 basis points. The corresponding estimate of the efficiency ratio in the case of ROE is also positive and significant, being equal to 1.08 in both versions of the model.

Having analysed the results of model (5), it should be noted that the initial results obtained from this model presented heteroskedasticity (but no autocorrelation) issues. The relevant Breuch-Pagan-Godfrey statistics on the initial regression results are reported in Table 7. In the end, the results on the regression vari-

ables reported in Table 7 are those obtained after correcting heteroskedasticity with the White method.

The results of model (6) on the influence exerted by the three key determining components of net cash flow, i.e. cash flow from operating activities, cash flow from investing activities and cash flow from financing activities, are reported in Table 8.

Table 8. Three-factor regression analysis of performance

Variable	Coefficient	*t*-statistic	Coefficient	*t*-statistic
	Panel A: Return on Assets (ROA)		Panel B: Return on Equity (ROE)	
Constant	1.17*	13.89	11.93*	22.81
Operating cash flow	0.02	0.22	0.19	0.46
Investing cash flow	–0.05**	–2.13	–0.38*	–3.47
Financing cash flow	–0.02**	–2.06	–0.22*	–3.18
R-squared	0.18	–	0.12	–
Heteroskedasticity testing: *F*-statistic (*P*-value)	7.40 (0.00)	–	5.51 (0.00)	–
Autocorrelation testing: *F*-statistic (*P*-value)	2.09 (0.22)	–	1.53 (0.11)	–

Note: * statistically significant at 1%; ** statistically significant at 5%.

Source: own estimation.

As expected, the estimates concerning cash flow from operating activities are positive both for ROA and ROE. However, these positive coefficients are not significant in statistical and economic terms. Consequently, we cannot establish a meaningful relationship between financial performance and operating cash flow.

By contrast, the estimates obtained for cash flow from investing and financing activities are all significantly negative. In the case of ROA, the relevant estimates are equal to –0.05 and –0.02. In the case of ROE, the coefficients of investing and financing cash flows are equal to –0.38 and –0.22, respectively.

Similar to the previous model, we have performed heteroskedasticity and autocorrelation testing, which has shown that, although autocorrelation is not an issue, heteroskedasticity is, as indicated by the corresponding F-statistics on the model's (6) initial results shown in Table 8. Heteroskedasticity has been corrected with the White method and the regression results presented in the table are the corrected ones.

The results of the seven-factor model (7) resemble those derived from model (6). These results are provided in Table 9. In particular, the estimates concerning the operating cash flow are statistically insignificant. On the other hand, the coeffi-

Table 9. Seven-factor regression analysis of performance

Variable	Coefficient	*t*-statistic	Coefficient	*t*-statistic
	Panel A: Return on Assets (ROA)		Panel B: Return on Equity (ROE)	
Constant	–5.77	–1.25	–133.79*	–6.73
Operating cash flow	–0.06	–0.62	–0.03	–0.17
Investing cash flow	–0.03*	–2.86	–0.18**	–2.14
Financing cash flow	–0.01***	–1.80	–0.16*	–2.90
Size	–0.01	–0.51	–0.03	–0.12
Leverage	0.08	1.46	1.60*	7.32
Liquidity	0.00	0.60	0.00	0.47
Efficiency	0.13*	3.18	1.05*	7.09
R-squared	0.27	–	0.39	–
Heteroskedasticity testing: *F*-statistic (*P*-value)	6.53 (0.00)	–	4.52 (0.00)	–
Autocorrelation testing: *F*-statistic (*P*-value)	0.49 (0.57)	–	1.98 (0.33)	–

Note: * statistically significant at 1%; ** statistically significant at 5%; *** statistically significant at 10%.

Source: own estimation.

cients of investing and financing cash flows are negative and statistically significant, though lower in absolute value compared to the corresponding estimates in Table 8.

Going further, as in model (5), the size factor presents no significant estimates. Leverage is significant in explaining bank performance only in the case of ROE. The sign of the impact of leverage on performance is positive as was the case in model (5). Liquidity is insignificant, while efficiency is positively related to the financial performance (both ROA and ROE) of the examined American banks. In regard to the statistical validity of these results, we should note that similar to model (6) results, heteroskedasticity was an issue in model (7). This problem was dealt with using the White correction method.

Overall, the results of models (6) and (7) verify our expectations about a negative impact of investing and financing cash flows on performance, but not our assumption about a significantly positive relationship between financial performance and cash flow from operating activities.

Conclusion

In this study, we have examined the relationship between cash flow and financial performance using data from a sample of 122 US banks. The study covers the period 2019–2022. Two alternative types of financial performance are considered, i.e. return on assets and return on equity, as well as five cash flow components, that is, cash flow from operating activities, cash flow from investing activities, cash flow from financing activities, net cash flow and free cash flow. Along with the cash flow factors, we have considered four control variables, namely the size of banks and their leverage, liquidity and efficiency ratios. From a methodological perspective, correlation analysis is applied along with panel single-factor and multi-factor regression analysis.

The empirical evidence of our study has revealed a negative relationship between financial performance and net cash flow, while the opposite is the case for free cash flow. These results contradict the findings of several studies in the literature, which indicate that financial performance is positively related to net cash flow but negatively associated with corporate performance. Regarding the constituting elements of net cash flow, our results show that cash flow from operating activities cannot affect performance. On the contrary, investing and financing cash flows can affect the financial performance of banks in the US but in a negative fashion.

When it comes to the control variables used in our analysis, the results indicate that size is not material in explaining bank performance. This is also the case for liquidity. Leverage is significant in explaining performance only when return on equity is taken into consideration. Finally, the impact of efficiency on banks' performance is positive and quite significant.

Overall, our study provides new empirical evidence on publicly available factors that can be easily exploited as selection tools when examining which banks present high prospects of a significant future financial performance. Such prospects are of particular interest to investors in the capital markets seeking investment opportunities that may reward them with higher dividends and, possibly, higher stock returns.

The main limitation of our study is that it assumes linear relationships between the examined variables. Thus, one could also examine the possibility of a non-linear relationship between financial performance and cash flow components, size, leverage, liquidity and efficiency. Other variables could also be considered in the analysis of performance. Indicatively, these variables could cover corporate governance issues, social issues and environmental risks resulting from or affecting banks' operations. Finally, comparisons between American banks and European banks (or banks from other continents) could also be applied to identify whether there are specific cash flow elements or other variables of a special national or regional nature that could affect financial performance in the banking sector.

Appendix

Study sample

No.	Name	Symbol
1	JPMorgan Chase Bank	JPM
2	Bank of America	BAC
3	Wells Fargo Bank	WFC
4	Goldman Sachs Bank USA	GS
5	U.S. Bank	USB
6	Truist Bank	TFC
7	Charles Schwab Bank, SSB	SCHW
8	Capital One	COF
9	The Bank of New York Mellon	BK
10	State Street Bank and Trust Company	STT
11	American Express National Bank	AXP
12	Citizens Bank	CFG
13	Fifth Third Bank	FITB
14	Ally Bank	ALLY
15	KeyBank	KEY
16	The Huntington National Bank	HBAN
17	Ameriprise Bank, FSB	AMP
18	The Northern Trust Company	NTRS
19	Zions Bancorporation, N.A.	ZION
20	Comerica Bank	CMA
21	Raymond James Bank	RJF
22	First Horizon Bank	FHN
23	Webster Bank	WBS
24	Western Alliance Bank	WAL
25	East West Bank	EWBC
26	Synovus Bank	SNV
27	Valley National Bank	VLY
28	Wintrust Bank	WTFC
29	BOKF	BOKF
30	Old National Bank	ONB
31	First National Bank of Pennsylvania	FNB
32	Associated Bank	ASB
33	UMB Bank	UMBF
34	Prosperity Bank	PB
35	Stifel Bank and Trust	SF

Study sample – cont.

No.	Name	Symbol
36	BankUnited	BKU
37	Hancock Whitney Bank	HWC
38	First Interstate Bank	FIBK
39	Commerce Bank	CBSH
40	Texas Capital Bank	TCBI
41	Simmons Bank	SFNC
42	Fulton Bank	FULT
43	Glacier Bank	GBCI
44	Ameris Bank	ABCB
45	First Hawaiian Bank	FHB
46	United Community Bank	UCBI
47	Bank of Hawaii	BOH
48	Eastern Bank	EBC
49	Cathay Bank	CATY
50	Pacific Premier Bank	PPBI
51	Customers Bank	CUBI
52	Washington Federal Bank	WAFD
53	Atlantic Union Bank	AUB
54	Columbia Bank	COLB
55	Bank of Hope	HOPE
56	Trustmark National Bank	TRMK
57	First Merchants Bank	FRME
58	Renasant Bank	RNST
59	Community Bank	CBU
60	Banner Bank	BANR
61	Northwest Bank	NWBI
62	Sandy Spring Bank	SASR
63	Dime Community Bank	DCOM
64	OceanFirst Bank	OCFC
65	First Foundation Bank	FFWM
66	First Financial Bank	FFIN
67	BancFirst	BANF
68	Busey Bank	BUSE
69	Veritex Community Bank	VBTX
70	Seacoast National Bank	SBCF
71	NBT Bank	NBTB
72	Berkshire Bank	BHLB
73	EagleBank	EGBN

Study sample – cont.

No.	Name	Symbol
74	Lakeland Bank	LBAI
75	Columbia State Bank	CLBK
76	Live Oak Banking Company	LOB
77	The Park National Bank	PRK
78	First Commonwealth Bank	FCF
79	Origin Bank	OBK
80	ConnectOne Bank	CNOB
81	Capitol Federal Savings Bank	CFFN
82	NBH Bank	NBHC
83	HomeStreet Bank	HMST
84	Banc of California	BANC
85	Brookline Bank	BRKL
86	Amerant Bank	AMTB
87	S&T Bank	STBA
88	Nicolet National Bank	NIC
89	Premier Bank	PFC
90	Flushing Bank	FFIC
91	1st Source Bank	SRCE
92	LendingClub Bank	LC
93	Luther Burbank Savings	LBC
94	The Bancorp Bank	TBBK
95	Horizon Bank	HBNC
96	Midland States Bank	MSBI
97	Amalgamated Bank	AMAL
98	Tompkins Community Bank	TMP
99	Southside Bank	SBSI
100	Stock Yards Bank & Trust Company	SYBT
101	Central Pacific Bank	CPF
102	Hanmi Bank	HAFC
103	Byline Bank	BY
104	Univest Bank and Trust Co.	UVSP
105	Peoples Bank	PEBO
106	Heritage Bank	HFWA
107	Westamerica Bank	WABC
108	Pathward	CASH
109	MidFirst Bank	FMBH
110	Washington Trust Bank	WASH
111	CrossFirst Bank	CFB

Study sample – cont.

No.	Name	Symbol
112	MidWestOne Bank	MOFG
113	Peapack-Gladstone Bank	PGC
114	Metropolitan Commercial Bank	MCB
115	German American Bank	GABC
116	Trustco Bank	TRST
117	Republic Bank	RBCAA
118	Cambridge Savings Bank	CATC
119	Independent Bank	IBCP
120	PlainsCapital Bank	SPFI
121	Farmers and Merchants Bank of Long Beach	FMAO
122	Regions Bank	RM

Source: own preparation.

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Forecasting foreign exchange rate volatility using deep learning: Case of US dollar/Algerian dinar during the COVID-19 pandemic

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Abstract

This study explores the application of deep learning techniques in forecasting foreign exchange rate volatility, leveraging the capabilities of neural networks to capture complex patterns and non-linear relationships within financial data. The volatility of exchange rates is a critical factor influencing investment decisions, risk management and financial market stability. Traditional models often struggle to capture the dynamic nature of market conditions, leading to increased interest in advanced machine learning methodologies. We applied the auto regressive integrated moving average (ARIMA) and machine learning linear regression (LR) model, deep learning models, i.e. recurrent neural networks (RNN), bidirectional LSTM (BiLSTM), long short-term memory (LSTM) and gated recurrent unit (GRU). In terms of forecasting errors, Python routines were used for such a purpose. Furthermore, in order to investigate the quality of the models used, we compared the performances of these algorithms in US dollar/Algerian dinar exchange rate forecasting through the application of significance statistical tests (*R*-squared, MSE, RMSE, MAE, MAPE).The results clearly depict that contemporary techniques have been shown to produce more accurate results than conventional regression-based modelling. The machine learning linear regression (LR) model provides the maximum accuracy rate (99.83%), followed by the RNN models, with the GRU model (92.27%), BiLSTM model (87.34%), LSTM model (74.68%) and ARIMA model (32.29%).

Keywords

- deep learning
- exchange rate
- forecasting
- ARIMA
- linear regression

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Introduction

Forecasting foreign exchange (forex) rate volatility is a complex task due to the dynamic and non-linear nature of financial markets. It has become an important subject in economics, business and finance (Bai et al., 2018). The foreign exchange market is a global financial market that is influenced by economic, political and psychological factors which are interconnected in complex ways. This complexity makes the foreign exchange market a difficult time-series prediction (Cappiello et al., 2006). At the end of 2019, the world was faced with the COVID-19 pandemic that didn't only affect public health but also the foreign exchange market, which influenced the trading behaviour (Zahrah, 2020). However, financial market prediction is a classic research problem in quantitative finance and the research area of neural networks. Financial time series often present characteristics such as volatility, non-stationarity, periodicity, non-linearity and long-term dependence (Huyghebaert & Wang, 2010). Traditional statistical models, including the multiple regression method, the autoregressive integrated moving average (ARIMA) model and the Generalized AutoRegressive Conditional Heteroskedasticity (GARCH) model Engle (2002), can accurately capture the volatility and periodicity of financial series and are widely used in the real world. The statistical models are also highly interpretable, but it is difficult for them to analyse non-stationary sequences and capture the non-linear relationships of financial time series (Zhang et al., 2019).

Deep learning (DL) is an advanced technique of machine learning (ML) based on artificial neural network (NN) algorithms. As a promising branch of artificial intelligence, DL has attracted great attention in recent years. Compared with conventional ML techniques such as a support vector machine (SVM) and k-nearest neighbours (kNN), DL possesses advantages of the unsupervised feature learning, a strong capability of generalisation and a robust training power for big data. Currently, DL has been applied comprehensively in classification and prediction tasks, computer visions, image processing and audio-visual recognition (Chai & Li, 2019). Although DL was developed in the field of computer science, its applications have penetrated diversified fields such as medicine, neuroscience, physics and astronomy, finance and banking (F&B), as well as operations management (Chai & Ngai, 2020). The existing literature lacks a good overview of DL applications in F&B fields. The aim of this research is to investigate whether or not the machine learning models offer better predictions than traditional models in terms of lower forecasting errors and higher accuracy in forecasts. More specifically, we will compare the autoregressive integrated moving average (ARIMA) and machine learning linear regression (LR) model, deep learning models, i.e. recurrent neural networks (RNN), bidirectional LSTM (BiLSTM), long short-term memory (LSTM)

and gated recurrent unit (GRU).Therefore, the research question is the following: which of the two models, i.e. conventional regression-based modelling (the ARIMA model) or deep learning models, perform better when forecasting future values of the Algerian dinar (DZD) exchange rate?

Generally, our study will try to test the following hypotheses:

H1: The ARIMA model provides the USD/NZD exchange rate forecasting with higher errors and lower accuracy.
H2: The deep learning models provides the USD/NZD exchange rate forecasting with lower errors and higher accuracy.

1. Background of the study

In order to better understand the issue under analysis, we present some recent studies on our research topic. Table 1 depicts the number of articles that use various DL models in exchange rate forecasting.

Table 1. Reviewed previous studies

Author(s)/Year	Country	Period	Methodology	Main findings
Aygün & Günay Kabakçı (2021)	USA	September 2013 – October 2020	DNN, RNN, CNN, MVA, ARIMA	the RNN yields better results
Larasati & Primandari (2021)	USA	4 August 2018 – 21 January 2020	RNN, LSTM	the best accuracy of the LSTM
Robinson & Kabari (2021)	Nigeria	December 2001 – September 2019	RNN, SVM, LSTM, GRU, ARIMA	the RNN provides the best accuracy
Kaushik (2020)	India	April 1994 – December 2018	RNN, SVM, LSTM, VAR	the best accuracy of the LSTM
Yasar & Kilimci (2020)	Turkey	1 January 2018 – 31 December 2018	CNN, RNN, LSTM, FSA, ARIMA	the best accuracy of Holt-Winters and ARIMA
Chen et al. (2020)	USA	August 2011 – July 2018	ANN, SVM, RF, LSTM, ARIMA	the best accuracy of the LSTM
Siami-Namini & Siami Namin (2019)	USA	January 1985 – August 2018	ARIMA, RNN, LSTM, BiLSTM	the best accuracy of the BiLSTM
McNally et al. (2018)	USA	August 2013 – July 2016	ARIMA, RNN, LSTM	the best accuracy of the LSTM

Source: authors' analysis based on literature review.

Several studies have examined the impact of COVID-19 on the foreign exchange market (e.g. Aslam et al., 2020; Umar & Gubareva, 2020). These studies applied traditional regression techniques to investigate the volatility of foreign exchange markets. However, these studies failed to consider the predictability of exchange rates during the COVID-19 and non-COVID-19 periods. Our study attempts to apply the best machine learning and deep learning algorithms to predict the foreign currency exchange rates during the COVID-19 pandemic and compare them with the rates during the normal non-COVID-19 period. It is important to predict the exchange rate accurately because it helps policymakers and businesspeople to improve the quality and quantity of appropriate management decisions and plan their finances more precisely (Fang & Bessler, 2018). Different methods are used to predict the foreign currency exchange rate (Mahmoud & Hosseini, 1994; Maya & Gómez, 2008; Windsor & Thyagaraja, 2001); most of them have been based on statistical analysis (Abedin et al., 2021).

2. Materials and methods

2.1. Autoregressive integrated moving average (ARIMA) model

The autoregressive integrated moving average (ARIMA) model is one of the time series forecasting methods which says that the current value of a variable can be explained in terms of two factors: a combination of lagged values of the same variable and a combination of a constant term plus a moving average of past error terms (Aloui & Hkiri, 2014).

As seen in **Equation 2.1**, the auto-regressive (AR) model expresses the time series x_t at time t as a linear regression of the previous p observations, that is:

$$x_t = \alpha + \sum_{i=1}^{p} \varphi_i x_{t-i} + \varepsilon_t \tag{2.1}$$

where ε_t is the white noise residual term and φ_i are real parameters.

In **Equation 2.2**, the Moving averages (MA)use dependency between residual errors to forecast values in the next period. The model helps to adjust to unpredictable events. The q^{th} order moving average model, denoted by MA (q), is defined as follows:

$$x_t = \alpha - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \cdots - \theta_q \varepsilon_{t-q} + \varepsilon_t \tag{2.2}$$

where α and θ_1 are real parameters.

The ARMA model combines the power of AR and MA components together. This way, an ARMA (p, q) model incorporates the p^{th} order AR and q^{th} order MA model, respectively.

We denote the AR and MA coefficients vectors by φ and θ. The α and ε_t captures the intercept and the error term at time t. The complete ARMA (p, q) model can be seen in detail in **Equation 2.3**, that is:

$$x_t = \alpha + \varphi_1 x_{t-1} - \varphi_2 x_{t-2} + \cdots + \varphi_p x_{t-p} - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} \cdots - \theta_q \varepsilon_{t-q} + \varepsilon_t \qquad (2.3)$$

ARIMAis a generalisation of the ARMA model by including integrated components, which are useful when data is non-stationary. The ARIMA applies differencing on time series to remove the non-stationarity. The ARIMA (p, d, q) represents the order for AR, MA and differencing components (Udom, 2018).

To forecast using a regression model with ARIMA errors, we need to forecast both the regression part of the model and the ARIMA part of the model, and combine the results. As with ordinary regression models, in order to obtain forecasts, we first need to forecast the predictors. When the predictors are known into the future (e.g. calendar-related variables such as time, day-of-week, etc.), this is straightforward. However, when the predictors are themselves unknown, we must either model them separately or use assumed future values for each predictor.

2.2. The machine learning linear regression (LR) model

Linear regression (LR) is a fundamental machine learning algorithm used for predicting a continuous outcome variable (also called the dependent variable) based on one or more predictor variables (independent variables). The basic idea behind linear regression is to find the linear relationship between the input features and the output variable.

The linear regression model assumes that the relationship between the independent variable X and the dependent variable Y.

There are two factors (x, y) involved in linear regression analysis. The equation below shows how *y* is related to *x*, known as regression:

$$y = \beta_0 + \beta_1 x + \varepsilon_t$$

Or equivalently:

$$E(y) = \beta_0 + \beta_1 x$$

Here, ε is the error term of linear regression. The error term accounts for the variability between both x and y, β_0 represents y-intercept, β_1 represents the slope. To put the concept of linear regression in the machine learning context in order to train the model, x is represented as input training dataset, y represents the class labels present in the input dataset. The goal of the machine learning algorithm then is to find the best values for β_0 (intercept) and β_1 (coefficient) to get the best-fit regression line. The best fit implies that the difference between the actual values and predicted values should be minimum. The minimisation problem can be represented as Grinsted et al. (2004).

$$Minimise \frac{1}{n}\sum_{i=1}^{n}(pred_i - y_i)^2$$

$$g = \frac{1}{n}\sum_{i=1}^{n}(pred_i - y_i)^2$$

Here, g is called a cost function, which is the root mean square of the predicted value of $y(pred_i)$ and actual $y(y_i)$, n is the total number of data points.

In summary, linear regression is a simple and widely used algorithm for predicting continuous outcomes based on the linear relationship between input features and the target variable.

2.3. Deep learning (DL) models

This section is devoted to briefly describe the basic principle of four non-linear machine learning models or deep learning models that will be used later for the exchange rate timeseries forecasting, namely RNN, LSTM, GRU, BiLSTM (Zouaoui & Naas, 2023).

2.3.1. Recurrent neural networks (RNN)

Forecasting with recurrent neural networks (RNNs) is a common application in time series analysis, where the goal is to predict future values based on past observations. RNNs are particularly well-suited for sequential data due to their ability to capture temporal dependencies. Here isa general guide on how to use RNNs for forecasting:

1. **Data Preparation**

- **Time Series Data:** Ensure your data is in the form of a time series, with each data point associated with a timestamp.
- **Normalisation/Standardisation:** Scale your data to a small range, typically between 0 and 1, to help the neural network converge faster.

2. **Sequence Generation**

- **Input Sequences:** Divide your time series data into input sequences. For instance, if your time series is [1, 2, 3, 4, 5, 6, 7, 8], you might create input sequences such as [1, 2, 3], [2, 3, 4], etc.
- **Output Labels:** Correspondingly, create output labels for each input sequence, representing the next value in the sequence. For the examples above, the output labels would be [4], [5], etc.

3. **Model Architecture**

- **Recurrent Layers:** Use RNN layers such as the LSTM (long short-term memory) or GRU (gated recurrent unit) in your model. These layers are designed to capture sequential dependencies.
- **Stacking Layers:** You can stack multiple recurrent layers to capture more complex patterns. However, be cautious about overfitting.
- **Dense Layers:** Add one or more dense layers at the end of your network to make the final predictions.

4. **Training**

- **Loss Function:** Use a suitable loss function for regression tasks, such as the Mean Squared Error (MSE) or Mean Absolute Error (MAE).
- **Optimizer:** Common optimisers include Adam, RMSprop or SGD.
- **Validation Data:** Split your data into training and validation sets to monitor the model's performance and avoid overfitting.

5. **Hyperparameter Tuning**

- **Learning Rate:** Experiment with different learning rates to find the optimal one for your specific problem.
- **Batch size:** Adjust the batch size based on your available computational resources.
- **Epochs:** Train the model for an appropriate number of epochs, monitoring validation performance.

6. **Evaluation**

- **Test set:** After training, use a separate test set to evaluate the model's performance on unseen data.

- **Metrics:** Use appropriate metrics such as the Mean Absolute Error (MAE), Mean Squared Error (MSE) or others, depending on your specific requirements.

7. **Post-Processing**

   Inverse transformation: If you have normalised or standardised your data, apply the inverse transformation to get the predictions in the original scale.

8. **Fine-tuning**

   Depending on the results, you might need to fine-tune hyperparameters, adjust the model architecture or gather more data for better performance.

9. **Deployment**

   Once satisfied with the model's performance, deploy it for making real-time predictions.

Remember that the effectiveness of an RNN for forecasting depends on the nature of your data and the complexity of the patterns it contains. Experimentation and iteration are crucial in finding the best model for your specific use.

2.3.2. Long Short-Term Memory (LSTM) model

Long Short-Term Memory (LSTM) is a type of recurrent neural network (RNN) architecture designed to overcome some of the limitations of traditional RNNs in capturing and learning long-term dependencies in sequential data. LSTM networks (LSTMs) were introduced by Hochreiter and Schmidhuber (1997) (Zeroual et al., 2020).

Here are some key features of LSTM:

Memory cells: LSTMs have memory cells that can store information over long periods of time. These cells can be thought of as conveyor belts, allowing information to be added or removed selectively.

Gates: LSTMs use three gates to control the flow of information into and out of the memory cell.

Forget gate: Determines what information from the previous state should be discarded.

Input gate: Determines what new information from the current input should be stored in the memory cell.

Output gate: Determines what information from the memory cell should be output as the final prediction.

Cell state: LSTMs have a separate cell state that runs across the entire chain. This allows LSTMs to carry information over long sequences without being diluted or lost.

The equations governing the flow of information in an LSTM network are more complex than those of a standard RNN, but they allow LSTMs to address the vanishing and exploding gradient problems associated with traditional RNNs.

The ability of LSTMs to capture long-range dependencies in sequential data makes them well-suited for a variety of tasks, such as natural language processing, speech recognition and time-series prediction (Ketkar & Moolayil, 2021).

2.3.3. Gated recurrent unit (GRU) model

Gated Recurrent Unit (GRU) is another type of the recurrent neural network (RNN) architecture, introduced by Cho et al. (2014). Similar to LSTMs, GRUs are designed to address the vanishing gradient problem in traditional RNNs and capture long-term dependencies in sequential data. The GRU is considered a more simplified version of an LSTM with fewer parameters. A GRU uses the hidden layers to transfer information and calls its two gates the reset gate and the update gate (Zouaoui & Naas, 2023).

The parameters of the GRU include Wr, Wz and W_h. The reset signal r_t determines if the previous hidden state should be ignored, while the update signal z_t determines if the hidden state h_t should be updated with the new hidden state $hat(h_t)$.

$$z_t = \sigma\left(W_z \cdot [h_{t-1}, x_t]\right) + b_z$$

$$r_t = \sigma\left(W_r \cdot [h_{t-1}, x_t]\right) + b_r$$

$$\hat{h}_t = \tanh\left(W_h \cdot [r_t \cdot h_{t-1}, x_t] + b_h\right)$$

$$h_h = (1 - z_t) \cdot h_{t-1} + z_t \cdot \hat{h}_t$$

Update gate (z_t): Controls the extent to which the information from the previous time step is passed along to the current time step. It decides what information to discard from the previous state.

Reset gate (r_t): Determines how much of the past information to forget. It decides which part of the previous state is relevant for computing anew candidate state.

Candidate state ($\hat{h}_t$): Similar to the memory cell in the LSTM, it represents new information that could be added to the hidden state.

Hidden state (h_t): Represents the output of the GRU at each time step. It is a combination of the previous hidden state and the new candidate state.

2.3.4. Bidirectional LSTM (BiLSTM)

Bidirectional long short-term memory (BiLSTM) is a type of the recurrent neural network (RNN) architecture that has proven effective in various sequence-related tasks, including time series forecasting. The bidirectional aspect allows the model to consider information from both past and future time steps, which can be beneficial in capturing complex patterns and dependencies in sequential data.

The idea of the BiLSTM comes from the bidirectional RNN (Schuster & Paliwal, 1997), which processes sequence data in both forward and backward directions with two separate LSTM hidden layers. It has been proved that the bidirectional networks are substantially better than the unidirectional ones in many fields (Cui et al., 2020).

The deep-bidirectional LSTMs are an extension of the described LSTM models, in which two LSTMs are applied to the input data. In the first round, an LSTM is applied on the input sequence (i.e. forward layer). In the second round, the reverse form of the input sequence is fed into the LSTM model (i.e. backward layer). Applying the LSTM twice leads to improving learning long-term dependencies, and thus it will improve the accuracy of the model [3] (Siami-Namini & Siami Namin, 2019).

2.4. Evaluation metrics

When evaluating forecasting models, it is important to use appropriate evaluation metrics to assess their performance. The choice of metrics depends on the nature of the forecasting problem and the specific goals of the forecasting task. Table 2 presents some commonly used evaluation metrics for forecasting.

Table 2. Performance evaluation metrics

Evaluation metric	Equation
Mean Squared Error (MSE)	$MSE = \frac{1}{n}\sum_{t=1}^{n}(y_t - \hat{y}_t)^2$
Root Mean Squared Error (RMSE)	$RMSE = \sqrt{\sum_{t=1}^{n}\frac{(y_t - \hat{y}_t)^2}{n}}$
Mean Absolute Error (MAE)	$MAE = \sum_{t=1}^{n}\frac{\lvert y_t - \hat{y}_t \rvert}{n}$

Table 2 continued

Evaluation metric	Equation
Mean Absolute Percentage Error (MAPE)	$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left\lvert\frac{y_t - \hat{y}_t}{y_t}\right\rvert \cdot 100$
R-squared	$R^2 = 1S\frac{\sum_{t=1}^{n}(y_t - \hat{y}_t)^2}{\sum_{t=1}^{n}(y_t - \mu)^2}$

Source: Korstanje (2021).

3. Results and analysis

3.1. Data description

The Algerian dinar exchange rate data('DZD') from "2000-12-01" to "2020-12-31", and was collected in daily time intervals. The total number of observations amounted to 4383 ($n = 4383$). The data were obtained from www.yahoo.finance.

It shall be noted that authors have just considered historical data from the previous three years in order to remove monotonic data from the initial US/DZD years. Since 2007, the DZD/USD price has become more volatile. The Algerian dinar price time series can be observed in Figure 1, where the linear trend and non-stationarity are highlighted as the first geometrical properties.

Figure 1. USD/DZD trend from 2004 to 2020

Source: based on Yahoo-finance datasets using Python code.

Despite a more favourable international context, marked by the rise in oil prices and the resumption of national and international economic activity, which was impacted by the COVID-19 pandemic in 2020, the depreciation of the Algerian dinar in 2021 accelerated against the US dollar and the euro, reflecting mainly the evolution of the American dollar against the euro. On annual average, the Algerian dinar further depreciated in 2021 by 6.1% against the US dollar and 9.3% against the euro, compared to respective depreciations of 5.9% and 7.7% in 2020 (Bank of Algeria, 2022).

The international economic context, marked by strong uncertainties and the persistence of twin deficits which still characterise the national economy, requires the deployment of all economic policy instruments. Indeed, the exchange rate which plays a major role in restoring imbalances by acting on the balance of payments, production and prices must be aligned with its equilibrium value. The year 2021 was marked by domestic inflation increasingly higher than that recorded in partner countries. This gap, combined with the loss of value of the Algerian dinar against several currencies, brought the real effective exchange rate closer to its level of balance. However, efforts must be made on the government's side to consolidate public finances to deal with disequilibrium macroeconomics.

3.2. ARIMA Model Analysis

The autoregression integrated moving average (ARIMA) takes into consideration the assumption that the past or previous data can forecast the behaviour of present and/or future data under normal conditions. The name clearly defines the aspects of the model, which is based on autoregression, integration and a moving average. It uses lag observations to determine the difference in raw observations and calculate error. The main parameters of the ARIMA model are the lag order (P), the degree of differencing (D) and the order of the moving average (Q). Before simulating the model, a scatter plot of the dataset is used to visualise the data as shown in Figure 2. The scatter plot (lag plot) shows a positive linear correlation with some outliers and randomness. The scatter plot helps to visualise the data and to determine what type of model is suitable for the data. In this case, the scatter plot is linear, so the use of an autoregressive model will be a good choice for predictions. The Dickey-Fuller test (DFT) is used to test for stationarity of the data (Figure 3). The dataset is said to be stationary when certain statistical properties are constant and have an independent covariance. This is particularly important as most statistical analysis works best on stationary data. Also, stationary datasets are easier to model, especially in time series analysis. From the DFT test, it can be seen that the dataset is not stationary (non-stationary) by the upward

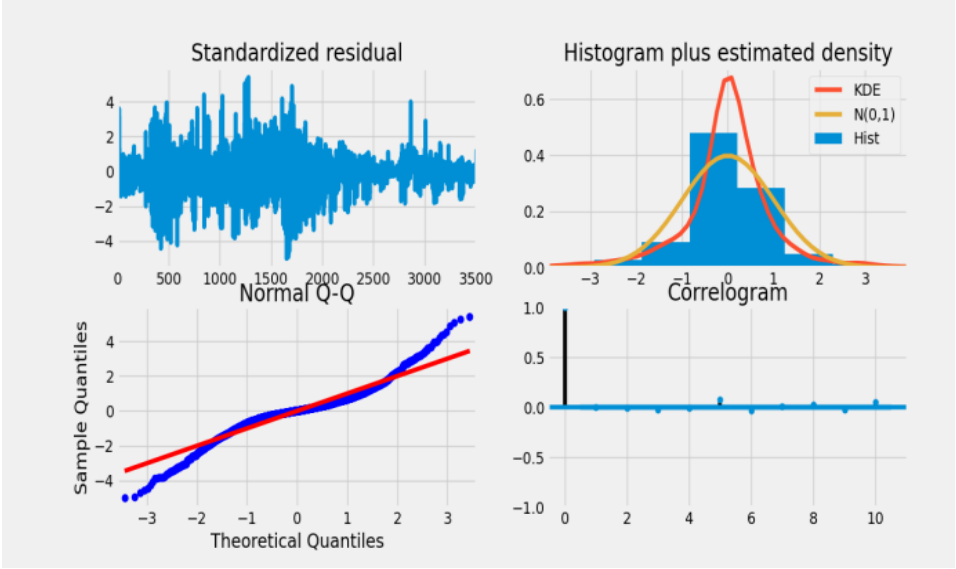

Figure 2. Auto ARIMA plot diagnostics

Source: based on Python code GitHub.

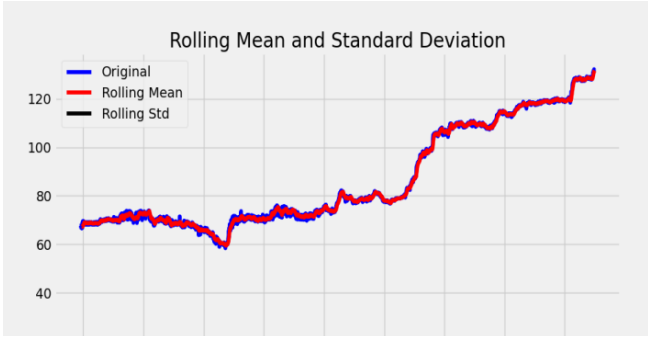

Figure 3. Dickey-Fuller test for stationarity showing upward and downward movement of rolling mean and standard deviation

Source: based on Python code GitHub.

and downward movement of the rolling mean and standard deviation as shown in Figure 3. Additionally, the static test is more than 5% of the critical value, and the p-value (0.49) is greater than 0.05. Thus, the Dickey-Fuller null hypothesis cannot be rejected. Before diving into the predictions, the dataset needs to be transformed into stationary data in order to have good results of the prediction. Non-stationary data can be converted to stationary data by applying decomposition and differencing techniques.

Decomposition is the separation of the trend and seasonality of the dataset, whereas differencing is finding the differences in the observations as shown in the code section of the ARIMA model. Once it is converted into stationary data, the auto ARIMA function is used to find the best values of p, d, and q (ARIMA hyperparameters code). The (p) parameter stands for the order of the autoregressive model, the (d) parameter stands for the order of differencing, and the (q) parameter stands for the order of the moving average. The (p) parameter uses past values in regression calculations, and the (d) parameter subtracts the previous and current values of (d). The (d) parameter is also used to convert the data from non-stationary to stationary. The (q) parameter defines the error of the model by a combination of previous errors. It determines the number of terms to be included in the model. After fitting the model, the optimal values of p, d, and q were (0, 1, 2), which can be written as Equation (3.1), where μ is the regressive parameter, $Yt-1$ the differencing, and $\theta 1$ et − 1 the moving average.

The diagnostic plots are used to visualise the auto ARIMA model. Figure 4 shows four graphs. In the top left corner, standardised residuals fluctuate around a mean of zero. The top right graph displays the density plot which shows a normal distribution. The bottom left graph represents a correlation which shows a normal liner distribution following the red line.

Finally, the bottom right graph is the ACF (correlogram) which shows that the residuals are not autocorrelated. From the diagnosis, the auto ARIMA will fit the data perfectly. An ARIMA model is then created with the optimal parameters of p, d, and q (ARIMA model evaluation). The dataset is divided into a training set (used for training the model) and a test set (used for comparing and validating the predictions), as shown in Figure 4. It shall be noted that 80% of the data is used for the training set and 20% is used for the test dataset. The mean absolute percentage error (MAPE) is used to evaluate the model. At is the actual value and Pt is the

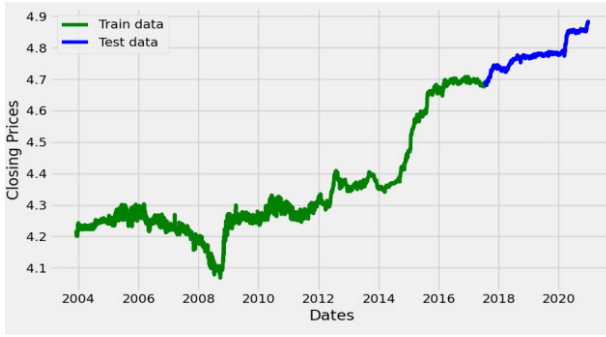

Figure 4. Training set and test dataset

Source: based on Python code GitHub.

predicted value. It is calculated by differencing the absolute of the actual value from the absolute of the predicted value divided by half the sum of the predicted and actual values. The result is summed for each fitted point (t) and divided by the number of fitted points (n). This equation evaluates the model by generating a positive and negative error while limiting the effect of outliers and bias. The prediction is done by using the predict function (which interprets the number of features it receives from the model and passes the number of features it receives to the output layer) of the future price range. The full code can be found on GitHub.

3.3. ARIMA forecasting results

To apply the ARIMA method, the time series data must be stationary. An augmented Dickey–Fuller test (ADF) is done to test whether the graph is stationary or not. Since p-value (0.588792) is > 0.5, the test has confirmed that the dataset is non-stationary. Before implementation, differencing in which seasonality and trend are eliminated to make data stationary. The original dataset and differenced dataset stationary results are presented in Figure 5 and Table 3.

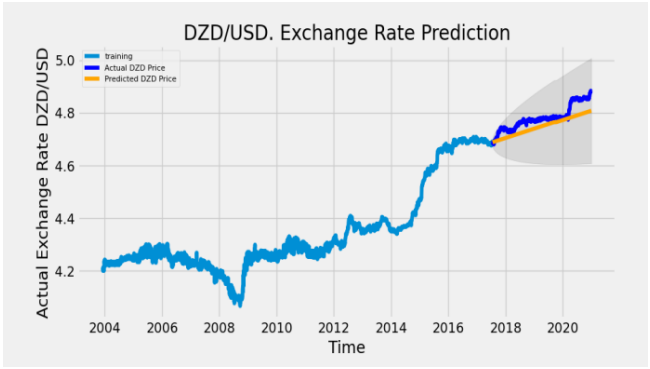

Figure 5. ARIMA (0,1,2) forecast graph

Source: based on Python code GitHub.

Our primary concern is to ensure that the residuals of our model are uncorrelated and normally distributed with zero-mean. If the seasonal ARIMA model does not satisfy these properties, it is a good indication that it can be further improved.

In this case, our model diagnostics suggest that the model residuals are normally distributed based on the following:

– In the top right plot, we see that the red KDE line follows closely the $N(0,1)$ line, where $N(0,1)$ is the standard notation for a normal distribution with a mean of

0 and standard deviation of 1. This is a good indication that the residuals are normally distributed.

- The Q-Qplot on the bottom left shows that the ordered distribution of residuals (blue dots) follows the linear trend of the samples taken from a standard normal distribution with $N(0,1)$. Again, this is a strong indication that the residuals are normally distributed.
- The residuals over time (top left plot) do not display any obvious seasonality and appear to be white noise. This is confirmed by the autocorrelation (i.e. correlogram) plot on the bottom right, which shows that the time series residuals have low correlation with lagged versions of themselves.

Those observations lead us to conclude that our model produces a satisfactory fit that could help us understand our time series data and forecast future values.

Although we have a satisfactory fit, some parameters of our seasonal ARIMA model could be changed to improve our model fit. For example, our grid search only considered a restricted set of parameter combinations, so we may find better models if we widen the grid search.

3.4. Forecasting performance of benchmark models

We train the neural network with the following hyperparameters (see Table 3):

- four hidden fully connected layers,
- each layer has 200 neurons,
- batch size of 64,
- 200 training epochs,
- 80–20 train-validation split,
- MSE as loss function.

Table 3. Hyperparameter of each model

Hyperparameter	LSTM, BiLSTM	GRU
Activation function	RELU	RELU
Loss function	MSE	MSE
Neurons	[200,200,200,200,200,1]	[200,200,200,200,200,1]
Learning rate	0.001	0.001
Optimiser	Adam	Adam

Note: Here [200, 200, 200, 200, 200, 1] represents the number of neurons from the first to the last network layer.

Source: authors based on Python code GitHub.

A special feature of a deep learning algorithm is that it can perform feature selection by itself and scale the data as required (Mathew et al., 2020). In this work, we have presented the actual versus predicted exchange rates with automatic scaled values generated by our proposed deep learning approach over time (see Appendices N:01). Table 4 presents the MSE, MAE, MAPE, RMSE and R-squared of all techniques.

Table 4. Comparison of the best model

Model	Parameters	MSE	MAE	MAPE	RMSE	R-squared
LR	test = 20% train = 80%	0.1602	0.2502	0.0090	0.3477	99.42
GRU	test = 20% train = 80%	1.3038	1.2338	0.0105	1.3906	92.27
BiLSTM	test = 20% train = 80%	3.4531	1.7924	0.0149	1.8583	87.34
LSTM	test = 20% train = 80%	6.9083	2.4146	0.0199	2.6284	74.68
ARIMA	order = (0,1,2) AIC= –27190.878	7.0445	0.0330	0.0068	0.0376	32.29

Source: authors based on Python code GitHub.

The experimental results revealed that the LR model is the best among the four methods. In terms of forecasting the performance measures, the MAPE is 0.009, MAE is 0.2502, RMSE is 0.3477 and R-squared is 0.9942, which is the lowest among the four forecasting models. Therefore, the LR model is superior to the other four models under analysis in terms of DZD/USD forecasting.

The preliminary results indicate promising outcomes, suggesting that deep learning models exhibit enhanced predictive capabilities in capturing the intricate volatility patterns inherent in foreign exchange markets. The findings contribute to the growing body of literature on the application of artificial intelligence in finance and offer insights into the potential improvements in the accuracy of volatility forecasting achievable through deep learning methodologies. As financial markets continue to evolve, embracing innovative technologies like deep learning becomes imperative for refining risk assessment and decision-making processes in the realm of foreign exchange trading.

Conclusion

In this study, we have focused on forecasting the USD/NZD exchange rate volatility during the period of the COVID-19 pandemic by proposing an ensemble of a deep learning approach and time series analysis using the ARIMA model.

We have applied other machine learning algorithms such as RNN and LR, as well as deep learning algorithms such as LSTM, GRU and BiLSTM.

Before the model was verified, we first analysed whether the data had periodicity, and the current time data were affected by past and future data. The data was then normalised and the criteria for evaluating the validity of the model were developed.

We confirmed the second hypothesis of study that DL models still performed well. We compared it with econometric existing prediction model in terms of the RMSE, MAE, MSE, MAPE and *R*-score.

The highly competitive prediction capacity of the proposed model during the COVID-19 period is beneficial for policymakers, entrepreneurs and foreign exchange brokers. Therefore, we can better understand the specific volatility in Algeria's foreign exchange rate during the COVID-19 pandemic. It is essential to analyse data such as exchange rate movements, central bank interventions and economic indicators like GDP growth and inflation, as these factors can provide insights into how the pandemic affected Algeria's currency market and the measures taken by authorities to stabilise it.

Appendices N:01

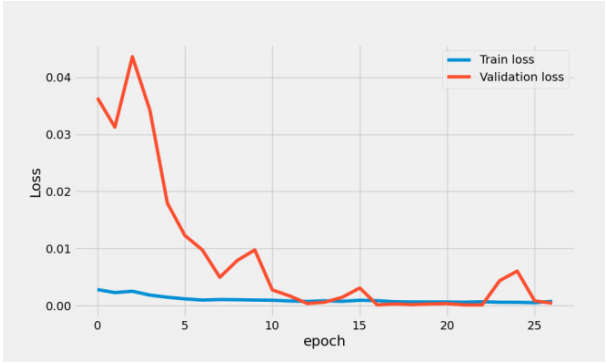

Figure 6. Train and test loss of LSTM model

Source: based on Python code GitHub.

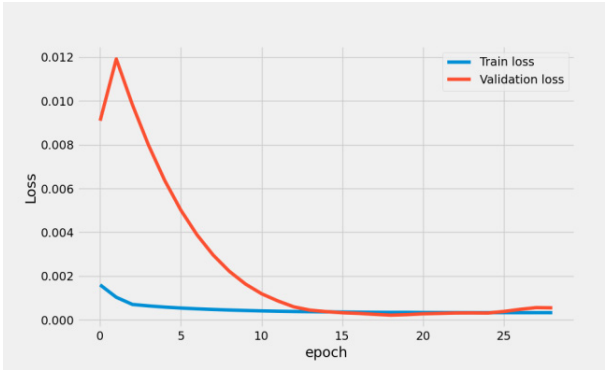

Figure 7. Train and test loss of BiLSTM model

Source: based on Python code GitHub.

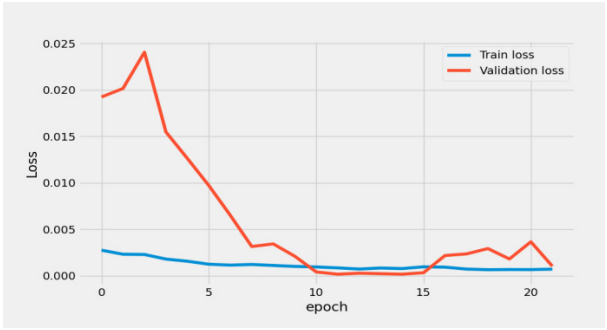

Figure 8. Train and test loss of GRU model

Source: based on Python code GitHub.

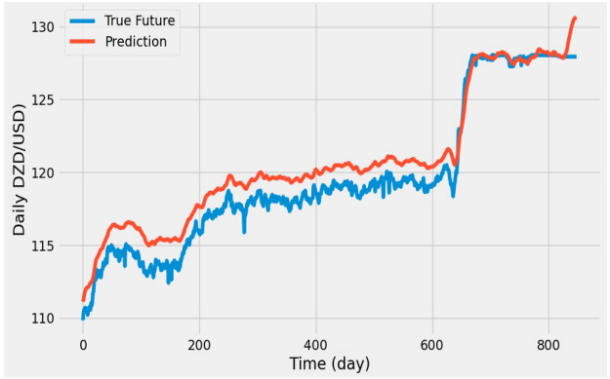

Figure 9. GRU forecast graph

Source: based on Python code GitHub.

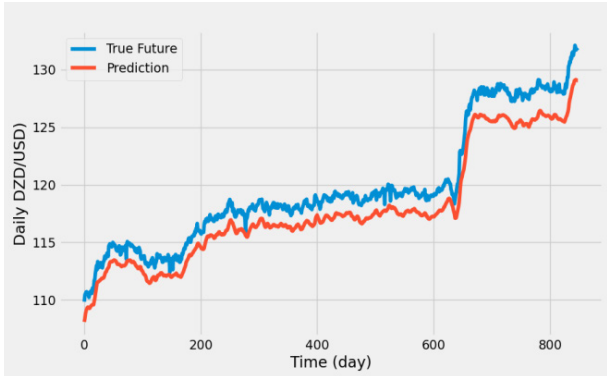

Figure 10. BiLSTM forecast graph

Source: based on Python code GitHub.

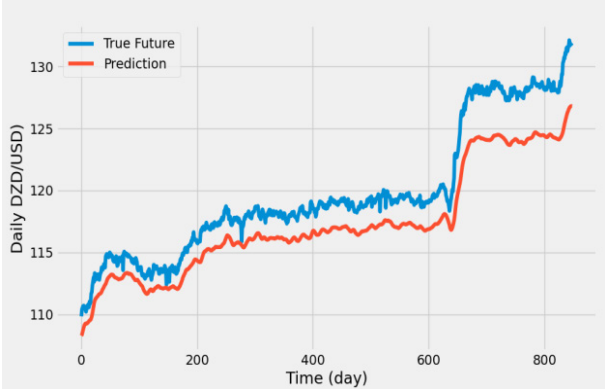

Figure 11. LSTM forecast graph

Source: based on Python code GitHub.

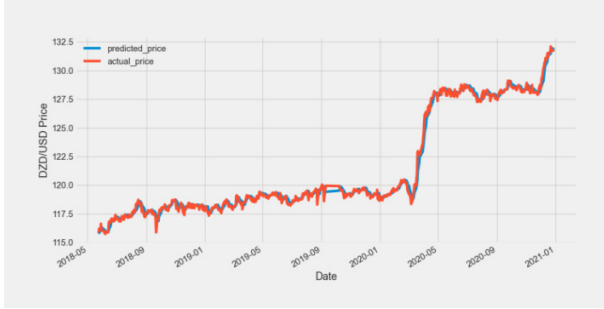

Figure 12. Linear regression forecast graph

Source: based on Python code GitHub.

Table 5. ARIMA model results

ARIMA Model Results

Dep. Variable:	D.Close	No. Observations:	3511
Model:	ARIMA(0, 1, 2)	Log Likelihood	11623.501
Method:	css-mle	S.D. of innovations	0.009
Date:	Tue, 30 Mar 2021	AIC	-23239.002
Time:	09:19:57	BIC	-23214.348
Sample:	1	HQIC	-23230.205

	coef	std err	z	P>|z|	[0.025	0.975]
const	0.0001	5.77e-05	2.356	0.018	2.29e-05	0.000
ma.L1.D.Close	-0.5234	0.017	-31.232	0.000	-0.556	-0.491
ma.L2.D.Close	-0.0895	0.016	-5.514	0.000	-0.121	-0.058

Roots

	Real	Imaginary	Modulus	Frequency
MA.1	1.5171	+0.0000j	1.5171	0.0000
MA.2	-7.3684	+0.0000j	7.3684	0.5000

Source: based on Python code GitHub.

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Institutional differences and threats to international tourists from the perspective of new institutional economics

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Abstract

The main aim of this article is to demonstrate theoretical connections in the context of institutional differences for the international tourist, which may constitute a source of threats due to institutional differences between countries. The article highlights theoretical threats stemming from institutional differences for international tourists from the perspective of new institutional economics, the research methods of which provide the analytical framework for this analysis. The post-pandemic period could transform preferences among international tourists, who are increasingly drawn to countries with significant cultural diversity. This creates dangers arising from institutional differences that may affect their sense of security and, consequently, have implications for social costs significant to the industry, as demonstrated during the COVID-19 pandemic, underscoring its crucial role in global economic development.

Keywords

- new institutional economics
- institutional system
- tourism

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Introduction

According to UNWTO (2020) data, tourism declined by 60–80% on the global scale during the COVID-19 pandemic in comparison to 2019. It resulted in a loss of 1 billion international tourist arrivals and a loss in international receipts of 1.3 trillion USD, with an estimated loss in global GDP of over 2 trillion USD. Tourism reached the level of 1990 which is 30 years ago with a total of 338 million international arrivals in 2020 (Skryl & Gregoric, 2022). COVID-19 in the tourism sector has caused tourist visits to drop drastically, closing hotels, restaurants and other tourism businesses. This has an impact on the economy of tourism activists because many tourism industries had to be closed either temporarily or permanently (Rahmah & Muliawanti, 2023). The impact of the COVID-19 pandemic on the global tourism situation is obvious, and the recovery of tourism will need a different development approach.

Currently, the tourism industry has begun to rebuild, shifting focus towards sustainable development (Sharpley, 2022). This shift has led to changes in tourist destination preferences, with an increased interest in culturally diverse locations. For example, the Middle East led the recovery by regions in relative terms, being the only region to overcome pre-pandemic levels, with arrivals 22% above 2019. Several destinations enjoyed extraordinary results, among which are Qatar (+90%) and Saudi Arabia (+56%) (UNWTO, 2024a). Furthermore, Asia and the Pacific reached 65% of the pre-pandemic levels, with a gradual recovery since the start of 2023 (Figure 1). These changes necessitate a deeper examination of institutional

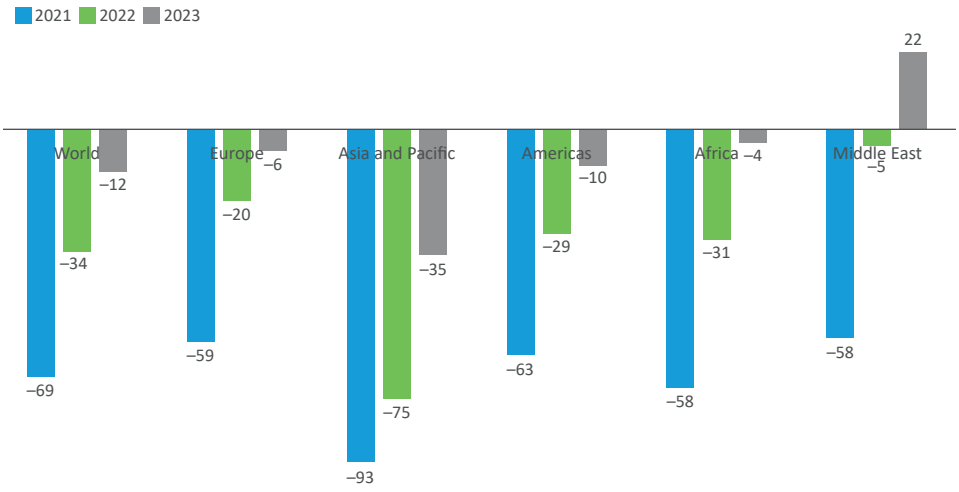

Figure 1. International tourist arrivals, world and regions (in %)

Source: (UNWTO, b.d.).

differences and their implications for international tourists. This article seeks to clarify these implications, particularly in relation to the so-called demerit goods, and the resulting social and economic costs, which include direct and indirect impacts, as well as externalities, affecting even those not engaged in these activities.

As Lin et al. (2022) indicated, the post-pandemic era has witnessed shifts in tourist preferences. In the opinion of Wanchaem et al. (2023), travel destinations have changed, and the significance of economic factors in destination countries has been reevaluated. Tourists have become more interested in factors related to cultural diversity than the level of economic development in their chosen destinations (Figure 1). These changes pose challenges to international tourism as the move from commonly favoured destinations to those with unique cultural or natural features can lead to variances in numerous facets of social and economic life, thereby creating uncertainty for tourists (UNWTO, 2024b). An example of that could be Qatar and Saudi Arabia (UNWTO, 2024a). This shift should be analytically described and supported with empirical evidence to underscore its impact on global tourism trends. The primary objective of this article is to identify theoretical institutional differences that may be of significance to international tourists. This objective corresponds to the directions for shaping the reconstruction of the tourism industry, with a focus on sustainability (in line with the principles of sustainable development) and reducing uncertainty for tourists, who may face negative consequences due to their lack of awareness of institutional differences. On the other hand, the cognitive aim of this work is to highlight the threats arising from the institutional differences for international tourists.

This article focuses on three fundamental cognitive elements: institutions, tourists and demerit goods. In the studied economic context, these cognitive elements affect the subject of the study, as illustrated by the achievement of the cognitive objective of the article.

1. Cognitive elements and research subject

Before embarking on the actual discussion, it is crucial to provide explicit definitions of cognitive elements as well as the subject of the study. This is necessary because, in the broader field of social sciences, these concepts are understood in various ways (Godłów-Legiędź, 2010).

Following the widely accepted definition by North (1990), institutions can be defined as the rules of the game within a society, along with the means of their enforcement by the overseeing authorities. Institutions are generally categorised as formal and informal (North, 1991). Formal institutions primarily include the constitution,

legal norms, property rights and regulations, whereas informal institutions encompass sanctions, taboos, customs, traditions, religion, language and codes of conduct.

A tourist, on the other hand, is an individual who stays in a specific location for at least one night for various purposes, such as leisure, sightseeing, medical treatment, religious activities, business, family visits, entertainment, shopping, and so on (Cymańska-Garbowska & Steblik-Wlaźlak, 2013). Demerit goods, in turn, refer to goods and services whose consumption is detrimental to health, has a degrading effect on individuals, or otherwise creates unwanted consequences for society while negatively impacting the consumers themselves. Common examples of goods and services that generate significant social costs include alcohol, tobacco, narcotics, gambling, prostitution, etc. Social costs encompass direct and indirect losses resulting from the consumption, production and exchange of demerit goods incurred by entities not participating in these processes (Sukiennik, 2012).

2. Justification for the article topic

The chosen topic appears to be significant from a cognitive perspective for several reasons. Firstly, in today's context, the economic dependence on tourism, including international tourism, is becoming increasingly evident. For example, estimates of tourism direct gross domestic product (TDGDP) point to USD 3.3 trillion in 2023, or 3% of global GDP, the same level as in 2019, driven by both domestic and international travel (UNWTO, 2024a). This became particularly apparent during the COVID-19 pandemic, which witnessed a sharp decline in tourism activity (OECD, 2020; UNWTO, 2024a). Consequently, the interdependence of institutions is crucial for both the business environment and the overall economic development, as appropriate institutional actions can lead to increased efficiency.

Secondly, there is a growing emphasis on individual rights and freedom of choice in various aspects of socio-economic life. This is particularly prominent in Western European economies.

Thirdly, within specific institutional frameworks such as the European Union, UNWTO (United Nations World Tourism Organization), WTO (World Trade Organization), etc., there is a push for harmonising regulations, which can increase institutional divergence both among its individual members as well as on a global scale. One example of this kind of harmonisation could be Proposal for a Regulation of the European Parliament and of the Council on data collection and sharing relating to short-term accommodation rental services (Council of the European Union, 2023). This proposal of formal act could be understood as an attempt to reduce differences in institutional constructs, including formal and informal institutions, both globally and at the country level.

It is worth noting that the same legal norms can have varying impacts depending on the degree of alignment (synchronisation) of regulations and informal institutions (North, 1990). Such a relationship was observed, for example, by Chang (2011), in the context of institutions contributing to economic growth in some countries but not in others. Other researchers also confirm this connection, suggesting that transplanting efficient institutions from one country to another may have a negative effect (Eggertsson, 2009). This phenomenon contributes to increased risks for international tourists and possible disharmony in the institutional system.

The basis for conducting this analysis concerning the relationship between institutions and threats to international tourists lies in the research methods of New Institutional Economics. Scholars in this field contend that understanding economic reality is only possible by considering the significance of the institutional environment in which a specific market operates. Economic performance is governed by institutional solutions constituting the existing order – legal, political, social, economic, etc. – that influences economic processes. It is worth noting that every society is characterised by a distinct institutional system. Therefore, our analysis aims to substantiate the claim that an effectively functioning institutional system promotes economic development, including development in international tourism, and contributes to reducing threats to international tourists.

3. The role of institutions in the institutional system

In the literature, there are various interpretations of the terms "institutions", "norms" and "rules", which are understood differently by various authors (Kingston & Caballero, 2009). Therefore, there is a need to specify some of these concepts for the purposes of this work. The most popular definition of institutions is presented by North (1990; 1991), who stated that institutions are human-made constraints that shape human actions. As a result, they construct the structure of incentives in the realm of interpersonal exchange, both political, social and economic. Institutional changes shape how societies evolve and are crucial to understanding historical transformations. Ultimately, institutions encompass not only formal and informal constraints but also the means of their enforcement.

Ostrom and Basurto (2010) represent a different perspective, which defines norms as people's beliefs about actions or their outcomes, and are not focused on short-term individual gains. Violating norms does not entail sanctions. On the other hand, rules are similar to human expectations, but their violation can result in sanctions if observed and prohibited by a supervising entity, such as a governmental agency.

An institutional system is defined as a combination of diverse formal institutions that may change within one generation and informal institutions that evolve over many generations (Williamson, 2000). This system can also be understood as a network of interrelated streams of economic activities, including consumption, production and exchange. It should be noted that each society is characterised by a distinct institutional environment. Additionally, formal and informal institutions are crucial in predicting interactions between individuals and shaping their actions. It is also worth noting that if formal and informal institutions are inconsistent, it signifies the dysfunctionality of the institutional system. However, in some areas, changing formal institutions, which leads to increased dysfunctionality within the system, may benefit its individual segments. For example, the establishment of legal regulations can lead to the development of competitive advantages in certain areas of economic activity; for instance:

– establishing legal regulations that facilitate the provision and utilisation of sexual services,
– establishing legal regulations that facilitate the production, sale and consumption of narcotics,
– establishing legal regulations that facilitate the provision and utilisation of gambling services,
– establishing legal regulations that facilitate the production, sale and consumption of alcohol.

This may be relevant from the perspective of tourism and international tourists interested in such services. However, it should be noted that the institutional system does not have a modular structure in which one module can be changed without considering how this change will affect other modules and the entire system (Leković, 2011). In other words, such activity would negatively impact the functioning of the institutional system. Therefore, frequent changes in formal institutions that may improve the functioning of the economy in a specific area are likely to lead to the dysfunctionality of the entire institutional system and, consequently, an increase in the threat to international tourists.

4. Tourism

Tourism is one of the most profitable sectors of the global economy (OECD, 2020; UNTWO, 2024). This phenomenon is characterised by immense dynamism, multiaspect nature and interdisciplinary aspects, which is why tourism is defined in various ways. Therefore, for the purposes of this article, several selected definitions of

tourism should be mentioned. For example, tourism can be seen as a set of activities of people traveling and staying outside their everyday environment for leisure and business purposes for up to one year (WTO, 1995). Kruczek (2006) represents a slightly different perspective; according to this researcher, tourism is a set of phenomena related to people's temporary and voluntary stay outside their everyday living environment. It has various consequences that result from the interaction between organisers and tourism service providers. Furthermore, modern concepts of tourism also consider the socio-economic dimension. For example, tourism can be seen as the totality of spatial mobility phenomena that result from voluntary changes in one's place of residence and personal contact with the visited environment (Przecławski, 1979): natural, cultural and socio-economic.

The tourism market is a process at the intersection of market entities such as the consumer and the seller (Stock, 2021). The object of the commercial transaction is the tourism product, sold at a specified price that determines its market value. In other words, all activities related to meeting the needs of participants in tourism constitute the subject of exchange in this market (Cymańska-Garbowska & Steblik-Wlaźlak, 2013).

In summary, tourism takes on various forms that change depending on consumer preferences and demand, defined as the tourist's readiness to purchase specific tourism goods at a specified price (Gaworecki, 2007). Due to its complex nature, tourism has a variety of classification models. One of the criteria for classifying the modern tourism movement can be the primary purpose of travel and the motive for the trip. In this division, the following types of tourism are distinguished: leisure, sightseeing, business, educational, sports, recreational, cultural, religious, pilgrimage, health, etc.

5. Institutional threats to international tourists

In this context, tourist safety can be understood as a state of being free from danger, certainty that there are no threats, a state of security and tranquillity. Safety is considered one of the highest natural goods for humans. This is reflected, among other things, in Maslow's hierarchy of human needs (1943, 1990), which places safety after physiological needs. According to the interpretation of Maslow's hierarchy proposed by Kamiński (1982), the need for protection (along with social needs, the need for love and the need for respect) is classified as deficiency needs. On the other hand, the need for self-realisation (Maslow, 1986), located at the top of the hierarchy of needs is need for development. For a person to develop, they must have the opportunity to satisfy deficiency needs,

including the need for safety. It should be noted that Maslow pointed out that only continuous and persistent deprivation of the opportunity to meet lower-level needs affects the motivation to fulfil higher-level needs. Considering that tourist trips serve various functions, including personal development and not just consumerism (MacCannell, 2002), repeated insecurity during tourist trips will lead to the atrophy of the need for self-realisation and diminish the usefulness of the trips.

Moving on to the practical form of individual and collective safety in international tourism, it is expressed in various threats to one's health, life and property. The level of safety is also a result of the development of a given country or tourist region. This safety can be considered as natural, political, religious and health-related. Similar conclusions can be drawn from the interpretation of the data presented by UNTWO (b.d.) (Figure 2).

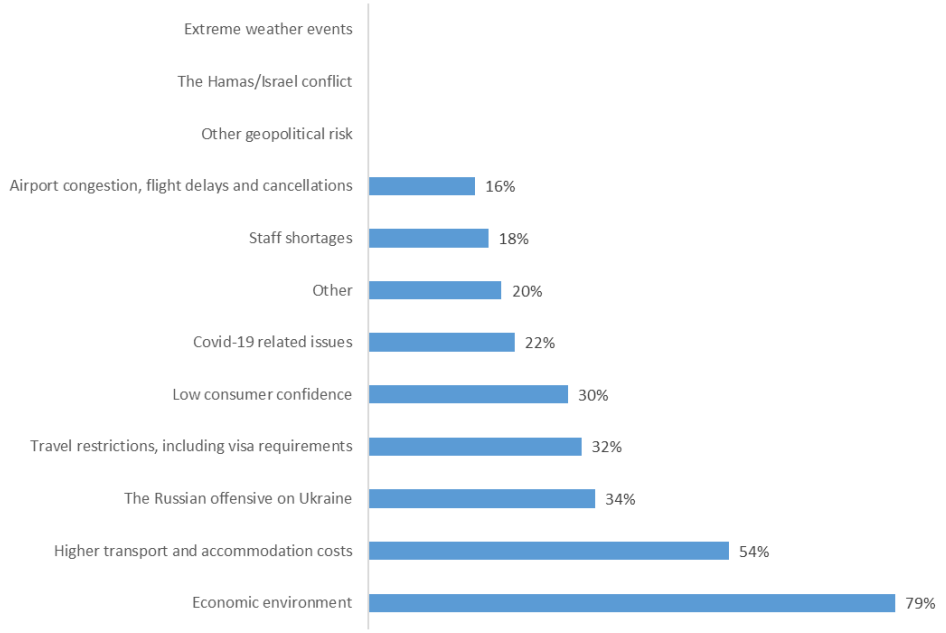

Figure 2. Main factors affecting the recovery of international tourism (January 2023 survey)

Source: (UNWTO, b.d.).

Above all, it is safety of tourists' health and life, followed by threats to their property. This variable (safety) is one of the most important criteria for choosing a travel destination and an element of the triad: attractiveness – safety – cost. Safety is, therefore, a state assessed from the point of view of foreseeable threats to human beings. Within the general concept of tourist safety, various threats can

be distinguished, such as (Bernaś & Pujer, 2014): natural, political, terrorist, religious; economic, social, criminal, disease-related, as well as physical harm, etc.

It appears that institutional threats, which can be understood as:

- institutional differences within formal institutions between the tourist's home country and the destination country,
- institutional differences within informal institutions between the tourist's home country and the destination country,
- institutional differences within formal and informal institutions in the destination country, etc.,
- can also be added to the category of international tourist dangers.

In this context, shaping legal regulations can lead to the establishment of competitive advantages or incentives in the area of choosing international travel destinations among tourists. It should be noted that the phenomenon of international tourism can be explained, among other things, by the fact that tourists are attracted to countries that offer some of the following: specific climate, natural conditions, unique cultural products, better medical care, supply of various goods that are lacking in the tourist's home country or are illegal there, supply of services that are lacking in the tourist's home country or are illegal there, etc.

An example of such actions can be the establishment of appropriate legal regulations in individual countries related to markets of demerit goods, which can lead to the flourishing of such phenomena as drug and/or alcohol tourism, tourism focused on gambling, sex tourism, etc. For example, trips known as drug tourism began in the 1960s by North American and Western European hippies searching for narcotic experiences in regions abundant with the desired substances (Hoffmann, 2014). Amsterdam gained the reputation of being the drug capital of the hippie generation, famous for its liberal drug policy, where people from all over the world flocked to experiment with marijuana, LSD and other psychoactive substances available in the Netherlands (Motyka, 2016). The drug itself would present a significant role as a motivation for travelling. Drug tourism could be seen as the journeys undertaken with the purpose of obtaining or using drugs, which are not available or are illegal in the tourists' origin places. As mentioned above, one of the most popular examples of drug tourism is cannabis tourism in Amsterdam, Netherlands (derived from literature searches and questionnaires in field research). Within the drug tourism, perhaps the most famous case is related to the Dutch coffee shops. According to Pereira and Paula (2016), 4.5 million tourists spending a night on the town and 26% of it visit at least one coffee shop and 10%.

It can be assumed, therefore, that institutions play a fundamental role in economic development and deriving benefits from it, even in areas that may raise normative doubts. In this context, an increase in danger, for example, related to the operation of the market for sexual services, the market for illegal drugs, etc.,

can be a stimulus for tourism. This means that specific formal solutions can be an incentive to travel to selected regions and contribute to an increase in the number of tourists. Nevertheless, the growth in this type of tourism has limited potential. Additionally, a significant institutional gap between countries or frequent changes in formal institutions in a given country may decrease tourism attractiveness for a particular region.

This implies that the level of danger will increase, which is one of the determinants of tourist movement in a given area. An increase in the level of threat will result in a decrease in tourist arrivals in the long run. In other words, the danger will act as a deterrent, leading to tourists avoiding dangerous destinations for various reasons (Stasiak & Śledzińska, 2017).

Conclusion

An important aspect for economies and international tourists is the functioning of states and markets, where entities, often pursuing their individual goals, need to pay attention to common interests. However, there is an increasing incentive for socially responsible action (Whittaker, 2011). Recognising the lack of spatial homogeneity is essential in understanding institutional differences in international tourism. This emphasis on spatial homogeneity aligns with findings in the literature (Canestrino et al, 2015) which examines the geographical and geopolitical context in tourism development. This is evident in guidelines based on sustainable development, which have been recognised as crucial for reconstructing the tourism industry after the COVID-19 pandemic in the UE (OECD, 2020). Hence, it is necessary to consciously shape institutions from a long-term perspective to contribute to the balance between economic growth, security and human health (Kuosmanen & Kuosmanen, 2009). From an economic perspective, this will have an impact on social costs. Specific forms of regulation are introduced in response to their emergence, both for individual countries and regions as well as institutional alliances, such as the European Union. The introduced regulations (mainly formal institutions) lead to changes in social costs, which creates a recurrence between the need to introduce new institutional solutions and the impetus to modify them. Regulations introduced in the area examined in this article involve such aspect as cognitive elements, namely institutions themselves, tourists and demerit goods.

Due to the fact that we currently live in a dynamically changing world, the likelihood of its destabilisation and unpredictability is gradually increasing. The world is full of various conflicts and tensions, and changes in the institutional nature are common, and sometimes even highly dynamic. All of these create conditions

for a decrease in individual and collective security, to some extent mitigated by institutional solutions. The period of the COVID-19 pandemic and the Ukrainian-Russian conflict demonstrate a particular need to pay attention to the possibilities of reducing the level of danger through the institutional system. It should be noted that the institutional system needs to be modular. Therefore, in the process of designing legal regulations – by the government, citizens or other individuals with legislative initiative – it is necessary to assess how a given change will affect not only individual parts of the institutional system but also the entire system.

To sum up, safety in tourism is a multidimensional problem that can and should be analysed on numerous fronts by specialists from various fields. Safety and threats in tourism are undoubtedly highly interesting for research, and reliable knowledge about them is advantageous for practical activities. This knowledge is sought after by the tourism industry, which must operate in an increasingly unstable socioeconomic reality.

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Application of a single-equation SARIMA model for short-term conditional forecast (projection) of CPI price dynamics in Poland

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Abstract

The aim of the article is to construct an optimal SARIMA model for short-term conditional forecasting (projection) of price dynamics expressed by the Consumer Price Index (CPI), as understood within the extended Box-Jenkins procedure. The construction of such a forecast aims to influence, through the expectations channel, the institutional trust of society in monetary authorities and assess the effectiveness of achieving the monetary policy goal within the framework of the democratic responsibility of the decision-making body of the National Bank of Poland – the Monetary Policy Council. The selection of the optimal SARIMA model was carried out using an iterative method within the Box-Jenkins procedure, with the goal of reducing the systematic bias of estimators – coherence with empirical data. The analysis was conducted on compiled secondary data of the monthly Consumer Price Index for goods and services from Statistics Poland (formerly: Central Statistical Office) for the years 2010-2023 (on a monthly basis). Results show that the short-term forecast demonstrated accuracy within a specified confidence interval. The application of the SARIMA model serves as a useful methodological tool for constructing elaborate DSGE models (for example, the NECMOD model) using procedures such as SEM (System for Averaging Models) from Norges Bank.

Keywords

- SARIMA
- forecasting
- CPI
- inflation targeting strategy
- monetary policy

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Introduction

The demand for the application of analytical tools through a quantitative description of price formation processes in the economy of a given country was indicated in the 20th century by the creator of the term "econometrics" – Paweł Ciompa (Gruszczyński, 2022). He was the author of a series of publications, including "Drożyzna w Galicyi i nędza urzędnicza", in which he identified the inflationary imbalance caused by the accelerated pace of relative price growth, exceeding the wage adjustments of workers in branches producing lower-order goods in the then-eastern part of the Austrian partition. The colloquial term "inflation" (of prices), as the increasing rate of change in absolute prices present in contemporary political economy discourse, is nothing more than the loss of purchasing power of a unit of wages at the current level of nominal production.

The genesis of inflationary imbalance in Poland, indicated by the Consumer Price Index (CPI) exceeding the upper limit of permissible deviation from the reference value, occurred in April 2021 when the relative value of CPI year-on-year reached 4.3%. The first instance of not achieving the overarching goal of monetary policy above the established nominal anchor with a symmetrical deviation range, since September 2012, took place in January 2020, with the relative value of the CPI year-on-year at 4.3%. However, the actual failure to meet the monetary policy target occurred during the period of deflationary trends from November 2018 to February 2019. The period of inflationary imbalance from January to March 2020 was mainly a result of government triangular intervention through the increase in the minimum wage to PLN 2,600 by the Regulation of the Council of Ministers of 2019. According to reports from Statistics Poland (formerly: Central Statistical Office) (GUS, 2021), this period also witnessed price adjustments in the sectors of food and non-alcoholic beverages (a decrease of –24.89% compared to January of the previous year) and housing and household operation (similarly – 19.17%). Although the Annual Report of the National Bank of Poland for 2020 (NBP, 2021) unequivocally attributed the increasing pace of CPI (year-on-year) to the negative supply shock, for which monetary policy had no direct reaction channel, there was also a clear upward trend in core inflation in 2020. The economic contraction period due to the COVID-19 pandemic led to a significant drop in energy and commodity prices, along with the appreciation of the nominal exchange rate of the Polish złoty against major trading partners from March 2020. In April 2021, the estimate from Statistics Poland showed a deviation from the reference value of the overarching monetary policy target – CPI inflation (year-on-year) at 4.3%, following a year of price stability (direct achievement of the inflation target with a symmetrical deviation range). The stimulating factor for inflationary adjustment

was the upward trend in commodity prices, particularly oil, as emphasised in the NBP's annual report. According to the report by Statistics Poland, the trade balance in 2021 was negative, amounting to approximately PLN 7 billion (GUS, 2022). This trade balance passivation also affected the worsening terms of trade and the average monthly real exchange rate of USD/PLN by approximately 8.02% compared to December of the previous year. In 2022, due to the armed aggression of the Russian Federation against Ukraine, commodity markets (especially futures contracts) experienced further price increases for oil (Brent and WTI) and gas, further amplifying the price adjustments resulting from the deepening passivation of the trade balance (in 2022, a negative trade balance was recorded at PLN 92.5 billion). Currently, the period of inflationary imbalance in Poland is driven by the accommodating fiscal policy, empirically verified by the estimates of the National Bank of Poland regarding core inflation, which indicated a continuously growing price dynamics from June 2021 (3.5% compared to the previous year) to March 2023 (12.3%). Empirical data clearly point to the significant impact of bottlenecks as a leading variable stimulating the pace of price changes in the Polish economy. It is essential to note that since December 2021, the National Bank of Poland has initiated a deflationary policy by reducing excess liquidity from the banking sector through the application of liquidity-absorbing fine-tuning open market operations. In addition to direct quantitative tightening through absorbing fine-tuning operations in December 2021, aimed at unifying the POLONIA rate to the level of the NBP reference rate, there was a series of increases in the basic interest rates (NBP, 2023) from October 2021 (keeping the deposit rate of basic open market operations unchanged at 0% until November 2021, when the volatility range of market interest rates was raised by 75 basis points) to September 2023. However, the cycle of raising the basic interest rates proved to be ineffective in the deflationary policy due to the disparity in the conducted "policy mix" in Poland. The income effect surplus, resulting from fiscal impulses in Poland and triangular intervention in the form of minimum wage regulations, over the NBP's "austerity" policy, although effective countercyclically (GUS, 2023a) (with a year-on-year real GDP growth of 6.9% in 2021 and 5.1% in 2022), was a leading stimulant of inflationary imbalance. The above observation of discretionary "policy mix" in Poland allows for the identification of the impact of fiscal impulses on real and nominal parameters with a shorter external lag compared to monetary policy, positively verifying the principle of the primacy of fiscal policy.

As a result of the national referendum on Poland's accession to the European Union on June 7–8, 2003, and the subsequent signing of the accession treaty (Athens Treaty) on May 1, 2004, Poland committed itself to adopting the principles of the Economic and Monetary Union (EMU), which is a formal structure within the concept of integration of member states under the Maastricht Treaty (Treaty on European Union signed on February 7, 1992). The formal commitment

arising from the status of a member state of the European Union involves joining the Economic and Monetary Union, fulfilling one of the nominal convergence criteria established under Article 140(1) of the Treaty on the Functioning of the European Union. A member state maintaining derogation status in the process of currency integration within the EMU structure is subject to a report prepared by the European Commission and the European Central Bank every two years or upon the request of a member state under derogation status, assessing the progress of the nominal convergence procedure for that specific country. According to the Convergence Report for 2022 (European Commission, 2022), the reference value for the most stable dynamics of prices measured by the Harmonised Index of Consumer Prices (HICP), according to Eurostat methodology, was set at 4.9% (with an allowable symmetrical deviation range of 1.5 percentage points according to Protocol No. 13 on Convergence Criteria). The indicator of the pace of absolute price changes HICP (12-month average HICP) for the basket of goods in Poland reached 7% in April 2022, according to Eurostat estimates, which does not meet the nominal convergence criterion set out in the Treaty on the Functioning of the European Union. The baseline dynamics of absolute prices, excluding the impact of price adjustments due to bottlenecks, showed a value of 5.3%. Among the main factors stimulating the pace of price changes were the service sector (change – 7.6%) and energy (change – 18.2%). It is important to emphasise that in April of the following year, HICP for Poland reached the value of 15.2%.

The aim of the work is to develop an optimal adaptive SARIMA model using the extended Box-Jenkins method (Box & Jenkins, 1983) with a seasonal component, an explanatory model's indicator (Kashpruk, 2021), and an assessment of the ex post prediction accuracy (Romanuke, 2022). The extended procedure is intended to apply the optimal SARIMA model for a reliable analysis and accurate conditional forecasting (projection) of the Consumer Price Index (CPI) year-on-year dynamics for the Polish economy.

The extended procedure for constructing and estimating the SARIMA model was conducted using data from Statistics Poland (GUS, 2023b) on the change in the year-on-year rate of absolute price changes – "inflation" CPI (y/y) from 2010 to 2023 on a monthly basis. The obtained secondary data show a sample of 223 observations for the examined time series. Estimates for the conducted verification tests and generated visualisations of the estimation were carried out in the Rstudio environment.

1. Literature review

The Inflation Targeting strategy is a multiparametric approach in which central banks use a reaction function through available monetary policy instruments (both standard and unconventional) to implement a monetary strategy with discretionary decisions regarding the scale and time frame (which determines the degree of flexibility in implementing the DIT strategy) of monetary policy target achievement. The multiparametric strategy is informationally inclusive, taking into account a broader set of parameters influencing the change in the price level. This strategy involves the analytical identification by monetary authorities and their expert bodies, such as the decision-making body (in Poland, the Monetary Policy Council), and analytical departments, of variables that determine deviations from the established equilibrium point of the nominal anchor. Although the implementation of the Direct Inflation Targeting strategy is multiparametric, the National Bank of Poland (the declaration of the monetary strategy was made in October 1997. Formal introduction of the inflation target took place in February 1998 by the newly established decision-making body – the Monetary Policy Council), concluding the period of systemic and banking system transformation from a monobank to relative independence of the banking sector in a universal model from the central bank, pursued the classical triad of monetary policy goals, with the final goal being the reference value of CPI (y/y) inflation dynamics (Pietryka, 2008). Since 2004, at the request of the Monetary Policy Council composition, the National Bank of Poland has been implementing the Direct Inflation Target with a reference value of 2.5% and a symmetric deviation range of 1 percentage point, gradually reducing the reference value from 8% in 1999. A significant change in the technical approach to achieving the target criterion in 2004 was the establishment of the reference value of price dynamics as a continuous value, rather than an annual one. Since then, the National Bank of Poland has adopted the monthly CPI relative to the previous year (y/y) as the nominal anchor, whereas previously, it was the annual average value adopted as the value in December relative to the previous year. The reduction of the reference value of the nominal anchor by the NBP decision-making body aimed to maintain coherence with the conducted disinflationary policy after the period of systemic transformation. The Monetary Policy Council, identifying the process of spillover effects as the diffusion of institutional and economic integration with foreign countries, not only expanded the framework of discretionary monetary policy but also recognised the impact of supply shocks on price dynamics. Accordingly, it decided to raise the reference value of the final target again in 2001. However, in 2000, anticipating the impact of bottlenecks on price adjustments and recognising the accommodative fiscal policy, it decided to lower the reference value. The National Bank of Poland, committing to achieving

the established target criterion, is subject to the assessment of society through institutional trust and democratic responsibility. This responsibility determines the degree of societal trust in the central bank through the evaluation of the achievement of the overarching goal of monetary policy. Furthermore, in the case of the National Bank of Poland, democratic responsibility lies with the decision-making body – the Monetary Policy Council and the President of the National Bank of Poland, indicating a collegial model of central banking in Poland. In the case of the National Bank of Poland, the implementation of the DIT strategy over time is flexible, as monetary authorities declare the reaction function over the medium-term horizon (Ancyparowicz, 2017).

The strategy of direct inflation targeting as a goal criterion of monetary policy, along with the reference value determining the target function, was first introduced by the Reserve Bank of New Zealand in 1990 (Gatnar, 2018) and the Central Bank of Chile (Mishkin & Schmidt-Hebbel, 2002), although it is officially accepted that Chile adopted the DIT strategy in 1999 (Banco Central de Chile, 2007). In subsequent years, central banks adopted DIT strategies with a symmetric deviation range or a deviation range, a point-target DIT strategy (a point determined by a constant reference value of inflation dynamics), as in the case of the Bank of England in 1992 (2%), or an asymmetric deviation range from the reference value, as in the case of the European Central Bank (2% and below). As indicated in Figure 1, selected central banks only introduced the Direct Inflation Targeting

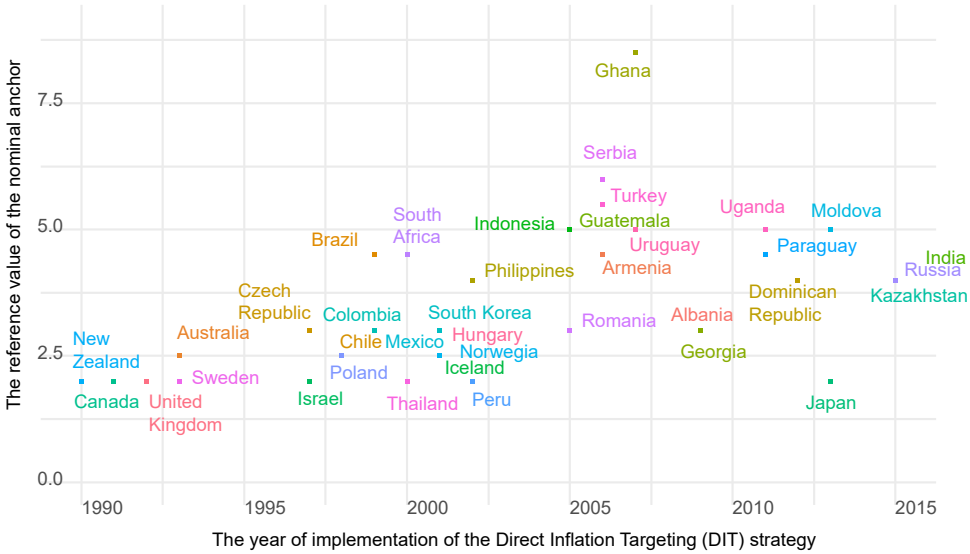

Figure 1. Decisions to adopt the inflation targeting strategy by selected central banks in the years 1990–2015

Source: own compilation based on data from (Roger, 2010; Hammond, 2011; Ciżkowicz-Pękała et al., 2019).

strategy as a goal criterion and the target function of monetary policy in 2015, including Russia, Kazakhstan and India.

Central banks, using analytical estimates and projection construction tools, influence the credibility and effectiveness of their monetary policy strategy through the expectations channel. The implementation of a monetary strategy, conditioned on achieving the stabilisation requirement of a chosen target value (conditioned by the goal criterion) as the nominal anchor of its reference level, belongs to the set of components (accountability) of the central bank's democratic responsibility (Matysek-Jędrych, 2014). This democratic responsibility does not only take into account qualitative aspects of the institutional image and societal trust in the central bank but also undergoes societal assessment through the execution of a monetary strategy conditioned by a specific measurable value – the policy target criterion. Communication with society in a collegial model of monetary policy occurs through the procedure of voting on the proposed value established as the target criterion of the monetary strategy. This is a communication channel conditioned by the transparency component. The qualitative aspect of societal trust, credibility, is a component that conditions the feedback loop with the independence aspect of the monetary policy decision-making body and determines (reduces or amplifies) the alternative cost of monetary authorities' reaction function to the chosen target criterion on other parameters. The alternative cost of the monetary strategy relative to the chosen nominal anchor (Rule of Thumb) was formulated by the Federal Reserve (Federal Reserve Board, 1996) to describe the difference in identifying responses to monetary impulses (quantitative tightening) within the framework of conducted disinflationary policies between the vector autoregression VAR model and the full macroeconometric DSGE model of the Federal Reserve – FRB/US. The construction of forecasts for selected macroeconomic parameters can be divided into two types: conditional forecast (projection) and unconditional forecast. Both forecast variants differ in the methodological approach regarding the identification condition in the monetary authorities' reaction function model (unconditional forecast). For example, identifying the change in the current (monetary) interest rate endogenously shaped by expectations of economic agents (liquidity preference) is an approach of the conditional forecast variant, which does not assume values such as the relative change in the CPI price growth rate in the analysed period (or periods) subject to projection. Sławiński (2011) defines the conditional forecast variant of the direct inflation targeting strategy as "a forecast assuming no changes in interest rates in the forecast horizon". Of course, "change in interest rates" is understood as a change in the central bank's reference rates. As emphasised by Misztal (2023), the most commonly used and simplest method of measuring credibility is the difference between the model's expected value (or inflation expectations) and the actual CPI inflation rate.

The measure of the absolute price change rate based on the basket of goods and services within the analysed "inflation basket" is not uniform across public institutions responsible for collecting and processing data in various countries for the purpose of societal statistical analysis and public institutions. Inflation rate indices take into account not only the change in price expressed in monetary units, which is a liquid medium retaining the function of a universal means of payment (whose condition of elementary primary exchange value is institutional trust) and a record-keeping function (the ability to scale and express in monetary units the objective utility value of a good or service – the supply price), but also changes in the supply of goods and services offered in economic transactions. The Consumer Price Index (CPI) estimated in Poland for the inflation basket by Statistics Poland follows a methodology similar to Eurostat (2018) for the Harmonised Index of Consumer Prices (HICP), based on the formula of the aggregated Laspeyres price index. The formula of the aggregated Laspeyres price index is based on the change in the price level in the current period, *t*, compared to the base period, *t*–1, which methodologically differs from the aggregated Fisher price index used by the US Bureau of Labour Statistics (BLS), which synthesises the methodologies of both Laspeyres and Paasche – as the root of the products of both indices. The generalised Fisher index is adjusted by a parameter that is the exponent, α, for the chosen index. Where the parameter $\alpha = 0.5$ is the classical Fisher index (Białek, 2014). The Laspeyres index is an indicator that measures the change in the price level, as the periodic difference concerns the component of price change. In the case of the Paasche index, the measure is of the change in the value of the consumer basket of goods and services. Therefore, the Laspeyres index is resistant to changes in the volume of the supply of goods and services in the market. The Laspeyres index takes the following form:

$$I_L = \frac{\sum_{i=1}^{N} p_i^t q_i^s}{\sum_{i=1}^{N} p_i^s q_i^s}$$

where:

$p_i^t = \left\{ p_1^t, p_2^t, \ldots, p_N^t \right\}$ – price vector for the current period t,

$q_i^t = \left\{ q_1^t, q_2^t, \ldots, q_N^t \right\}$ – quantity vector for the current period t,

$p_i^s = \left\{ p_1^s, p_2^s, \ldots, p_N^s \right\}$ – price vector for the current period s,

$q_i^s = \left\{ q_1^s, q_2^s, \ldots, q_N^s \right\}$ – quantity vector for the current period s.

The measure of the CPI indicator in Poland is adjusted by a weighting system (see Table 1) (Hałka & Leszczyńska, 2011), which assigns certain weights to specific goods and services. These weights are estimated based on the shares of indivi-

dual goods and services in overall consumer expenditures in the previous period. However, the CPI index does not remain an ideal (unbiased) indicator that would account for the change in relative prices resulting from the diffusion of their level through the impact of specific impulses (including the transmission of monetary flows) within the first-round effect. The "diffusion of price levels" (Keynes, 1930) distorts the weighting system for calculating the marginal utility of specific goods and services, consequently reducing the resistance of the CPI index to price changes in branches of production of heterogeneous goods (due to consumer preference effects) that include a percentage markup on unit costs, as indicated by the Ramsey rule (Raa, 2009).

Table 1. The weighting system used in estimating the CPI index by Statistics Poland in Poland

Respective	2019	2020	2021	2022	2023
Food and non-alcoholic beverages	24.89	25.24	27.77	26.59	27.01
Alcoholic beverages and tobacco products	6.37	6.25	6.91	6.32	5.75
Clothing and footwear	4.94	4.94	4.21	4.47	4.27
Housing and utility costs	19.17	18.44	19.14	19.33	19.63
Household furnishings and appliances	5.70	5.80	5.83	5.71	5.29
Healthcare	5.12	5.29	5.39	5.69	5.71
Transportation	10.34	9.89	8.88	9.54	9.92
Communication	4.18	4.54	5.00	4.90	4.48
Recreation and culture	6.44	6.62	5.78	6.07	6.14
Education	1.07	1.15	1.02	1.16	1.21
Restaurants and hotels	6.20	6.12	4.56	4.77	5.11
Other goods and services	5.58	5.72	5.51	5.45	5.48

Source: own elaboration based on GUS data.

White (1999) points out the main sources of measurement bias in the relative value change rate of the CPI index based on the Laspeyres index:

1. Systematic measurement bias: Measurement bias arising from the adopted measurement methodology pertains to the data aggregation stage and the procedure of averaging the prices of goods and services at various points of sale (especially at the lowest level of aggregation).
2. Measurement bias resulting from the substitution effect in the production branches of homogeneous goods.
3. Measurement bias resulting from changes in the qualitative characteristics of individual goods and services.

4. Measurement bias resulting from the introduction of new goods and services to the market.
5. Measurement bias from the substitution of markets: Measurement bias arising from new sources of acquiring goods and services and discrepancies in the prices of individual goods.

The measurement bias of the CPI index corrected for the weighting system of the Laspeyres index for individual goods is the result of the aforementioned delays in the time horizon relative to the imposed weights as a surrogate for the marginal utility of the consumer concerning individual goods and services in the inflation basket. Therefore, the Laspeyres index aims to approximate the real utility of individual goods and services expressed by the Cost of Living Index (COLI).

In the analysis dedicated to the CPI index bias for Poland in the scientific work of Hałka and Leszczyńska (2011), it is essential to identify the underestimation of the CPI index using the Laspeyres index method, mainly due to the lack of adjustment of the index for the substitution effect, the operation of the "plutocratic gap" and, as the authors point out, the impact of demand rigidity in branches producing heterogeneous goods (which empirically verifies the susceptibility of the index to the degree of monopolisation in specific branches of production of autonomous consumption goods).

The single-equation linear ARIMA (AutoRegressive Integrated Moving Average) model, which directly originates from the work "Time Series Analysis: Forecasting and Control" by G. E. P. Box and G. M. Jenkins, is, according to the typology of macroeconometric model classification (Hara et al., 2009), a time series model. However, the specificity of the model distinguishes its structure from other models, as the construction stage of the model is based on the empirical identification and optimisation of the model (as a linear combination of parameters of autoregressive and moving average processes under specified assumptions regarding the integration process) based on a time series of a particular macroeconomic variable. In contrast to multivariate models, whose construction is based on the selection of estimated parameter matrices, single-equation ARIMA models do not require empirical reduction of identification bias in the model or diagnosis of causality between selected structural parameters of the models. ARIMA models, focusing on the empirical identification of the time series of a selected variable, serve as analytical tools for conditional forecasting, where the processes shaping events not captured by the model are endogenous within the system and integrated with the studied variable, which itself is integrated with the information flowing from the system. Although ARIMA models do not identify the direct impact of changes in exogenous factors (such as structural shocks caused by "policy mix" impulses or supply shocks) and represent an example of an analytical tool for conditional forecasting, as emphasised by Yusifov (2014), ARIMA models, whose construc-

tion is based on the stochastic properties of the studied variable, are resistant to Lucas Critique. The extension of ARIMA models to nonlinear identification of the stochastic process of conditional variance through the synthesis of a GARCH-class model – ARIMA-GARCH (Zhou et al., 2006) allows for more accurate forecasting of a selected parameter and risk mitigation, addressing the systematic error burden of linear combination models in the ARIMA class. An analytical tool, especially recommended by Eurostat (2009), for comprehensive estimation of an optimal SARIMA model (seasonal adjustment) is TRAMO-SEATS (Time Series Regression with ARIMA noise, Missing values and Outliers & Signal Extraction in ARIMA Time Series). The TRAMO-SEATS method synthesises two methodologies for the optimal estimation procedure of the SARIMA model:

- estimation of the ARIMA model with the identification of outliers, missing data correction (observations) and leverage value correction (e.g. to adjust the stochastic process for reducing impulses resulting from calendar effects) – TRAMO procedure (Time series Regression with ARIMA noise, Missing values and Outliers),
- decomposition of the linearised time series[2] through the identification of the harmonic structure (spectral analysis of the spectral density function of the time series) of components (orthogonal to each other) of the time series; systematic component (trend), seasonal component and irregular component.

Statistics Poland currently predominantly utilises the TRAMO-SEATS procedure within the JDEMETRA+ package for seasonal adjustment of time series in quarterly and monthly sequences, including average employment, average monthly earnings and the Labour Force Survey (quarterly).

Time series models, including ARIMA models, though they serve as reliable methodological tools for identifying quantitative relationships and understanding the impact of time on the development of selected parameters with reduced systematic error (through optimisation procedures and diagnostic indicators), are sensitive to the replicability of studies and the forecasting horizon. This sensitivity is mainly due to the influence of exogenous factors such as “policy mix” or “black swan” events, where extrapolation is sensitive to shocks. This constitutes a dimension to be considered in the macroeconomic time series modelling within the framework of Lucas Critique. The analytical foundation of the decision-making body of Norges Bank utilises a system of averaging SAM models through the optimisation procedure of the DSGE model – NEMO (Norwegian Economy Model). This

[2] As indicated by such authors as Grudkowska and Paśnicka (2007), a time series, before undergoing the SEATS procedure, undergoes linearisation. In this process, the time series in its original form is logarithmised and then decomposed into the sum of a seasonal component and a non-seasonal component.

involves constructing the probability density distribution of estimated outcomes of short-term conditional forecast models. There are 172 models for short-term projections of "core inflation" (CPI-ATE) and 221 for the conditional GDP forecast (Gerdrup & Nicolaisen, 2011). In this way, before constructing the DSGE – NEMO model, which maintains strong coherence with the New Neoclassical Synthesis theory[3], Norges Bank builds short-term forecasts that are subject to the SAM model averaging system. This process involves identifying exogenous assumptions and a heuristic technique that makes assessment and verification through the expertise of Norges Bank. The NEMO model of Norges Bank is a macroeconometric model using empirical data on a quarterly basis. Short-term forecasts (projections) based on such models as vector autoregression (161 models), indicator-based (5 models) and factor-based (5 models) provide forecasts for a horizon of up to 5 observations (5 quarters). The NEMO model constructs a conditional forecast for 8 to 12 quarters, considering supply blocks (Kravik & Mimir, 2019) and exogenous factors, including government (impact of fiscal impulses and triangular interventions), energy market (oil), foreign trade block, as well as the banking sector block.

Alan Greenspan (2008), the former chairman of the Federal Reserve from 1987 to 2006, penned a highly insightful article in the Financial Times titled "We will never have a perfect model of risk". In this article, he pointed out the main cause of the systematic errors in macroeconometric models – expectations. Although DSGE models introduce microeconomic foundations that identify the roles of expectations[4] and aim to maximise the marginal utility function of household consumption, they derive these foundations from neoclassical theory, which does not account for the heterogeneity of expectations[5]. Furthermore, these models (DSGE, similar to Cowles Commission structural models before Sims' critique) are unable

[3] Described by Norges Bank as a "New Keynesian" model (Tura, 2011), it incorporates conflicting assumptions, including rational expectations, wage and price stickiness, Walras's law and information asymmetry.

[4] These are the expectations of rational agents, which do not account for adaptive expectations, information asymmetry and animal spirits.

[5] The attention to the heterogeneity of expectations, which constitutes the foundation for the volitional calculation of individuals (Mises, 2011), is emphasised by Kenneth Arrow: "One of the things that microeconomics teaches you is that individuals are not alike. There is heterogeneity, and probably the most important heterogeneity is heterogeneity of expectations" (Hommes, 2005, p. 2). The production process resulting from a sequence of subjective expectations determining time preferences determines the demand for the extension of stages in the production structure ("cumulative process" in this case, according to Wicksell, will persist until the marginal efficiency of capital equals the monetary interest rate), within the Ricardian effect (Ruys, 2017). This is done not only to expand the real stock of intermediate goods but also to deepen capital. The goal of deepening capital is based on the demand for a lasting stock of intermediate goods. Moreover, this reflects the endogenous nature of introducing innovations into the production process and emphasises the qualitative character of identifying the heterogeneity of stages in the production structure, contrary to the homogeneous structure of capital in the classical-neoclassical school.

to identify crises caused by exogenous factors, the so-called "black swans" (including wars, political trends, pandemics and psychological aspects of mass behaviour). The experience of Norges Bank brings a significant tool to macroeconometric modelling, involving the implementation of an inductive-deductive approach of expert[6] background and adjusting the long-term forecasting model NEMO with the probability density of the conditional short-term forecasts from various time series models. In summary, SARIMA models can serve as a useful tool for short--term conditional forecasting at the initial stage of the NECMOD model construction procedure, which requires re-estimation not only in terms of theoretical coherence but also empirical coherence.

2. Research method

The elementary condition for the optimal selection of parameters in the autoregressive and moving average processes is the execution of tests that identify the optimal model for a time series with a stationary process. Stochastic processes can be categorised into strictly stationary (narrow-sense stationarity) or weakly stationary (broad-sense or covariance stationarity) processes. Weakly stationary processes are challenging to identify, as they require the joint probability density of the stochastic process $\{Y_t\}$ for any observation $\{t_1, t_2, \ldots, t_n\}$ to be equal for the realised processes; $\{Y_{t1}, Y_{t2}, \ldots, Y_{tn}\}$ and those shifted in time by $k\{Y_{t1+k}, Y_{t2+k}, \ldots, Y_{tn+k}\}$. For the inferential reasoning of tests identifying the parameters of the ARIMA model, the realisation of a weakly stationary process is often sufficient, ensuring that the conditions for the stability of central tendency statistics – mean and variance dispersion – are met:

$$\textit{Mean condition: } \mu_t = \mu$$
$$\textit{Variance condition: } \sigma_t^2 = \sigma^2$$
$$\textit{Covariance condition: } \gamma_{k,t} = \gamma_k$$

where:

$$E\left[(Y_t - \mu)(Y_{t-k} - \mu)\right] = \gamma_k, k = 1, 2, 3, \ldots$$

[6] Norges Bank's use of a short-term conditional forecasting model with vector autoregression based on subjective probability of Bayesian reasoning and a heuristic approach to prediction evaluation fulfils Keynes's proposition in *A treatise on probability* (Keynes, 1921) to imply specific a priori assumptions in the form of qualitative analysis instead of approximating reality with a certain error calibration of the econometric model (which was particularly the cause of Keynes's methodological dispute with Tinbergen).

The hypothesis regarding the stationarity of a time series is subject to verification after estimating tests that examine the presence of a unit root or investigate the stationarity of the time series. Accordingly, stationary tests can be divided into two groups (Miłek, 2017). The first group, examining the presence of a unit root, includes tests such as the DF (Dickey-Fuller test), ADF (Augmented Dickey-Fuller test), AD (Adki-Dickey test), with their permutation versions, as well as the Perron-Phillips test (Phillips & Perron, 1988). The second group, examining the stationarity of a time series, includes tests such as KPSS (Kwiatkowski-Phillips-Schmidt-Shin test) and versions designed to identify a stationary process for the seasonal component; the CH test (Canova-Hansen), HEGY (Hylleberg et al., 1990), ADFSI (ADF Seasonal Integration test), and DHF (Dickey et al., 1984). In the case of a zero-degree integration process ($Y_t \sim I(0)$), meaning the integration parameter $d = 0$, the time series is stationary. Conversely, if the hypothesis of non-stationarity of the time series is accepted, then the time series process is integrated to the first degree ($Y_t \sim I(1)$, corresponding to $d = 1$). In this case, first-order differencing is performed to transform the time series into a stationary form: $\Delta Y_t = Y_t - Y_{t-1}$. However, if the test statistic value still indicates the presence of a unit root or non-stationarity in the first--order differenced time series, second-order differencing should be conducted, involving differencing of differences: $\Delta^2 Y_t = \Delta Y_t - \Delta Y_{t-1}$. For a thorough analysis of the time series integration process, tests such as ADF (H_0: the process is integrated to the first degree) and KPSS (H_0: the time series is stationary) will be conducted to identify the parameter d. The selection of tests from both groups is based on the sensitivity of both tests, where the ADF test is sensitive to the persistence (autocorrelation process) of the time series, the occurrence of structural innovations or the presence of outliers. Meanwhile, the KPSS test is sensitive to replicability and the sample size, which may pose challenges in constructing an iterative procedure for the optimal selection of parameters for adaptive ARIMA class models.

In the classical Box-Jenkins procedure, the identification stage of constructing a single-equation adaptive ARIMA model involves selecting the autoregressive process parameter (p) and the moving average process parameter (q) by identifying them using the partial autocorrelation function (PACF, which allows for the identification of partial autocorrelation effects) and the autocorrelation function (ACF, which allows for the identification of disturbance effects) of the time series observations. The Partial Autocorrelation Function estimates the monotonic relationship between the observation at the current time period t, and the observation at time period $t - k$, with a reduction in the interaction of observations between the two periods, in such a way that:

$$PACF_{(y_t,\, y_{t-k})} = \frac{Cov\left(y_t, y_{t-k} \mid y_{t-1}, y_{t-2}, \ldots, y_{t-k+1}\right)}{\sigma_{y_t \mid y_{t-1}, y_{t-2}, \ldots, y_{t-k+1}} \sigma_{y_{t-k} \mid y_{t-1}, y_{t-2}, \ldots, y_{t-k+1}}}$$

Estimating the autoregressive process parameter, in the case of statistical significance for the partial autocorrelation of observations in the time series at a given lag, should be considered as the preliminary selection of the optimal level of the parameter p (when the time series information assumes the character of a stationary process, and in reality, most commonly it takes the form of covariance stationary[7]):

$$Y_t = \sum_{i=1}^{p} \phi_i Y_{t-i} + \varepsilon_t$$

The autocorrelation function helps identify the moving average process and select the parameter q as a sequence of disturbances (errors) on the information series. The moving average process of the MA model is a weighted average realisation of white noise over time. Accordingly, autocorrelation is determined as the ratio of covariance Y_k to variance Y_0, with k representing the lag:

$$ACF = r_{t,s} = r_k = \frac{\sum_{t=k+1}^{k} (Y_t - \bar{Y})(Y_{t-k} - \bar{Y})}{\sum_{t=1}^{k} (Y_t - \bar{Y})^2} = \frac{cov(Y_t, Y_{t-k})}{var(Y_t)} = \frac{\gamma_k}{\gamma_0}$$

where:

$\{Y_t: t = 0, \pm1, \pm2, \pm3 \ldots\}, t \in R$ – univariate time series representing the realisation of a stochastic process,

$n = |t - s|, t, s = 0, \pm1, \pm2, \pm3 \ldots$ – lag order.

The form of the MA model for the determined lag parameter of the moving average process is given by:

$$Y_t = \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} + \varepsilon_t$$

The maximum likelihood method applied in the estimation of the model in this study is a statistical technique that involves minimising the variance of the error term and maximising the logarithm of the likelihood function. Accordingly, the logarithm of the likelihood function is estimated as follows:

$$\ln \mathcal{L}(\phi, \theta, \sigma_\varepsilon^2) = -\frac{N}{2} \ln 2\pi\sigma_\varepsilon^2 - \frac{\sum_{t=-M}^{n} \left[E\left(\varepsilon_t | \phi, \theta, Y\right) \right]^2}{2\sigma_\varepsilon^2}$$

[7] More commonly, a time series is transformed into a process of first differences, becoming a differenced-stationary process (Hamulczuk et al., 2011).

where:

σ_{ε}^2 – variance of the residual component for specified parameters of the autoregressive and moving average processes,

M – constant satisfying the condition that the absolute difference between the expected values of Y_t and Y_{t-1} is smaller than the random component.

The classical Box-Jenkins procedure for constructing ARIMA models, consisting of the stages of identification, estimation and diagnosis, does not optimise the model by reducing the bias of the estimators. Therefore, the extended procedure, incorporating explanatory indicators, allows for the identification of an optimal selection of autoregressive and moving average process parameters for the time series, including the seasonal component. The extended procedure involves an iterative approach, selecting parameters for the ARIMA model that minimises a given explanatory indicator of the model. Chakrabarti and Ghosh (2011) formulated a significant conclusion in time series model construction procedures, suggesting a departure from the arbitrary decision of the researcher regarding the selection of an information criterion due to the specific sensitivity of statistics to, among other things, the complexity of a given time series model. The researchers recommend selecting parameters for single-equation adaptive time series models using the Akaike Information Criterion (AIC) due to its forecasting properties (which is the subject of this study) and sensitivity to model complexity, as opposed to the Bayesian Information Criterion (BIC), which is resistant to model complexity. Information criteria are based on estimation using the maximum likelihood method that maximises the likelihood function, and empirical coherence is achieved by utilising the logarithm of the likelihood function, where $\ell = \ln(\mathcal{L})$. The AIC for the selected model is estimated as follows:

$$AIC = -2\frac{\ell}{N} + 2\frac{K}{N}$$

where:

N – number of observations,

K – number of model variables,

ℓ – logarithm of the likelihood function.

An elementary condition for optimising the ARIMA model and estimating it through the maximum likelihood method is the assumption of a Gaussian process for the residual component of the ARIMA model. Therefore, the estimation of the variance of the random component is obtained from the following equation:

$$-2\frac{\ell}{N} = const + \ln(\tilde{\sigma}_{\varepsilon}^2)$$

$$AIC = \ln(\tilde{\sigma}_{\varepsilon}^2) + 2\frac{K}{N}$$

A popular indicator used to assess the accuracy of ex post forecasts of a selected model is the root mean square error (RMSE). The RMSE indicates the average deviation of empirical values conditioned on the information sequence in the time series from the expected forecast values by the model. The estimation of the root mean square error is calculated by:

$$RMSE = \sqrt{MSE} = \sqrt{\frac{1}{N}\sum_{t=1}^{N}\varepsilon_t^2}$$

Of course, in the literature, one can find many methods for estimating forecast errors and assessing the predictive ability of the model, including, among others, mean absolute error of ex post forecast (MAE), mean absolute percentage error (MAPE), and Theil's coefficient (Dmytrów & Doszyń, 2014).

The final stage of the procedure involves testing the hypothesis of a Gaussian distribution of the estimated model's residual component and the autocorrelation effect. To test the hypothesis of a Gaussian probability distribution of the residual component, the Jarque-Bera goodness-of-fit test will be conducted, which is based on the $\chi 2$ distribution with 2 degrees of freedom, skewness (third central moment) and kurtosis of the distribution (fourth central moment). The JB test is designed to examine the Gaussian nature of the residual component in single-equation models (Domański, 2010), including ARIMA class models. This is due to the test's sensitivity to the complexity of the N-dimensional residual component of multivariate time series models. The JB test (H_0: $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$) is conducted by estimating:

$$JB = \frac{N}{6}\left(\frac{\sum_{t=1}^{N} u_t^3}{N}\right)^2 + \frac{N}{24}\left(\frac{\sum_{t=1}^{N} u_t^4}{N}\right)^2$$

The rejection of the null hypothesis about the presence of a Gaussian residual component process, known as the leptokurtosis effect, most commonly results from the nonlinearity of the time series process, influenced by asymmetric information, leverage effects and variance clustering effects (e.g. the ARCH effect). In such a situation, SARIMA models require further optimisation procedures to incorporate the synthesis of conditional heteroskedasticity processes, such as ARIMA-GARCH models (Zhou et al., 2006). The realisation of a white noise stochastic residual component process determines the elementary condition of the absence of autocorrelation. Testing the hypothesis of autocorrelation is done using a portmanteau test; in this work, the Ljung-Box test statistic based on the $\chi 2$ distribution will be applied:

$$LB = N(N+2)\sum_{k=1}^{K}\frac{r_k^2}{N-k}$$

In the case of a Gaussian process integrated of order zero[8], for the residual component of the ARIMA model (r_k), the null hypothesis assumes values for $k \in 1, 2, \ldots, K$.

3. Results

The author has arbitrarily chosen a confidence interval for hypothesis testing with a significance level $\alpha = 0.05$. Significance levels for the estimation procedure are denoted by "*", such that significance levels are indicated as "** ≤ 0.01", "** ≤ 0.05", "* ≤ 0.1". The conducted tests and results of the estimation of constructed models were prepared using available libraries in Rstudio.

The generated time series plots (see Figure 2) for price dynamics, seasonal component and first differences allow for an initial assessment of stationarity. However, testing the hypothesis of stationarity requires conducting appropriate tests. After performing an extended Augmented Dickey-Fuller (ADF) test for the presence of a unit root, the results of statistics for the time series of Consumer Price Index (CPI) dynamics (–0.1544) and the seasonal component (–2.1081**) showed the absence of a unit root for the seasonal component. However, after conducting the KPSS test, both time series showed non-stationarity (for price dynamics – 1.32*** and the seasonal component – 1.049***). Following the ADF test for the CPI dynamics time series (–5.94***) and the seasonal component (–6.087***), the statistics indicated the absence of a unit root – stationarity of the time series in a broader sense. Accordingly, the integration parameter is assumed to be $d = 1$ and $D = 1$ (for seasonal component).

The initial selection of autoregression and moving average process parameters for the first difference time series, according to the classical Box-Jenkins procedure, showed statistical significance for the parameters; $p = 1$, $q = \{0,1,2,3\}$ (see Figure 3 and Table 2).

In the case of the seasonal component, optimal parameter selection according to the classical procedure indicates: $P = \{1,2\}$ and $Q = \{0,1,2,3\}$ (see Table 3).

[8] A Gaussian process integrated of order zero is assumed for Y_t:

$$Y_t \sim N(0, \sigma_t^2)$$
$$Y_t \sim I(0)$$

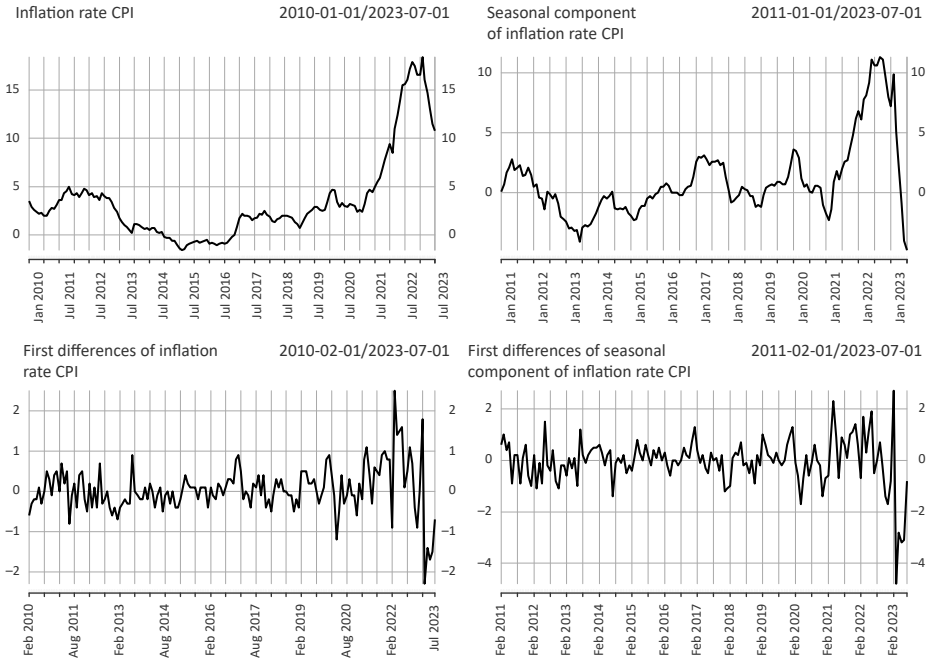

Figure 2. Time series charts; dynamics of CPI and seasonal component along with their first differences

Source: own elaboration.

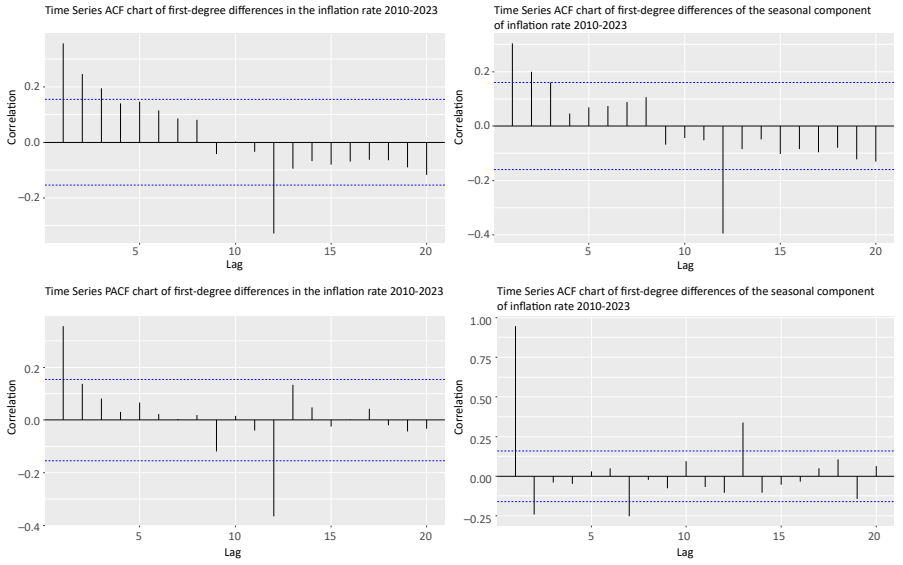

Figure 3. Autocorrelation charts and partial autocorrelation charts of selected components' processes

Source: own elaboration.

Table 2. Autocorrelation function (ACF) and partial autocorrelation function (PACF) statistics for selected lags of time series of CPI first differences

Lag	PACF	Significance	Lag	ACF	Significance
1	0.356736711031677	*	0	1	*
2	0.136288373134338	–	1	0.356736711031677	*
3	0.0818348962699699	–	2	0.246205248439543	*
4	0.0309894557029078	–	3	0.194573144706838	*
5	0.0654148792313358	–	4	0.14068731473643	–
6	0.0220859225688047	–	5	0.146903050935267	–
7	0.00391326094689732	–	6	0.115106817856936	–
8	0.0193427687124015	–	7	0.08513534408966	–
9	–0.119093117231304	–	8	0.081570634360881	–
10	0.0160967796089348	–	9	–0.0414943618958088	–

Note: * indicates statistical significance.

Source: calculations carried out using Rstudio.

Table 3. Autocorrelation function (ACF) and partial autocorrelation function (PACF) statistics for selected lags of time series of CPI first differences of seasonal component

Lag	PACF	Significance	Lag	ACF	Significance
1	0.94722613529003	*	0	1	*
2	–0.241023924223004	*	1	0.304848924414357	*
3	–0.0396112161986772	–	2	0.19892884491104	*
4	–0.0468058372979025	–	3	0.160870204960376	*
5	0.0300364579425894	–	4	0.0463530127322375	–
6	0.0507735091284552	–	5	0.0690582444834766	–
7	–0.251364686585908	*	6	0.0731551560011233	–
8	–0.0232292345056342	–	7	0.0881495591938981	–
9	–0.0759147182405396	–	8	0.107249735009197	–
10	0.0933647933626355	–	9	–0.0686675152624796	–

Note: * indicates statistical significance.

Source: calculations carried out using Rstudio.

According to the specified extended procedure, the optimal linear combination of autoregressive and moving average process parameters will be estimated using an iterative method based on the AIC information criterion for the first differences of time series.

The estimation showed the best empirical coherence of the model with empirical data based on the information derived from the time series for ARIMA(1,1,2) (see Table 4).

Table 4. Akaike Information Criterion (AIC) statistics for autoregressive and moving average process parameters for the time series dynamics of CPI prices

	$q = 0$	$q = 1$	$q = 2$	$q = 3$
$p = 0$	290.949	275.8887	272.8257	271.9058
$p = 1$	270.0245	265.532	267.4238	269.2545
$p = 2$	268.3041	267.4356	265.4293	267.4223
$p = 3$	268.5437	269.2918	267.4222	264.1817

Source: calculations carried out using Rstudio.

The iterative estimation of the AIC criterion for the seasonal component showed the best fit to the data for the models SARIMA(1,1,2)(2,1,2)12 and SARIMA(1,1,2)(2,1,3)12 (see Table 5). According to the above results, these models are optimal in terms of the extended procedure and will be used to construct short-term conditional forecasts.

Table 5. Akaike Information Criterion (AIC) statistics for autoregressive and moving average process parameters for the time series of seasonal component of dynamics of CPI prices

	$q = 0$	$q = 1$	$q = 2$	$q = 3$
$p = 0$	404.0197	394.3976	393.5301	391.737
$p = 1$	391.2828	389.2711	391.2365	393.629
$p = 2$	390.7691	391.2394	386.6657	388.2564
$p = 3$	391.205	392.9151	388.1219	385.7171

Source: calculations carried out using Rstudio.

The results of the estimation of SARIMA(1,1,2)(2,1,3)12 models showed a better fit for the SARIMA(1,1,2)(2,1,3)12 model (see Table 6). This is indicated by a lower value of the Akaike Information Criterion (AIC) and a higher likelihood ratio value.

The generated unit circles (Nazarko & Chodakowska, 2022) for selected SARIMA models indicate that the roots of the characteristic equation of autoregressive and moving average process parameters are inside and on the complex plane (see Figure 4), thus both models are stationary (Dritsaki, et al., 2021) (stable) and invertible.

The constructed fan chart (see Figure 5) for both models for the forecast period August 2023 – July2024 indicated deflationary tendencies. According to the SARIMA(1,1,2)(2,1,2)12 model, a return to the implementation of the inflation targeting strategy by the Monetary Policy Council's decision-making body is expected

Table 6. Results of estimating optimal (according to the extended Box-Jenkins procedure) SARIMA models

		$SARIMA(1,1,2)(2,1,2)_{12}$	$SARIMA(1,1,2)(2,1,3)_{12}$
$d = 1$	$p = 1$	0.201 (0.746)	–0.134 (0.392)
	$p = 2$	–	–
	$q = 1$	–0.425 (1.495)	–0.010 (0.657)
	$q = 2$	–0.092 (0.832)	–0.271 (0.324)
$D = 1$	$P = 1$	–0.021 (1.643)	–0.978 (0.075)
	$P = 2$	0.047 (0.289)	–0.802 (0.066)
	$Q = 1$	–0.425 (1.498)	0.503 (0.596)
	$Q = 2$	–0.092 (0.832)	0.460 (0.614)
	$Q = 3$	–	–0.525 (0.595)
AIC		282.01	271.69
Likelihood ratio		–133	–126.85

Source: calculations carried out using Rstudio.

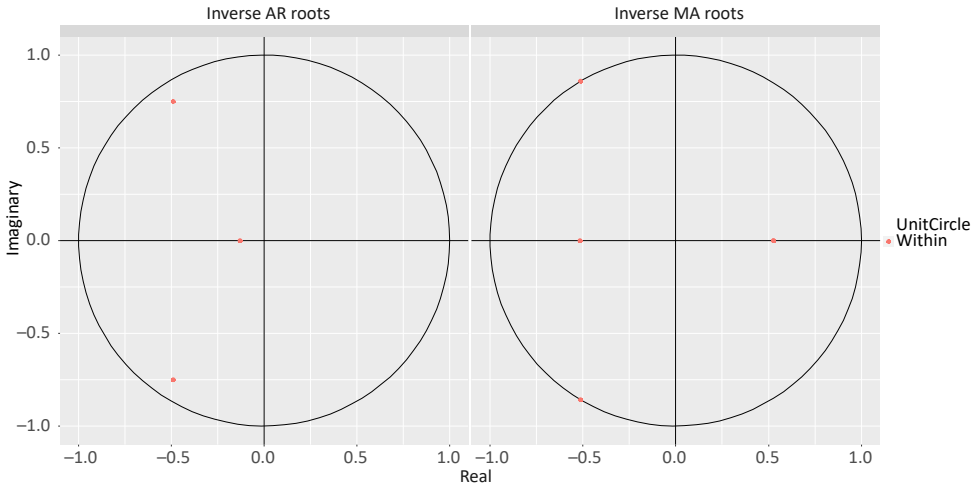

Figure 4. Unit circle plots for the optimal parameters of SARIMA models

Source: own elaboration.

in February 2024, while for the SARIMA(1,1,2)(2,1,3)12 model, it is expected in January 2024. Table 7 shows the exact point forecast with 95% confidence interval.

The ex post forecast accuracy assessment based on the root mean square error (RMSE) estimator indicates a smaller systematic bias (stronger coherence with em-

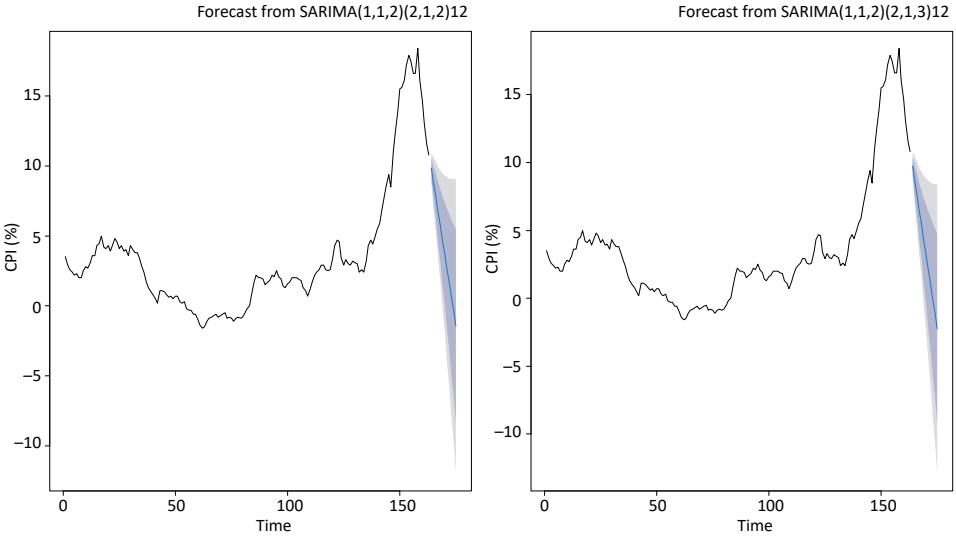

Figure 5. Conditional forecast (projection) of CPI price dynamics for the period August 2023–July 2024 (in monthly sequence) using optimal SARIMA models

Source: own elaboration.

Table 7. Expected values for the forecast period (point estimate and interval estimate with a 95% confidence interval) estimated using optimal SARIMA models

SARIMA(1,1,2)(2,1,2)$_{12}$			SARIMA(1,1,2)(2,1,3)$_{12}$		
Point Forecast	**Lo 95**	**Hi 95**	**Point Forecast**	**Lo 95**	**Hi 95**
9.843662341	8.762592	10.92473	9.745816077	8.714403	10.77723
8.823335356	7.023673	10.623	8.693728448	6.937199	10.45026
7.794948859	5.306436	10.28346	7.541947745	5.065332	10.01856
6.767388709	3.561343	9.973434	6.440060713	3.286568	9.593553
5.740168176	1.770953	9.709383	5.419793454	1.518554	9.321033
4.713126937	–0.06694	9.493192	4.273083439	–0.49974	9.045909
3.686127531	–1.95123	9.323482	3.185492976	–2.43392	8.804908
2.659141617	–3.88	9.198285	2.141331493	–4.39045	8.673114
1.63215858	–5.85137	9.115687	1.007297191	–6.51867	8.533265
0.605176356	–7.86359	9.073945	–0.073635778	–8.5896	8.442329
–0.421805702	–9.91511	9.071495	–1.134460416	–10.699	8.430052
–1.448787715	–12.0045	9.106925	–2.257532488	–12.9292	8.414181

Source: calculations carried out using Rstudio.

pirical data) for the SARIMA(1,1,2)(2,1,3)12 model (RMSE = 0.52) compared to the SARIMA(1,1,2)(2,1,2)12 model (RMSE = 0.55). Accordingly, the higher accuracy of the short-term conditional forecast tool using the SARIMA(1,1,2)(2,1,3)12 model allows for shaping forward guidance policy with greater confidence by influencing expectations channels. It serves as an optimal tool for constructing a conditional short-term forecast, and among the selected optimal models with strong empirical coherence, it enables the construction of the probability density function for the expected CPI dynamics.

In the further diagnostic procedure of short-term conditional forecast model optimality, the SARIMA(1,1,2)(2,1,3)12 model will be utilised, as it exhibited a lower bias of the estimator after estimating the results of the root mean square error ex post (RMSE) for both SARIMA models.

The generated charts (see Figure 6), including Quantile-Quantile plots, Gaussian probability density functions along with histograms (frequency distributions adjusted using the Freedman-Diaconis technique), Epanechnikov kernel density estimator, as well as theoretical and empirical cumulative distribution functions of the Gaussian distribution, clearly show the intensity of the dispersion of outlier values in the tails of the distribution. This is a result of the leptokurtosis of the residual component in the SARIMA(1,1,2)(2,1,3)12 model. After conducting the

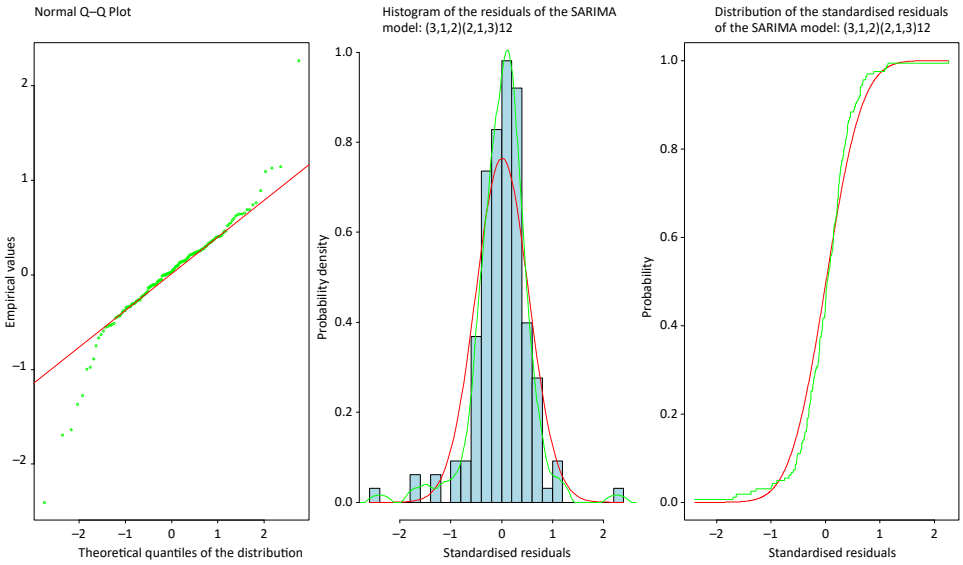

Figure 6. Charts: probability density distribution, quantile-quantile plot and cumulative distribution function plots for the residual component of the SARIMA(1,1,2)(2,1,3)$_{12}$ model

Source: own elaboration.

Jarque-Bera goodness-of-fit test for the univariate residual component of the SARIMA(1,1,2)(2,1,3)12 time series model, the alternative hypothesis of a distribution different from normal for the residual component should be accepted (172.68***). Additionally, testing for kurtosis revealed leptokurtosis (4.9), and skewness indicated left-skewness (–0.59). According to the developed diagnostic procedure, there is a stochastic process with stronger empirical coherence than the process based on the SARIMA(1,1,2)(2,1,3)12 model. The leptokurtic distribution of the residual component may arise from the nonlinearity of the time series, suggesting an extension of the model to a combination of SARIMA and GARCH-class conditional heteroscedasticity models (Pahlavani & Roshan, 2015) to reduce systematic bias through the identification of variability (conditional variance) of the residual component. Baciu (2015) makes a similar point about the process of conditional heteroskedasticity, identifying the non-Gaussian process of the residual component of the constructed ARIMA model.

Table 8. Autocorrelation process statistics for the residual component of the SARIMA(1,1,2)(2,1,3)12 model

Lag	Ljung-Box	*p*-value
1	0.000671489	0.979327
2	0.066421	0.967335
3	0.130059343	0.988001
4	0.805266847	0.937741
5	1.035684448	0.959637
6	1.775718802	0.939127
7	2.334342314	0.939046
8	2.513942771	0.961078
9	2.631238116	0.977143
10	2.750996158	0.986692

Source: calculations carried out using Rstudio.

The SARIMA(1,1,2)(2,1,3)12 model, at the stage of diagnosing the autocorrelation process of the residual component, exhibited a lack of persistence after conducting the portmanteau test (see Table 8). For the included lags of the residual component, the null hypothesis of no autocorrelation process should be accepted.

Conclusion

Although the conducted stage of diagnosing the optimal model, following the extended procedure, reduced the model's reliability stemming from the leptokurtosis effect of the residual component, the SARIMA(1,1,2)(2,1,3)12 model for the examined time series spanning from January 2010 to July 2023 remains a high-quality model conditioned by values of explanatory indicators, ex post forecast accuracy and lack of persistence (lack of autocorrelation process in the residual component of the model). Furthermore, the results of short-term conditional forecasting, considering the current statistics from Statistics Poland regarding the relative values of the CPI dynamics indicator for the periods from August 2023 to November 2023, exhibited accuracy within an arbitrarily set 95% confidence interval.

An analogous procedure for identifying the orthogonal parameters of the optimal SARIMA model for the construction of a conditional forecast of the rate of change in prices as measured by the CPI was used for the economies of the Philippines (Corpin et al., 2023), Turkey (Şanlı & Özmen, 2017) and Ghana (Havi, 2023), among others. The developed procedure allowed the selection of an optimal model with low values of explanatory indices and ex-post forecast accuracy ratings, which defines the SARIMA model as a reliable tool for building short-term conditional forecasts of price dynamics for the analytical background of central banks.

An interesting application of SARIMA models to the construction of a conditional forecast of core inflation in the Ukrainian economy is presented by Krukovets (2024). The author, conducting validation and evaluation of the predictive ability of selected models, includes the form of the SARIMA model and a version that is a combination of the form of the model along with the integration of the neural network machine learning technique (LSTM) for the process of the residual component of the optimal SARIMA model. The results of the estimation of the integrated SARIMA model with the LSTM machine learning technique show that the model has the best fit to the empirical data among the tested models.

The constructed SARIMA model is a model with short memory, as a single-equation time series model with strong empirical coherence that does not include variables that, from the perspective of a given theory (calibration incorporating rational expectations and microeconomic foundations) or empirically conditioned coherence and structural examination of causality, would allow for the identification of structural shocks and the resulting price adjustment processes. The SARIMA model is a short-term conditional forecasting model, and therefore, the stochastic process allows for constructing forecasts based on information obtained in the optimisation procedure (reduction of estimator bias) of orthogonal parameters of the SARIMA model.

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Digitalisation and income inequality in Central and Eastern European countries

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Abstract

The COVID-19 pandemic has highlighted the importance of digital technologies in business and daily life. The paper aims to explore the theoretical and empirical aspects of the relation between digitalisation and income inequality in Central and Eastern European (CEE) countries between the years 2000–2020. It contributes to existing research on determinants of income inequality, focussing on the potential negative role of digitalisation as an unnoticeable driver of income inequality in CEE countries. To investigate the potential impact of digitalisation on income inequality, empirical analysis was performed for a sample of 10 CEE countries, namely Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic and Slovenia. The results of the canonical correlation analysis indicated that the sets of variables related to digitalisation and inequality as a group are significantly related to each other and a strong correlation exists between them. The relative contribution of each indicator to each standardised function showed that the highest values of significant standardised coefficients were observed for income inequality indicators such as the top 10% share, the Gini coefficient and the top 1% share, while in digitalisation measures, the highest value was observed for Internet users as well as fixed and mobile broadband subscriptions.

Keywords

- income inequality
- digitalisation
- canonical correlation
- Central and Eastern European countries

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Introduction

The years of the COVID-19 pandemic have shown how important and irreplaceable digital technologies are in our business and daily life. The growing importance of digital technologies or the so-called digital transformation (sometimes referred to as revolution) began to reshape the world of business and work in profound ways even before the pandemic, which, however, has significantly accelerated these processes (Götz et al, 2018; Kraus et al., 2021; Verhoef et al., 2021; Vial, 2019). Some commentators argue that digitalisation can become a new engine of economic growth by increasing capital and labour productivity, lowering transaction costs and facilitating access to global markets (Arendt, 2015; Dahlman et al., 2016; Myovellaet al., 2020). But with new opportunities come new challenges. As digitalisation is impacting many areas of our lives, the gains from it seem to not spread evenly across economies. In the last two decades, together with the rapid adaptation of new digital technologies, income inequality has increased in practically all advanced economies. Are these megatrends of our time connected? This question seems to be particularly important in the case of Central and Eastern European (CEE) countries in which digitisation is considered one of the key drivers of economic growth. Furthermore, a growing number of recent empirical analyses show that income and wealth inequalities in Eastern Europe since the fall of socialism have increased significantly more than previously suggested (Brzeziński & Sałach, 2022).

Taking this into account, the main goal of the presented study is to explore the theoretical and empirical aspects of the relation between digitalisation and income inequality in CEE countries between the years 2000–2020. We hope that such stated goal will allow us to address the research question: How does digitalisation influence income inequality in Central and Eastern European (CEE) countries between 2000 and 2020, and what are the underlying theoretical mechanisms driving this relationship? The choice to analyse this relation in the years 2000–2020 stems primarily from data availability constraints, particularly regarding digitalisation metrics. During this period, data collection and reporting on digitalisation-related indicators in CEE countries gradually improved, albeit from a relatively low starting point. The level of digitalisation in these countries was notably limited during this timeframe, characterised by slower adoption rates compared to more developed regions. Furthermore, it is essential to note that several countries within the CEE region joined the European Union during this timeframe, influencing their economic and policy landscapes, including their approach to digitalisation and its implications for income distribution.

This article hopes to contribute to existing extensive research on determinants of income inequality, focussing on the potential negative role of digitalisation as

an unnoticeable driver of income inequality in CEE countries. This group of countries seems to be especially interesting not only because comparative evidence on the relation between digitalisation and inequality in this group is scant but also because this geographical region has distinct cross-country patterns in digitalisation and income inequality trends.

To investigate the potential impact of digitalisation on income inequality in the studied countries, two main data sources have been used. Indicators related to the level of digitalisation indicated by data on access to and use of ICT by households and individuals have been obtained from the International Telecommunications Union (ITU), a specialised United Nations agency for information and communication technologies. Income inequality estimates were received from the World Inequality Database (WID.world). Empirical analysis was performed for a sample of 10 CEE countries, namely Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic and Slovenia over the period 2000–2020. The selection of specific variables was sometimes limited due to the availability of the data.

The remainder of this paper is structured as follows. Section 2 describes the key theoretical findings on the potential relation between digitalisation and income inequality, focussing on channels through which digital transformation is affecting income inequality. Section 3 discusses general trends in income inequality and digitalisation trends in CEE countries. Consequently, section 4 aims to study the empirical relation between the digitalisation and income inequality in CEE with the method of hierarchical canonical correlation analysis. Finally, the last section concludes the article.

1. Digital transformation and inequalities – literature review

The matter of increasing income inequality is publicly debated in most developed countries. Books such as Deaton (2013) or Piketty (2014) have spurred worldwide interest in income and wealth inequality, making this topic one of the most popular topics in both empirical and theoretical analyses. In the cauldron of scientific as well as socio-political debate, much of the blame for the rise in income inequality is heaped on factors such as globalisation, liberalisation, financialisation, inefficient labour market institutions, education, etc. (Roine & Waldenström, 2015). However, current developments related to the COVID-19 pandemic and the connected and rapid acceleration in the implementation of new digital technologies force us to focus on another traditional and well-studied driver of income in-

equality, that is, technological change. As indicated, an especially interesting and important element of contemporary technological change is the ongoing transformation of the economy toward a digitalised production and work environment, a phenomenon called digitalisation (Butryn, 2020).

It seems that concerns related to the impact of technology on the working population and its possible negative consequences on the labour market, including income distribution, have been one of the core concerns of economists for as long as economics has been considered a distinct field of study. For example, Berg (1980) has gone so far as to argue that the debate on the machinery question that emerged in the wake of the Industrial Revolution was instrumental in the birth of the new science of economics during the mid-19th century. Almost a hundred years later, in 1933, John Maynard Keynes made a frequently cited prediction of widespread technological unemployment, arguing that "due to our discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour" (Keynes, 1963, p. 364). Although contemporary economists no longer use terms such as "machinery question" or "intellectual machinery" to frame the debate over new technology and the labour market, current concerns about the effects of technology are remarkably similar to those of the past. Although there is a broad consensus on the positive impact of digital transformation on productivity and its effect on economic growth (Gal et al., 2019), the impact on the labour market and its different elements, including expected income inequalities and wage polarisation, remain a matter of debate.

In general, there is a consensus among researchers that digitisation contributes to the exacerbation of inequalities. This effect can be analogised to the phenomenon described by Simon Kuznets (1955) in his famous Kuznets curve, where sectors or job locations experiencing digitisation yield higher incomes. The transition from an industrial to a digital economy is at play here. However, there remains no consensus regarding the specific mechanisms through which this phenomenon occurs. Various factors are involved in this process. For example, Qureshi (2021) argues that the uneven diffusion of new digital technologies between firms is of great importance both for productivity dynamics and income distribution. The fact that new digital technologies have been captured for the most part by a relatively small number of larger firms in which productivity growth has been relatively strong while it has slowed considerably in the vast majority of other, typically smaller firms. This process has resulted not only in the growth of inequalities in productivity performance between firms, but also caused income disparities to rise. For the author of this paper, much of the blame for the ongoing increase in income inequality is attributable to increased wage differences between firms. A similar argument is presented by Song et al. (2019); these authors used a massive, matched employer-employee database for the United States and found that one third of the rise in the variance of earnings occurred within firms, whereas

two-thirds of the rise occurred due to a rise in the dispersion of average earnings between firms. However, this rising between-firm variance is not accounted for by the firms themselves, but by a widening gap between firms in the composition of their workers. Furthermore, the results obtained indicate that two-thirds of the rise in the within-firm earnings inequalities occurred within mega firms (10,000+ employees), which saw a particularly large increase in the variance of earnings compared to smaller firms. However, in a study aimed at analysing wage inequality patterns and their firm dimension in Central and Eastern European countries, they found that, unlike many other advanced economies, wage inequality levels have decreased in CEE countries during the 2000–2014 period and particularly in those countries that previously had the highest wage inequality levels (Magda et al., 2021). Furthermore, the relative size of the between-firm component of wage inequalities varied substantially between countries and was highest in countries with the highest levels of wage inequality. However, the authors revealed that, as in the case of previous studies, firms played an important role in shaping wage inequality in both the early 2000s and 2014, as wage inequality in CEE was greater between firms than within them.

Another strand of literature concentrates on the role of digital transformation in the shaping of individual wage inequality (wage differentials that arise within firms). The long history of these analyses has its roots in the literature on skill-biased technological change (SBTC) (Acemoglu, 2002; Autor et al., 1998; Card & DiNardo, 2002; Griliches, 1969; Katz & Murphy, 1992). This approach explains the growing wage inequality due to changing occupational tasks or skill requirements as a result of the fact that technology increases the demand for educated workers, thus allowing them to command higher wages. In more recent studies, the observed increase in wage inequality is usually attributed to SBTC, associated with new computer technologies. For example, Frey and Osborne (2017) focus on the effects of digitalisation on the occupational composition of the labour market and argue that digitalisation will primarily hit low-skill and low-wage jobs. According to their estimates, about 47% of the total US employment is at risk, causing a potential increase in the level of income inequality. Fiedler et al. (2021) analysing the impact of industrial robots, as well as investments in computing equipment and digital technologies on different indicators of income distribution, found that robot density is positively associated with income inequality, while no robust evidence was found for computing equipment and digital technologies. Their results indicate that the income shares of the bottom 20% and 50% decrease with automation, while the income shares of the top 10% and 1% increase, which supports the job and wage polarisation hypothesis. Acemoglu and Restrepo (2022) documented that between 50% and 70% of changes in the US wage structure over the last four decades are accounted for by relative wage declines of worker groups specialised in routine tasks in industries experiencing rapid automation. Moll et

al. (2022) showed that automation can increase inequality not only by increasing high-skilled labour wages but also by raising returns to wealth. The benefits of new technologies accrue to owners of capital in the form of higher capital incomes and to most qualified workers in the form of higher wages. Mönnig et al. (2019) in a future-orientated study using a macroeconometric input-output model, which accounts for circular flow in the economy and feedback loops, predict that digital transformation increases wage inequality especially at the upper end of the distribution, although to a low extent. The authors emphasise that the mechanism through which digital transformation is impacting wage inequality refers to the fact that digitalisation strengthens the unequalising role of structural change. In an earlier study by Antonczyk et al. (2009), in which changes in the German wage structure for full-time working males were investigated from 1999 to 2006, the authors concluded that only wage dispersion at the top of the wage distribution can be observed. Keister and Lewandowski (2017) studied the shift from manual to cognitive work in 10 Central and Eastern European economies and found that in all countries routine cognitive tasks were most common in the middle of wage distribution but increasingly rare among the top earners. They concluded that if technological progress reduces demand for routine work, a large proportion of workers would be affected and wage inequality would rise.

Summing up this short review of studies related to the impact of technological change, including processes of digital transformation on wage inequality, it is interesting to note that most authors assume that digital transformation plays an important role as a driver of income inequalities; however, there is no agreement on the main channels and the scale of this relation.

2. Inequality levels and digital transformation in CEE countries

Before transformations, income inequalities were relatively low in socialist countries, primarily stemming from ideological motives that aimed to flatten the pay structure (Bukowski & Novokmet, 2017; Novokmet, 2017). Additional contributing factors included low registered unemployment, measures to prevent intergenerational transfer of private assets, price subsidies, rationing and non-wage remuneration. Moreover, socialist states boasted a higher percentage of working women compared to western countries (Flemming & Micklewright, 2000). However, it is essential to note that despite low-income inequalities, there were pronounced consumption disparities due to the scarce and regulated access to commodities. Obtaining rare products relied on personal connections, party membership and

hierarchies within the communist party (e.g. exclusive stores accessible only to party activists, security personnel and high-ranking officials). In the 1990s, income inequality underwent significant transformations – it not only increased but also became more diverse, which is a phenomenon unprecedented in other regions (Milanovic, 2001). Over a decade, the average Gini coefficient, a measure of income inequality, increased by 0.10 points, indicating a rapid shift towards greater inequality in these countries compared to western counterparts. This rise was particularly marked within former Soviet Union countries, while countries that later joined the European Union (that is, our study group) experienced a milder change in this area (Alvaredo & Gasparini, 2015).

The natural starting point of the analysis of the distributional consequences of digitalisation and the possible role of digital transformation in the process of polarisation of income in CEE countries is the analysis of the indicators related to the inequality levels. In this analysis, measures such as Top 1%, Top 10%, Top 10% to Bottom 50% ratios and values of the Gini index of pre-tax income for years 2000–2020 obtained from the World Inequality Database were used (see Figure 1 and Figure 2). As Figure 1 indicates, the countries differ significantly both in terms of the levels of observed inequalities and the trends and dynamics of income disparities. Countries such as the Czech Republic, Hungary, Poland, the Slovak Republic and Slovenia exhibited stabilisation or even a small decrease in the range of indicators analysed even after initial growth in inequalities indicated by an increase in income shares and the Gini index in the early 21st century. However, in countries such as Bulgaria, Estonia, Latvia, Lithuania and Romania, a much greater variation can be observed. It is important to note that the highest level of income inequality was observed between the countries studied in Bulgaria and Romania. The Gini index reached as high as 0.55 in 2020 for these countries. The share of income going to the top 10% was 43.5% in Bulgaria and 41.4% in Romania and the top 1% shares were 18.3% and 14.4%, respectively. The lowest levels of inequalities were observed in the Czech Republic and the Slovak Republic, where the Gini index value in 2020 amounted to 0.37; the share of the top 10% was 28.6% in the Czech Republic and 26.5% in the Slovak Republic, and the top 1% shares were 10.1% and 7% respectively. While analysing income inequality trends in this group of countries, it is also worth spotting the rapid increase of all measures related to inequalities in Bulgaria in the last few years and the significant decrease of inequalities in Estonia since 2004.

In verifying the potential relationship between digitalisation and inequality levels in CEE countries, indicators such as the proportion of individuals using the Internet, data on fixed and mobile subscriptions to high-speed access to the public Internet (a TCP/IP connection), and the indicator related to international Internet bandwidth (bits/s) per Internet user were used. Data availability in the case of the last two indicators is limited. Looking at one of the most natural, as

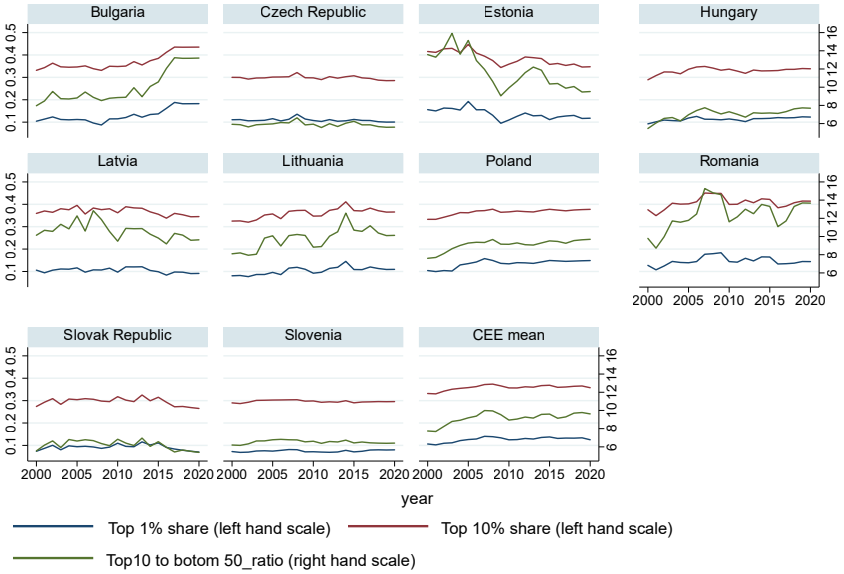

Figure 1. Income inequalities in 2000–2020 in CEE countries

Note: The CEE mean was calculated as population weighted average.

Source: own elaboration based on data from the World Inequality Database (https://wid.world/)

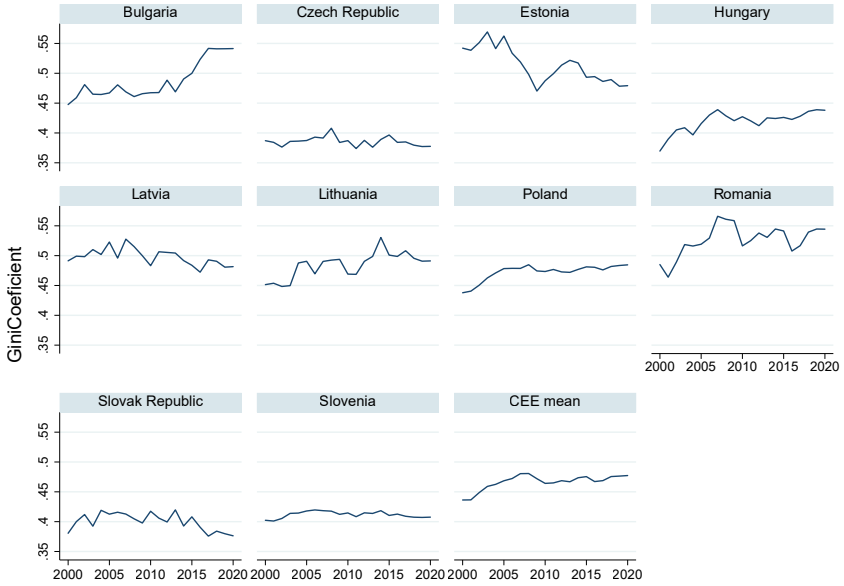

Figure 2. Gini coefficient in 2000–2020 in CEE countries

Note: The index ranges from 0 to 1; the higher the index the more unequal the income distribution. The CEE mean was calculated as population weighted average.

Source: own elaboration based on data from the World Inequality Database (https://wid.world/)

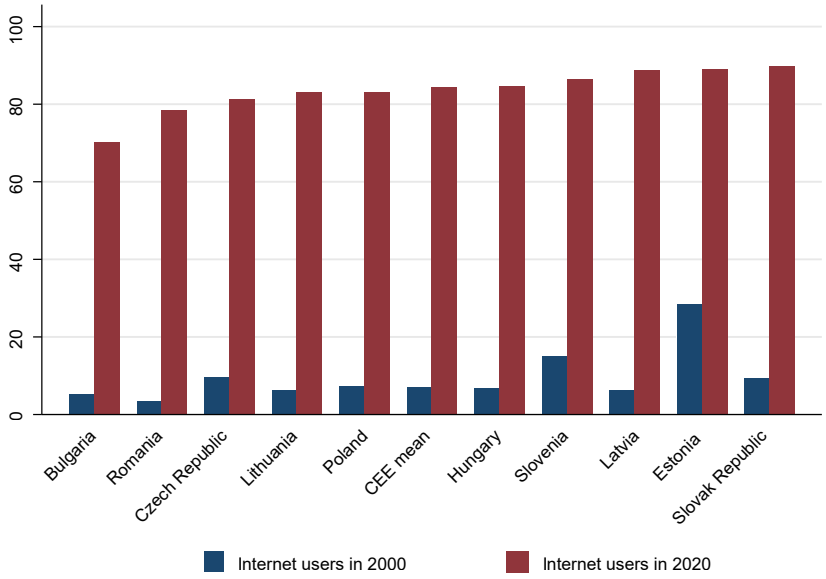

Figure 3. Internet users in 2000 and 2020 in CEE countries (% of population)

Note: The CEE mean was calculated as population weighted average.

Source: own elaboration based on data from The International Telecommunication Union (ITU) (https://www.itu.int/en/Pages/default.aspx)

well as the broadest, indicator of the level of societal digitalisation, namely the share of the population using the Internet (presented in Figure 3), an immense growth in the popularity of the Internet can be observed. In 2000 only the share of Internet users in Estonia was higher than 20%. Compare that with 2020, where the indicator exceeded 80% in most countries. The lowest shares were observed in Bulgaria and Romania, where the shares of internet users reached 70.16% and 78.45% in 2020, respectively, while the highest values – almost 90% – were observed in Latvia, Estonia and the Slovak Republic.

After analysing the next two indicators (see Figure 4) related to the digitalisation, namely the number of active fixed- and mobile-broadband subscriptions per 100 inhabitants, two main trends can be observed. First, the level and dynamics of fixed broadband subscriptions were similar among the entire studied group. The number of fixed subscriptions increased steadily from almost nil in 2000 to around 30 subscriptions per 100 inhabitants in 2020. The change in mobile broadband subscriptions was much more rapid and diverse. In the last ten years there has been a doubling in subscriptions and, in some countries, even a tripling in countries such as Latvia, Estonia and Poland in 2020 to the levels of 141, 165, and 197 subscriptions, respectively. These data indicate that, for example, in Poland in 2020 on average there were two devices connected to the broadband Internet per person.

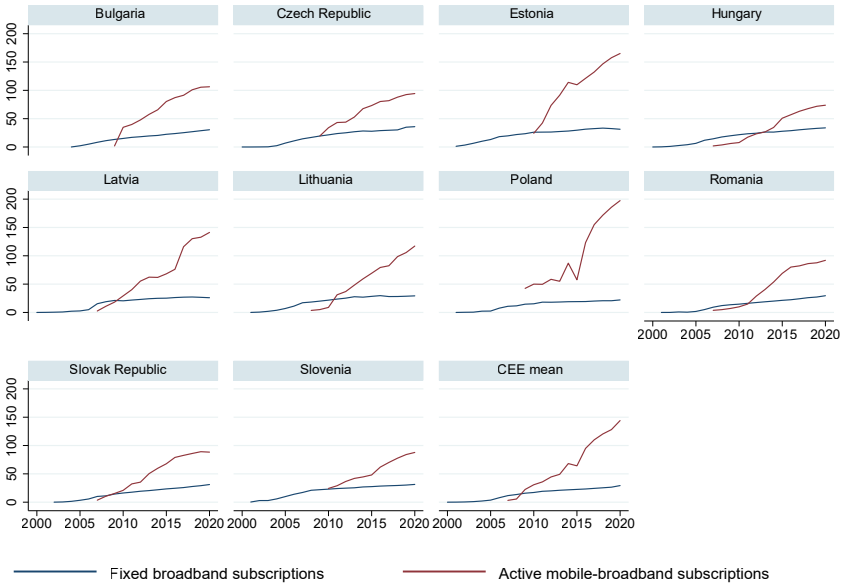

Figure 4. Fixed and mobile broadband subscriptions in CEE countries (per 100 inhabitants)

Source: own elaboration based on data from The International Telecommunication Union (ITU) (https://www.itu.int/en/Pages/default.aspx)

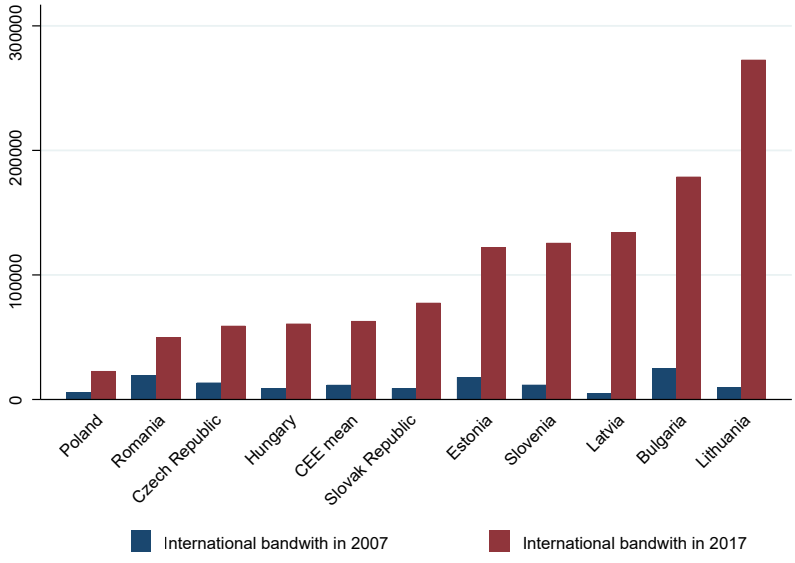

Figure 5. Fixed and mobile broadband subscriptions in CEE countries (per 100 inhabitants)

Note: International Internet bandwidth (bit/s) per Internet user is calculated by converting to bits per second and dividing by the total number of Internet users. Due to data availability analysis covers the years 2007-2017.

Source: own elaboration based on data from The International Telecommunication Union (ITU) (https://www.itu.int/en/Pages/default.aspx)

The last indicator related to the level of digitalisation, that is, international bandwidth per Internet user, is an indicator showing the maximum quantity of data transmission (rate) from a country to the rest of the world. It is worth underlining that this indicator is sometimes used to measure the level of development of digital infrastructure in a country (Di et al., 2022). As the data in Figure 5 indicate, CEE countries differ significantly in terms of the speed of international Internet bandwidth, which has increased significantly since 2007. The lowest level of these indicators was observed in Poland, with an average value of 22k (bits/s), while the highest value was observed in Lithuania of 272k (bits/s). However, assessing data related to International Internet bandwidth, we have to remember that since 2017 (the last year with reliable data), a rapid growth in the quality of international bandwidth has been observed in most CEE countries. Therefore, the presented data should be seen as an indication of the dynamics rather than a measure of the levels of the studied phenomenon.

3. Relation between digitalisation and income inequality in CEE countries – empirical verification

To study the empirical relation between digitalisation and income inequality in CEE, canonical correlation analysis (CCA) was used. This analysis was carried out to test whether there is a difference between the indicators related to digitisation on the one hand, and income inequalities on the other. Basically, this method provides a simultaneous analysis of the set of dependent variables and the set of independent variables. In general, it determines whether two sets of variables are independent of each other in a linear sense. This is done by finding a composite for the multiple dependent variables and a composite for the multiple independent variables. These composites are correlated simultaneously to obtain a canonical function. This process continues until all the correlations between the two sets are included. In effect, this analysis allows for the evaluation of the strength of the overall relationships between the linear composites (canonical variates; a pair of canonical variates is called a canonical root), for the independent and dependent variables, as well as the relative contribution of each variable to the canonical functions (relationships) that are extracted (Hair et al., 2014, p. 17). The relative contribution of each variable can be evaluated by the canonical loadings and cross loadings which reflect the variance that the observed variable shares with the canonical variate and can be interpreted like a factor loading in assessing the relative contribution of each variable to each canonical function. The larger the coefficient, the more important it is to derive the canonical variate (Dattalo, 2014,

p. 12). An illustration of the canonical correlation analysis is presented in Figure 6. The objective is to find a linear combination (projection) of sets X and Y, or the rotated canonical space, by maximising the linear correlation between the two sets of new canonical variables U and V.

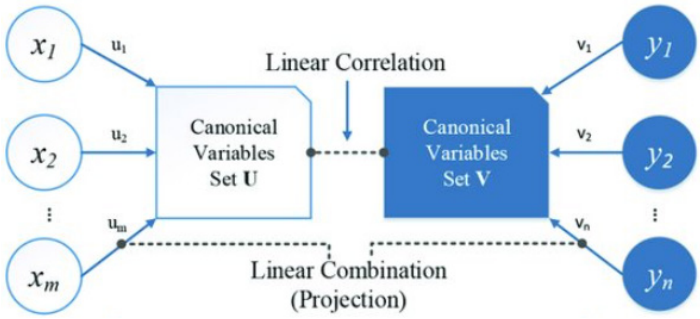

Figure 6. Schematic illustration of canonical correlation analysis

Source: own elaboration, based on (Fan et al., 2018).

The new feature space is constructed by canonical variables set U and V, which correspond to original (X and Y variables – in our case inequality and digitalisation indicators). Formally CCA can be formulated as follows:

$$\arg\max_{U \in Rp,\, V \in Rq} = \frac{U^T X^T Y V}{\sqrt{\left(U^T X^T X U (V^T Y^T Y V)\right)}} \tag{1}$$

where X is a $n \times p$ matrix that represents n samples in p-dimensional space; Y is a $n \times q$ matrix that represents n samples in q-dimensional space; X and Y are two sets of paired variables that correspond to *n* samples.

In order to investigate the potential interdependence of digitalisation and income inequalities in CEE countries, CCA was performed and tested in hierarchal form for the standardised sets of inequality and digitalisation indicators discussed in the previous section. The basic statistics of the variables used in CCA are presented in Table 1.

As already mentioned, the purpose of CCA is to determine the number of canonical variables (dimensions) that are significant in explaining the association between the set of variables related to the digitalisation and the measures related to the levels of income inequality in CEE countries. Table 2 shows the values of the canonical correlations, as well as the values of the Wilks' Lambda tests, which allows the verification of the significance of the assumed relation. The results obtained indicate that the canonical correlation is statistically different from zero for the combined canonical correlation functions (the p-value of Wilks' Lambda test

Table 1. Data used in CCA

Variables	(1) N	(2) mean	(3) sd	(4) min	(5) max
Gini coefficient	231	0.460	0.0499	0.370	0.569
Top 10% to bottom 50%	231	8.953	2.408	5.394	15.91
Top 10% share	231	0.348	0.0415	0.265	0.450
Top 1% share	231	0.116	0.0261	0.0689	0.192
Internet users	231	54.93	24.03	3.614	90.23
Fixed broadband subscriptions	220	17.13	10.51	0.0119	35.91
Mobile broadband subscriptions	141	64.60	42.63	1.895	197.4
International Internet bandwidth	135	91 168	114 647	5 084	729 708

Source: own elaboration.

for the first dimension is < 0.001), thus these results indicate that the sets of variables related to digitalisation and inequality as a group are significantly related to each other and there is a strong correlation between them. More specifically, in the case of the first pair of canonical variates (functions 1 to 4 root 1), a maximum canonical correlation of 0.7917 was extracted; this value indicates the possibility of a strong relation between the studied phenomena. Based on the residual variance, the other variates were tested in step-down order. The second, third, and fourth canonical variates had canonical correlations of 0.5701, 0.2825 and 0.1114, respectively. All but the last pairs of canonical covariates were statistically significant.

Table 2. Canonical corelation analysis results

Canonical dimensions (roots)	Canonical correlations	Wilks' lambda	$df\,1$	$df\,2$	F	Prob > F
Functions 1–4 (root 1)	0.7917	0.228902	16	348.913	13.5276	0.0000*
Functions 2–4 (root 2)	0.5701	0.613422	9	280.03	6.9194	0.0000*
Functions 3–4 (root 3)	0.2825	0.908745	4	232	2.845	0.0250*
Functions 4 (root 4)	0.1114	0.987581	1	117	1.4712	0.2276

Notes: asterisks denote 5% significance level, *p*-value is less than 0.05.

Source: own elaboration.

Table 3 shows the standardised canonical coefficients (weights) which present the relative contribution of each particular indicator to each canonical function. Standardised canonical coefficients are interpreted in a manner analogous to interpreting standardised regression coefficients. Taking into account the relative contribution of each digitalisation measure in CEE countries to each statistically

Table 3. Canonical corelation analysis results

Dimensions	Indicators	Coef.	Std. Err.	t	$P > \|t\|$	(95% Conf. Interval)	
Root 1	gini coefficient	–60.627	14.128	–4.29	0.000*	–88.598	–32.656
	top 10% to bottom 50%	0.238	0.228	1.04	0.299	–0.214	0.690
	top 10% share	73.755	15.269	4.83	0.000*	43.526	103.984
	top 1% share	–69.250	9.404	–7.36	0.000*	–87.867	–50.633
	internet users	0.092	0.010	8.86	0.000*	0.071	0.112
	fixed broadband subscriptions	0.023	0.025	0.93	0.357	–0.026	0.072
	mobile broadband subscriptions	–0.032	0.003	–10.88	0.000*	–0.038	–0.026
	international Internet bandwidth	0.000	0.000	0.52	0.601	0.000	0.000
Root 2	gini coefficient	153.867	26.391	5.83	0.000*	101.620	206.115
	top 10% to bottom 50%	–1.126	0.426	–2.64	0.009*	–1.970	–0.283
	top 10% share	–183.131	28.522	–6.42	0.000*	–239.597	–126.665
	top 1% share	108.833	17.566	6.20	0.000*	74.056	143.609
	internet users	0.064	0.019	3.33	0.001*	0.026	0.103
	fixed broadband subscriptions	–0.128	0.046	–2.75	0.007*	–0.220	–0.036
	mobile broadband subscriptions	0.025	0.006	4.58	0.000*	0.014	0.036
	international Internet bandwidth	0.000	0.000	–2.75	0.007*	0.000	0.000
Root 3	gini coefficient	–26.096	62.170	–0.42	0.675	–149.178	96.986
	top 10% to bottom 50%	2.164	1.004	2.15	0.033*	0.176	4.152
	top 10% share	–81.945	67.190	–1.22	0.225	–214.965	51.074
	top 1% share	–6.969	41.380	–0.17	0.867	–88.892	74.955
	internet users	–0.063	0.046	–1.37	0.172	–0.153	0.028
	fixed broadband subscriptions	0.278	0.109	2.54	0.012*	0.061	0.494
	mobile broadband subscriptions	0.001	0.013	0.10	0.919	–0.025	0.027
	international Internet bandwidth	0.000	0.000	–0.12	0.904	0.000	0.000

Notes: Asterisks denote 5% significance level, p-value is less than 0.05.

Source: own elaboration.

significant canonical function, that is, roots 1, 2 and 3, it can be noticed that the highest values of significant standardised canonical coefficients were observed for income inequality indicators such as the top 10% share, Gini coefficient and top 1% share, whereas in the case of digitalisation measures, the highest values of canonical weights were observed for indicators such as: Internet users and fixed and mobile broadband subscriptions.

The results of the canonical analysis indicate that there is an important relationship between inequalities and digitalisation, specifically in Central and Eastern European (CEE) countries. The analysis highlights the relative contribution of different digitalisation measures to statistically significant canonical functions.

The highest values of significant standardised canonical coefficients were observed for such income inequality indicators as the top 10% share, the Gini coefficient and the top 1% share. This suggests that income distribution plays an important role in shaping the relationship between inequalities and digitalisation in CEE countries. These indicators capture the concentration of income among the top segments of the population, which can have significant implications for social and economic dynamics.

However, the highest values of canonical weights were observed for digitalisation measures such as Internet users, fixed broadband subscriptions and mobile broadband subscriptions. This implies that these indicators of digitalisation have a strong influence on the relationship with inequalities. Internet users and broadband subscriptions represent access to information and communication technologies, which are vital for participation in the digital economy, accessing educational resources and connecting with opportunities.

The combination of high canonical coefficients for income inequality indicators and high canonical weights for digitalisation measures suggests that the level of digitalisation in CEE countries interacts with income inequalities. It implies that the extent of access and use of digital technologies has the potential to either exacerbate or alleviate existing income disparities.

Conclusions

The presented paper aimed to study the theoretical and empirical aspects of the relation between digitalisation and income inequality in CEE countries between the years 2000–2020. In the analysis of the relation between digitalisation and inequality, both qualitative and quantitative methods have been used.

The literature review indicates that the analyses related to the potential negative distributional consequences of technological change have a very long tradi-

tion dating back almost to the first independent economic analysis. While there is a broad consensus on the positive impact of digital transformation on productivity and its effect on economic growth, the impact on labour market and its different elements including expected income inequalities and wage polarisation remain a matter of debate. In the majority of conducted analyses, digital transformation is assumed to be an important driver of income inequalities; however, there is no agreement on the main channels and the scale of this relation. From one side, some authors argue that uneven diffusion of new digital technologies across firms matters greatly for both productivity dynamics and income distribution, resulting in the growing wage differences between firms. Another strand of literature assumes that wage differences arise within firms. This approach explains the growing income inequality due to changing occupational tasks or skill requirements as a result of the fact that technology increases demand for specialised skills, thus allowing skilled employees to command higher wages.

The empirical verification of the relationship between digitalisation and income inequality in CEE countries indicates that the studied countries differ significantly in terms of income inequalities and digitalisation trends. The highest level of income inequalities among the studied countries was observed in Bulgaria and Romania, while the least polarised as far as income inequalities are concerned were the Czech Republic and the Slovak Republic. Analysis of the indicators related to the digitalisation indicated a rapid increase of all indicators related to the implementation of new digital technologies in the studied period; however, some important differences can be observed. For example, in 2000 only the Estonian share of Internet users was higher than 20%, whereas in 2020 in most countries the indicator was higher than 80%.

A deeper empirical verification of the potential interdependence of digitalisation and income inequalities in CEE countries based on canonical correlation analysis indicated that the sets of variables related to digitalisation and inequality as a group are significantly related to each other and a strong correlation exists between them. Analysis of the relative contribution of each indicator to each canonical function showed that the highest values of significant standardised canonical coefficients were observed for income inequality indicators such as the top 10% share, the Gini coefficient and the top 1% share, while in digitalisation measures, the highest values of canonical weights were observed for indicators such as Internet users and fixed and mobile broadband subscriptions.

It is important to underline that conducted analysis underscore the intricate interplay between digitalisation and income inequality in CEE countries, shedding light on the multifaceted challenges and opportunities facing the region. It becomes evident that addressing the underlying socio-economic disparities is crucial for harnessing the full potential of digitalisation to foster inclusive growth. Concurrently, investments in enhancing digital infrastructure and promoting digital literacy are

imperative steps towards building a more resilient and competitive landscape in the region. By tackling these issues holistically, CEE countries can pave the way for sustainable development and ensure that the benefits of digitalisation are equitably distributed across society.

The authors want to underline that analysing the correlation between various macroeconomic values is important to acknowledge that the presence of a correlation does not necessarily establish a definitive causal relationship, nor does it provide insight into the direction of the correlation being examined. While the results of the analysis may indicate associations between variables, it is crucial to exercise caution in attributing causality or inferring a specific cause-and-effect relationship based solely on the observed correlations. To truly understand the underlying dynamics and causal mechanisms at play, further research and a comprehensive analysis of additional factors are necessary.

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Stock market return and merger and acquisition activity in Poland

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Abstract

This article explores mergers and acquisitions trends in the Polish market in a period between 2019 and 2022, focusing on transactions exceeding one million dollars and their correlation with sector-specific stock market returns. The research reveals that the real estate sector, encompassing both development and property management, dominated M&A activity, comprising 25% of transactions in 2022. Significant positive correlations were observed between transaction volumes and average stock market returns, notably in sectors like real estate (R-Pearson = 0.75) and TMT (R-Pearson = 0.87). These findings indicate that sectors with higher returns attracted more M&A activity, reflecting investor confidence and strategic growth opportunities. Despite fluctuations in company valuations post-pandemic, the overall volume of M&A transactions continued to rise, driven by firms with strong cash reserves leveraging lower valuations for strategic expansions. The study anticipates sustained momentum in technology and real estate sectors, alongside emerging opportunities in energy and biotechnology, influenced by global trends and technological advancements. This research contributes valuable insights into the evolving landscape of M&A in Poland, highlighting sectoral attractiveness and strategic implications for investors and businesses.

Keywords

- rates of return
- stock market
- economic conditions
- mergers and acquisitions
- correlation

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Introduction

Processes of mergers and acquisitions (M&A) are increasingly playing a pivotal role in the Polish economy, becoming a key driver of market dynamics since 2019. The study focuses on sectors such as real estate, technology, and energy, which attract significant investor attention. The analysis demonstrates that these industries not only grow rapidly but also offer strategic opportunities for expansion and profitability. This confirms their attractiveness to companies seeking growth opportunities and access to new markets, resulting in an increase in both the number and value of M&A transactions conducted.

1. Literature review

1.1. The role of mergers and acquisitions in the economy

The development of the financial market has led to the increased popularity of consolidative processes related to mergers and acquisitions among enterprises. Before joining the European Union, Poland's economy, during its transformation, presented numerous barriers that hindered the influx of foreign investors into the country (Piasecka-Głuszak & Adamczyk, 2010, p. 278). Consolidation processes can be motivated by various factors. In recent years, the motives for consolidating Polish companies have evolved amidst a highly dynamic market as well as legal and geopolitical environment, focusing primarily on the strategic acquisition of resources from the acquired companies. These resources aim to provide flexibility in the face of significant events and crises, such as the pandemic and war.

From an economic perspective, mergers and acquisitions can be classified as:

- horizontal mergers or acquisitions: involve companies operating in the same economic sector,
- vertical mergers or acquisitions: involve companies that operate at different stages of the same value chain or in different, but complementary, sectors,
- other mergers or acquisitions (Maćkowiak, 2012, p. 120).

Analysing M&A transactions based on the adopted strategy criterion allows the identification of processes oriented towards:

- achieving economies of scale, primarily relevant to mature markets,
- streamlining, where the strategic assumption in such mergers is vertical integration; often occurs in industries such as the fuel sector,

– the concentration of resources and, consequently, increasing the value of the offering to the customer, thereby enhancing customer loyalty to the products and services of the acquiring company (Wnorowski, 2015, p. 14).

The primary drivers of mergers and acquisitions in the Polish market differ depending on the structure and objectives of the specific transaction. One universal factor in such processes is the acquisition of assets from the target company. Increasingly observed in the market are situations where the acquirer purchases only selected assets or a portion of the target company's assets, avoiding the assumption of the target company's liabilities. Consolidation processes are conducted with various benefits in mind for the companies involved. One of the main benefits is the ability to scale and grow the business, allowing the company to expand its market share and reach new customer segments. However, the analysis of the literature shows that the degree of profitability of M&A transactions is not always the same for both parties. Numerous market studies on the effects of mergers and acquisitions of public companies indicate a general trend where the greatest beneficiaries, in terms of value creation, are the acquired companies. Shareholders of these companies achieve higher additional returns compared to the shareholders of the acquiring companies (Perepeczo, 2011, p. 460).

Geographical expansion into new markets facilitates the adoption of new technologies, acquisition of talented employees from foreign markets and development of product portfolios, particularly crucial for companies providing IT solutions, such as software for production. Another motive for consolidating several companies is the optimisation of operating costs through the elimination of duplicated resources. Strategic motives include the pursuit of increasing added value and market share, as well as the elimination of unnecessary assets. Financial motives can involve the use of excess cash and an increase in stock value in the capital market (Maćkowiak, 2012, p. 121).

In the aftermath of mergers or acquisitions, merged companies often leverage economies of scale in purchasing, production and distribution. Diversification of the product portfolio is another key driver, helping companies reduce the risk associated with operating in specific markets. Furthermore, unfavourable economic events, such as pandemics or wars, typically foster intensified M&A activity, as entities with significant market share and high cash reserves invest in the assets of financially distressed companies. These issues align with the topics described in the literature related to the creation of synergy effects as a result of mergers and acquisitions. These factors can be divided into two groups: operational, such as increasing sales revenue, reducing operating costs and enhancing the growth dynamics of the company, and financial, such as tax benefits, the utilisation of excess cash and reducing the cost of capital (Maćkowiak, 2012, p. 128). This trend has been observed in the Polish market in recent years.

Companies often strive to achieve synergy by integrating different types of activities into a single economic entity or in the form of a capital group. This is because the combined enterprise can gain access to resources and capabilities that it would not have had before merging or forming a new company (through a merger), such as a knowledge base, patents or licenses (Łojek & Toborek-Mazur, 2022, p. 61). The synergy effect means that companies that are capital integrated or organisationally integrated can generate greater value than separate economic entities. This value, which arises from the merger of companies, represents a real increase in wealth for shareholders (Maćkowiak, 2012, p. 126).

If a merger or acquisition is executed efficiently and effectively, it can bring value to the shareholders of both the acquiring and target companies in the form of increased stock prices, dividends expanded market share and investor interest. This strengthens the market competitiveness of the acquiring company, which gains new assets for future economic benefits. Acquiring a competitive company can reinforce and increase market position, making it easier to acquire new customer segments and expand into foreign markets. In the analysis of M&A transaction motives, it is important not to overlook strictly financial factors, such as the utilisation of internal surpluses or the reduction of capital costs. Every company aims to maximise profits while minimising the use of its own capital. This objective allows for the establishment of financial and technical foundations that are essential for the company's further development, especially in highly competitive markets or in unstable economic conditions (Łojek & Toborek-Mazur, 2022, p. 62).

In addition to the mentioned motivators of M&A processes, other factors include:

- convergence of technologically advanced industries,
- low technological capabilities and the need for improvement,
- adoption of a multinational or transnational strategy,
- supply of local companies, e.g. as part of privatisation programs,
- strengthening market position,
- interests in culturally and psychologically distant countries (Piasecka-Głuszak & Adamczyk, 2010, p. 278).

The creation of value for the target company's shareholders can also occur when a bank is involved in the transaction. The benefits or losses for the acquiring party are also ambiguous in the case of banks, which also applies to the outcomes of the transaction (Perepeczo, 2011, p. 460). Mergers and acquisitions also create strict financial potential related to the consolidation of capital and, consequently, gain new sources of financing needed for the development and implementation of new investment and research projects.

While enumerating the benefits of mergers and acquisitions, it is essential to acknowledge that these processes entail risks and do not always yield expected

results. Therefore, it is crucial to conduct thorough preparation and analysis before commencing a transaction, as well as careful management of integration and resource consolidation after its completion. Contemporary mergers and acquisitions are more strategic than ever, with the potential for development being a decisive factor in the acquisition of a company, mainly derived from accumulated knowledge (Wnorowski, 2015, p. 17). Consolidation often involves industries in a growth phase, making it significant to examine rates of return from a specific market along with the number of mergers and acquisitions in the industry.

1.2. Current trends in the mergers and acquisitions market in Poland

According to reports prepared by Navigator Capital Group and Fordata, as well as a report by Grant Thornton (2023), the Polish market witnessed 341 disclosed-price M&A transactions in 2022, representing an increase of 18% compared to the previous year and surpassing the 300 transactions barrier for the first time since 2010. This record-high number of M&A transactions in 2022 indicates that challenges and unexpected situations in the market, such as the COVID-19 pandemic and the war in Ukraine, do not discourage investors from acquiring stakes in Polish companies. On the contrary, they seem to favour consolidation across different sectors of the economy.

Notably, nearly three-quarters of transactions in recent years in the Polish market have involved industry investors, with the primary goal of achieving synergy effects and the long-term development of the acquired companies. Financial investors accounted for the remaining 20% of transactions. The average EBITDA of the target companies in M&A transactions in Poland in 2022 was PLN 10 million, with revenues at the level of PLN 90 million, confirming that small and medium-sized enterprises have been the most attractive targets for consolidation processes in the Polish market.

A noteworthy observation is the decrease in the average valuations of companies undergoing M&A processes in 2022 compared to the previous year. This trend is likely influenced by the situation on the Polish stock exchange and the consequences of the financial crisis, which may contribute to the decline in the value of assets of acquired companies. The popularity of flexible mechanisms for determining transaction prices, such as splitting the price into tranches and settling part of the price based on the future financial performance of the company, is directly linked to the decrease in average valuations.

Similarly, there is a growing emphasis on the responsibility of sellers for the compliance of business assumptions with applicable law (compliance) and social

good (ESG). Investors pay particular attention to issues related to sanctions, anti-money laundering (AML) and environmental protection. In response to lessons learned from the early months of the pandemic, investors are now incorporating force majeure and material adverse change clauses into M&A transactions, ensuring flexibility in their commitments to close transactions in the event of unforeseen market events with a significant impact on their operations.

According to the M&A Index Poland report by Navigator Capital Group and Fordata (Navigator Capital Group & Fordata, 2023), global private capital reached nearly 2 trillion dollars in 2022, and it is estimated that with the end of the decade, the so-called "dry powder", i.e. unallocated capital on the market, will constitute over 25% of the assets of private equity and venture capital funds. In 2022, there were 13 acquisitions in the Polish market involving private equity funds, representing an increase of 5 compared to the same period in 2021. Industries such as telecommunications, media, technology (TMT), real estate, as well as the energy sector were particularly attractive for such transactions.

Despite the challenging market environment, the increasing number of M&A transactions indicates positive perception of the Polish market by foreign investors, unaffected even by the ongoing armed conflict on the eastern border of the country. This is attributed to the faster development of Central and Eastern European countries compared to parts of Western Europe and the more attractive valuations of investment targets in these regions. Analysing the structure of investors in the Polish M&A market, private investors dominated among sellers, accounting for two-thirds of announced transactions, while the share of private equity and venture capital funds among buyers remained similar to the previous year, standing at 11%.

A study conducted by Grzegorz Bącal and Jarosław Bem revealed that in 2012, the largest share of all disclosed transactions (14.2%) involved the manufacturing sector, followed by the finance and insurance sectors, contributing to 10% of all transactions, and the TMT sector, which accounted for 8.8% (Bącal & Bem, 2014). Taking into account the current M&A market structure in Poland, it can be inferred that the trends observed in the early part of the last decade have been maintained, leading to increased investment attractiveness in the M&A market for companies in modern sectors of the economy.

Grant Thornton analysts, in their report covering the years 2017–2022, found that over 75% of all transactions in the M&A market concerned traditional industries, providing basic societal needs related to food production, cleanliness products, household goods, as well as infrastructure and industry (Grant Thornton, 2023). Investors still aim to acquire entities in traditional markets, where typically large and mature companies operate, providing synergies and expanding strategic options. The attractiveness of the Polish market increases further as production and labour costs in Poland remain lower than in Western European countries. However, the share of transactions in the TMT sector has been growing year by

year. In 2017, there were 26 transactions in this sector, increasing to 54 in 2021 and further to 73 in 2022. Simultaneously, the consumer products sector saw the fewest transactions in 2022 since 2010. Similarly, the energy sector, including photovoltaic farms and wind energy, has gained increasing interest over the years, with transaction volume growing from 8 to 51 between 2017 and 2022.

In a report by Kochański & Partners focusing on the M&A market structure in the first half of 2019, 17 out of 62 transactions involved real estate and property development, making it the largest industry in the study, accounting for over 27% of all transactions (Kochański & Partners, 2019). Over 11% of deals were signed between entities in the IT sector providing e-commerce services and software production, and nearly 10% of transactions occurred in the medical and biotechnological industries. These findings align with trends from other reports and studies, emphasising the investment attractiveness of the IT and medical sectors.

The existing research on the transaction structure is also complemented by a report published by the consulting company KPMG, which shows that in 2022 there were over 340 M&A transactions (KPMG, 2023). There could have been even more such transactions, but naturally, some of them were not finalised, and the main reason for departing from the considered transaction was the seller's overly high expectations. However, the main investment motive for strategic investors is to acquire client portfolios, distribution channels as well as product/service portfolios. Among the other most frequently cited motives for merger and acquisition transactions by investors are cost synergies (28% strategic investors and 14% financial investors), business diversification (28%) and geographic expansion (28%). Also noteworthy is the fact that in the group of strategic investors, 16% of transactions amounted to sums exceeding PLN 500 million, and 24% up to PLN 100 million, while among financial investors, the largest group (43%) comprised investments worth less than PLN 100 million. The report also presents a group of economic sectors that are most attractive to investors in the mergers and acquisitions market. Among them, 47% of investors point to companies related to new technologies, 32% to healthcare, 32% to the e-commerce sector and IT companies, and 30% of investors are interested in renewable energy. According to the authors of the report in question, the value of the Polish capital transactions market in 2022 amounted to PLN 74.9 billion, and the annual value of private equity investments in Poland reached PLN 2.1 billion in 2022, which is 30% less than in 2021.

Similar research has also been conducted in foreign centres and published in their literature. Many authors have drawn interesting conclusions from their studies. Heater et al. (2021) confirmed the role of aggregated M&A activity in predicting future returns, in line with price reaction to improved macroeconomic outcomes resulting from such activity. Choi et al. (2020) examined the dynamics of M&A activity and sectoral efficiency. They confirmed a positive relationship between these variables, with M&A activity playing a key role in identifying industries with high

potential. This study also focused on the correlation between M&A activity and financial performance at the industry level. Kellner (2024) examined the European mergers and acquisitions market from 2010 to 2021 in the context of reflecting the effects of these transactions on the stock prices of acquiring and acquired companies. The results of his study indicate a strong positive increase in the stock prices of target companies, but a minor reaction from the acquirer. Bos et al. (2018) analysed the oil stock market by examining the predictive ability of mergers and acquisitions (M&A) in relation to returns and volatility of oil. The authors indicate that M&A activity conducted by oil companies carries significant predictive power both in terms of oil profits and their volatility. Grigorieva (2020) focused her research on analysing M&A transactions in developed and emerging capital markets in the context of increasing efficiency. The results of the author's research indicate that in developed capital markets, shareholders of acquiring companies usually achieve slight profits in the short term, while in emerging economies, shareholders of these companies mainly benefit from merger and acquisition transactions.

When comparing the main motivators of mergers and acquisitions in the analysed period and in the earlier period, from the beginning of the 21st century, based on the cited literature, a fundamental difference between these factors on the Polish market should be indicated. In the first two decades of the current century, the aim of M&A processes was mainly to acquire a broader infrastructure and resource base in natural or human terms, as well as to combine capital to increase investment capabilities. In the current period, when most companies undergoing M&A processes are in a mature phase of their operations, the motivations for these transactions are based on reducing the cost of capital, acquiring new sources of funding and opening up to new markets to diversify operations.

2. Methodology

The subject of the study conducted in this article is transactions on the Polish M&A market in the years 2019–2022 with a disclosed value exceeding 1 million dollars. Such a criterion allowed for the analysis of transactions in a representative sample involving companies with a significant position in their industry and high asset value. In 2019, there were 95 transactions; in 2020, there were 77; in the following year, 72 transactions with a value exceeding one million dollars were recorded, and in 2022, there were 55 agreements in the examined sample. The study focused on the industry structure of these transactions and data on the profile of activities of the acquired companies, and the transaction volume based on the specified criterion was obtained from the EMIS DealWatch database. This information was compared with the rates of return on stock investments in compa-

nies from the respective sectors, which were obtained from the industry database on the Biznes Radar platform. To present the correlation between the volume of M&A transactions and the rates of return from a given sector, the Pearson correlation coefficient was calculated, based on which the statistical significance and strength of this correlation were determined.

3. Results and discussion

3.1. The industries structure of mergers and acquisitions transactions in Poland in the years 2019–2022

The first stage of the study, addressed in this article, involves identifying the main sectors with the highest number of mergers and acquisitions in the years 2019–2022 in the Polish market, as well as analysing the dynamics of changes between individual industries during this period. The analysed period encompassed numerous unforeseen yet impactful events on inflation levels and the situation of Polish entrepreneurs, including the COVID-19 pandemic and the outbreak of the war in Ukraine. For each year within the specified timeframe, M&A transactions that took place in the Polish market and had a value exceeding 1 million dollars were selected from the EMIS DealWatch database. The results of these studies, broken down by economic sectors and the number of transactions, are presented in Table 1.

Table 1. Volume of M&A transactions with value exceeding 1 million dollars in Poland in 2019–2022

Industry	2019	2020	2021	2022
Medical	0	2	0	0
Industrial	5	12	4	5
Food	2	0	3	0
TMT	8	14	13	5
Energy	5	6	11	5
Financial	3	9	7	1
Construction	19	6	6	15
Logistics	0	1	1	0
Real estate rental	24	8	12	10
Others	29	19	15	14
Total	**95**	**77**	**72**	**55**

Source: own study.

The first observation that can be made is the total number of all transactions each year above one million dollars – it decreases each year, which may be a result of investors' concern and increased caution in the M&A market in Poland due to the pandemic and the outbreak of war on our eastern border. In 2019, this market condition favoured M&A transactions because the valuations of individual company stocks and industry indexes were rising, giving investors hope for further growth. Their enthusiasm was interrupted by the COVID-19 pandemic, which led to a decline in the value of company stocks and indexes, as well as reduced availability of capital that companies could allocate to further investments in assets of other entities. As a consequence, in 2022, there was a decrease of over 40% in the number of transactions compared to 2019.

From the analysis of the data in Table 1, it is evident that the most popular industries for investors in the context of M&A transactions are those related to real estate leasing, construction and broadly defined TMT services. In recent years, the real estate market has seen a steady increase in the value of properties and rental rates, convincing investors to acquire stocks of companies offering protection of capital against high inflation and a steady return in the form of dividends. Difficulties in the housing market related to the shortage of properties for potential buyers and various government programs primarily targeting young people looking to buy their first home have created an attractive time window for developers expecting high returns from their construction projects mainly related to building new residential blocks. Companies offering IT services, software production and IT infrastructure systems which automate business operation have also been frequent subjects of M&A transactions. This is not surprising because the IT industry is an attractive place for investors expecting a high level and regularity of cash flows from investments in a particular company. Moreover, this sec-

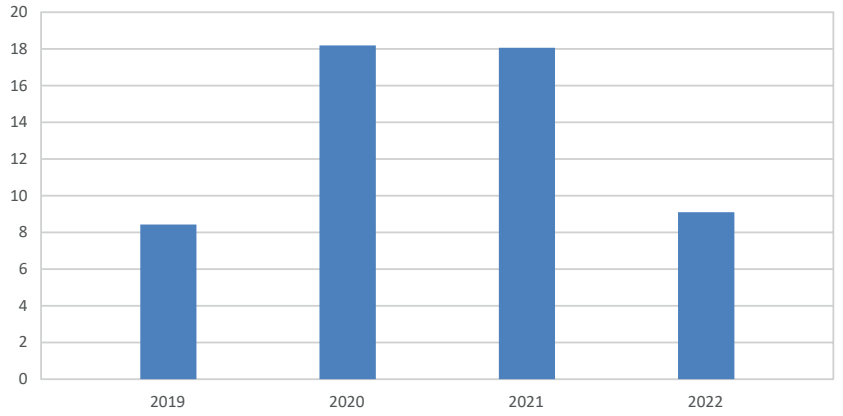

Figure 1. Share of the TMT sector in the total number of analysed transactions (in %)

Source: own study.

tor is in constant development and has a high potential for further growth due to the popularisation of IT services and the use of software for companies in various industries. The share of this sector in the total transactions in each year is presented in Figure 1.

As may be seen in Figure 1, the highest number of entities undergoing consolidation processes occurred in the year 2020, where 18% of transactions involved the acquisition of shares or taking control of companies providing IT services, software and telecommunications.

The next position in terms of the transaction volume was industrial production, including industrial processing, production of plastics and steel, furniture and window joinery, as well as household goods. With the increasing number of apartments on the market and newly constructed houses, industrial products necessary in the construction process and interior finishing exhibit high market demand. In the valuation reality of industrial companies, which are below the average in recent years, entities with a significant market share and high cash reserves invest in the assets of smaller companies showing considerable potential for further growth.

The energy sector is also noteworthy in the analysis of the main industries undergoing consolidation processes in the Polish market in 2022. This is particularly important from the perspective of investors expecting high returns on investments in a given company. Polish entities implementing projects in the field of renewable energy sources (RES), energy infrastructure, installation of photovoltaic panels and heat pumps, as well as in the field of hydropower, are an attractive target for consolidation processes, confirming the findings of the conducted study. Figure 2 shows the share of transactions in the energy industry analysed in the years 2019–2022.

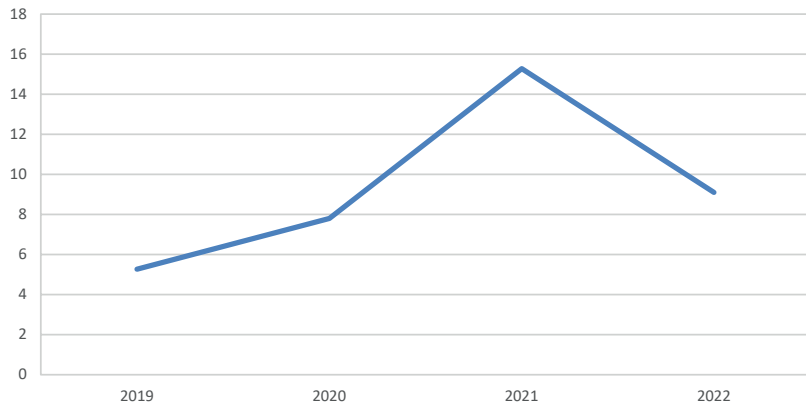

Figure 2. Share of transactions in the energy sector in the entire sample in 2019–2022 (in %)

Source: own study.

The largest share of transactions in the energy sector was recorded in 2021, when it reached 15%. In the following two years, this share decreased. However, due to strong emphasis by state and private institutions on the use of renewable energy sources, energy independence and gradual reduction in the use of fossil fuels for energy production, the number of transactions in the renewable energy sector and entities developing energy infrastructure should continue to grow steadily in the coming years, catching up with the level of consolidation in the TMT and real estate sectors.

Another noteworthy sector is the one related to medical services, innovations and biotechnology, where only 2 transactions exceeding one million dollars were recorded in 2020. This situation is surprising, taking into account market trends which see growth factors for medical and biotechnology companies in global indices in the coming years. One reason for this may be that this industry usually consists of start-up entities, whose value does not always exceed one million dollars for consolidation purposes. Additionally, the Polish biotechnological sector is not among the strongest, and the medical companies in Poland are not highly competitive globally at the moment, which may also impact the lower intensity of M&A processes in this sector. Similar to the TMT industry, the share of mergers and acquisitions in medical companies in the overall transaction volume should increase in the coming years due to global trends, which largely focus on health protection services, medical infrastructure, software and IT systems supporting the operation of healthcare facilities.

The category labelled as "Others" in this study mainly includes transactions in the automotive, fitness, financial intermediation and insurance industries. Figure 3 depicts the structure of the Polish M&A market in 2022, the last year of analysis, already in the post-pandemic period and after the outbreak of the war in Ukraine.

The analysis of the above chart reveals that transactions in the construction sector constituted 25% of the total in 2022, meaning that every fourth recorded transaction involved a merger or acquisition of shares between developers undertaking residential and independent block construction projects. Consolidations of companies managing packages of residential or commercial properties accounted for 18% of the transactions. The sectors described above, which ranked in terms of transaction frequency, including industrial production, TMT and the energy industry, each represented 9% of the total analysed transactions.

According to the presented analysis, potential investors seeking to acquire assets in other companies in Poland are focusing on industries benefiting from a good real estate market, such as residential housing developments, single-family homes and office buildings. Additionally, companies involved in renting these properties to individual and institutional clients are experiencing rapid growth. Software development companies, encompassing telecommunication services, new technologies and a variety of IT services, including software production and

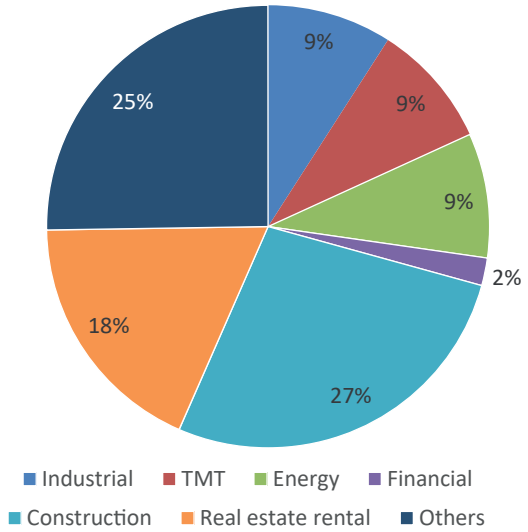

Figure 3. Industry structure of the Polish M&A market in 2022

Source: own study.

artificial intelligence, are also rapidly expanding and becoming primary targets for consolidation processes in the Polish and global markets.

Analysing the results of the study, one notable aspect is the high participation of transactions in sectors of the traditional economy, including industrial production and services. Poland is still a developing market, and the dynamics depend on economic conditions. Therefore, manufacturing companies related to the steel industry, production of plastic elements, windows and roofing still demonstrate high growth potential in the long term, attracting investors acquiring stakes in consolidation processes.

Analysts predict that in the coming years, transactions in traditional economy sectors will gradually decrease in favour of knowledge-based economy sectors such as TMT. The sector related to medicine and biotechnology may gain importance in terms of transaction volume due to global trends, Poland's demographic situation, an ageing population and advancements in clinical and laboratory research.

In conclusion, the findings from the research align with qualitative information regarding the attractiveness of sectors based on trends from reports and articles addressing investment potential in these industries. To determine whether the number of merger and acquisition transactions is indeed correlated with the investment attractiveness of a sector, an analysis of the correlation between the number of transactions and stock market returns in a given sector was conducted.

3.2. Correlation of M&A transaction volume in a given sector with stock market return rates

The chart below illustrates the total transaction volume during the analysis period in a given sector and the average rate of return from the stock index of a given sector between 2019 and 2022. This data was used to calculate the Pearson correlation coefficient for each analysed industry.

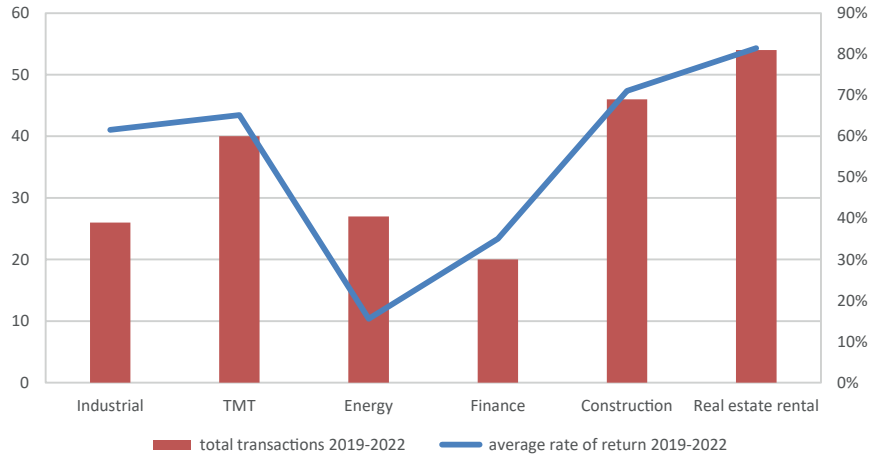

Figure 4. Total transactions and average rate of return of the given industry index in 2019–2022

Source: own study.

As we can see in Figure 4, the highest average rate of return during the study period were recorded for companies involved in real estate rental and construction. Additionally, these companies experienced the highest number of M&A transactions. Based on the graphical analysis of the chart's layout, it can be concluded that there is a positive correlation between the indicated variables. The exact value of this correlation was determined in the subsequent stage of the study.

Table 2 presents the Pearson correlation coefficient (R-Pearson) between the number of M&A transactions in the Polish market during the study period and the rates of return from the index of a given sector.

In each subsequent year of the analysis, which was the subject of the study, the companies most frequently involved in M&A processes represented the real estate sector, with particular emphasis on development companies and companies managing rental properties. A strong correlation has been observed between the attractiveness of this industry for investors and the level of rates of return from

Table 2. Correlation coefficient between transaction volume and rates of return from the index of a given sector in 2019–2022 on the Polish market

Industry	*R*-Pearson
Broad market	0.89**
Industrial	0.62**
TMT	0.87**
Energy	0.16**
Finance	0.77**
Construction	0.84**
Real estate rental	0.75**

** p-value < 0.05.

Source: own study.

this index – in 2022, the average rate of return from the index of development companies was 29.9%, and for companies renting real estate – 31%; outside the TMT sector, it was the highest level of rates of return from industry indexes analysed in this study in 2022. When interpreting the data in Table 2 above, what is noteworthy is the high value of the correlation coefficient between the volume of all transactions above 1 million dollars and the rate of return from the entire market index; it indicates a strong interdependence between these two variables from the perspective of the overall market, without dividing into individual sectors. M&A market activity and its intensity are a direct consequence of companies' ability to generate high and regular cash flows and increase their value; hence, such a high level of this dependency indicates rates of return from the shares of these companies as one of the main factors that investors pay attention to when assessing the profitability of M&A processes. Similarly, a high level of the studied correlation coefficient, indicating a significant and strong dependency, was also noted for the TMT and construction sectors. It is de facto a confirmation of the observation of market analysts who, due to the increasingly wider application of artificial intelligence and implemented housing programs, see companies from these two sectors of the economy as attractive investment entities with high potential for further growth in value. Throughout the study period, the industrial sector, i.e. the branch of the traditional economy, whose index also showed steady returns, presented a high share in the total number of transactions – in 2021, it was even 38%. The exception to the rule described above is the energy sector; in 2021, there were 11 transactions involving companies from this industry, the most in the analysed period, and in 2020, there were 6 such transactions, even though the rate of return on the index was negative in both years (–20.1% and –12.8%, respectively). In 2022, however, despite the average rate of return on this

index above 6%, influenced by the widespread use of heat pumps along with photovoltaic panels, as a step towards increasing energy independence and moving away from the use of fossil fuels, there was no increase in the number of transactions; on the contrary, there was a decrease of over 100% (from 11 in 2021 to 5 in 2022). This inversely proportional regularity in transactions and rates of return of the energy companies index is confirmed by the relatively low level of the Pearson correlation coefficient compared to other analysed industries, which indicates a low level of dependency between the two analysed features in the conducted correlation analysis.

The analysis of the above dependencies, which they represent, confirms, in principle, a directly proportional relationship between rates of return from a given sector and the volume of M&A transactions in those industries, and the thesis that the most attractive entities in the M&A market are companies whose share value is increasing, contributing to higher rates of return from the index of a given sector. The analysis of the Pearson correlation between the rates of return on the industry index and the number of M&A transactions in a given industry was 0.70, indicating a significant relationship of moderate strength between the phenomena described in this subsection.

Conclusion

In the Polish mergers and acquisitions market, records in the volume of completed and disclosed transactions, both in terms of quantity and value, are broken year by year. Even though in 2022 valuations of acquired companies fell below the average of the previous years, the increasing number of transactions indicates a good financial condition of Polish companies, both on the acquirer's side, which has high cash reserves to purchase assets of other companies, and on the target side, where businesses have developed enough to be attractive to larger entities in their sector. The high cash reserves, often used to acquire stakes in other companies, may result from financial shields received in high value by large companies during the COVID-19 pandemic and surpluses retained in companies in the years 2016–2019, when the Polish market experienced a good economic boom and many companies significantly improved their financial results. These factors contribute to the post-pandemic years when company valuations are lower; larger entities can acquire smaller players in their industries, counting on economic recovery and the continued ability of these companies to generate high profits and cash flows. Many industry leaders, such as Orlen acquiring Lotos, engage in consolidation processes to achieve synergy and scalability in their business and gain

new customer segments. The structure of M&A transactions in the Polish market from 2019 to 2022 aligns with global trends, with a particular focus on companies in the field of new technologies, IT services and those leveraging artificial intelligence. Real estate management companies are also emphasised, benefiting from favourable market conditions. Based on the analysis presented in this article and observations of the development trends in the Polish market, further growth in the significance of the mentioned sectors in terms of investment attractiveness is anticipated. Additionally, the author foresees significant consolidation potential for energy companies, those involved in defence and military equipment, as well as companies providing services based on artificial intelligence, which have the opportunity to revolutionise the Polish and global markets similarly to the impact of the Internet.

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