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EDITORIAL

SCIENTIFIC ARTICLES

Editorial

JAN MERTL

Dear readers,

time has passed by, and we are offering you to read the new issue of ACTA VSFS journal. We have encountered one personal change – our editor-in-chief, Petr Wawrosz finished in its role and passed the scepter to me. I would like to thank Petr for his work at ACTA, as he significantly contributed to the journal's development during recent years, both as editor-in-chief and member of the executive board. I do not consider it as a formal farewell, but he really left his trail at the journal's shaping and focus and helped to improve the quality of its content.

Because of my new role, the place of executive editor has been vacated and I welcomed that a colleague of mine, Naděžda Petrů, had agreed to collaborate with me on the journal. Because she has a different research/scientific profile than me, she can help to improve and widen the process of articles' selection and I hope this will pay off during the future issues.

We have prepared four articles for you in this issue.

The first one, "Audit committee characteristics and environmental disclosure among Nigeria listed non-financial firms", comes from afar and looks at the influence of audit committee characteristics on corporate environmental disclosure. The study found evidence of the critical role of audit committee characteristics in the disclosure of environmental information by Nigerian listed non-financial companies. Therefore, the authors recommend that efforts should be made to encourage a higher composition of female and independent members on the audit committee.

The second one titled "Correlation between the ECB Pandemic Policy and the STOXX Europe 600 Sector Performance Sensitivity" is by a German co-author and focuses on financial markets related to central banking. The results confirm a correlation for the selected sectors, indicating a possible general sensitivity for the entire period under investigation. On this basis, further research on sectors and variables such as inflation and a comparison with Fed interest rates and the S&P 500 is recommended.

The third paper "Linkages between property prices and macroeconomic determinants: evidence from Germany" is also by a German author. It takes into account that property prices currently play an important role on the financial markets, but also exhibit significant macroeconomic correlations. On the one hand, the results confirm a positive relationship between real estate prices and real GDP. On the other hand, a negative correlation was found for real short-term interest rates and inflation. No significant relationships were found between real estate prices and the unemployment rate or long-term interest rates, despite a culture of long-term fixed interest rates in Germany.

The fourth paper titled "Relations between development of e-government and government effectiveness, control of corruption and rule of law in 2010–2020: a cluster analysis" comes from Czech author. Its aim is to compare the progress of e-government between

2010 and 2020 in the member states of the European Union based on selected global indices. It is an interesting topic researched on international comparative basis. The best results in this area are achieved by the states in the north of the EU (for example, Denmark, Finland and Sweden), on the contrary, the worst results are achieved by the states in the east of the EU (for example, Bulgaria and Romania).

One more change is, that this issue is published in physical form, but since the next issue we shall have published our journal in electronic form only. That is a big shift of the form of publishing, but it corresponds with current trends in journals' development and good practice. The readers can also register at the website for email notification that they receive when the new issue is released. So, the convenience and content for the reader will remain the same, even if the physical form vanishes.

I hope that you'll remain faithful to our journal. I wish you a pleasant reading and Happy New Year 2024!

Doc. Ing. Jan Mertl, Ph.D.
editor-in-chief

Audit Committee Characteristics and Environmental Disclosure Among Nigeria Listed Non-Financial Firms

ADEBAYO OLAGUNJU, RISIKAT MOTUNRAYO SHITTU, TITILAYO MOROMOKE OLADEJO, AMOS OLUSOLA AKINOLA, NUKA NADUM NWIKPASI & RUTH TONY OBIOSA

Abstract

This study investigates the influence of audit committee attributes on the corporate environmental disclosure using listed non-financial firms in Nigeria as case study. The population of the study consists of all non-financial listed firms on the Nigerian Exchange Group (formerly NSE). Using purposive sampling techniques, the study selected a total 70 listed non-financial firms having required information necessary for the study between 2011 and 2020. The study employed fixed effect and feasible generalized least square (FGLS) panel regression technique. The fixed effect of FGLS regression analysis indicates that while audit committee independent and audit committee gender diversity recorded significant positive influence on the environmental disclosure among Nigerian listed non-financial firms, the impact of audit committee size and audit committee meetings were negligible. Based on results, it is not the size of the committee nor the number of their meetings that matter for the disclosure of environmental information but the composition of the committee in terms of female and independent members representation. In conclusion, the study found evidence in support of the critical role of audit committee characteristics in environmental disclosure practices among Nigerian listed non-financial firms. Hence, it is recommended that efforts should be made to encourage higher composition of female and independent members on the audit committee.

Keywords

environmental disclosure, audit committee diversity, audit committee independence, audit committee meetings, audit committee size

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1 Introduction

Though the expansion of business sector influence economic development of a nation through its impact on humans, corporate activities which affect country's environment through its contribution to natural disasters and environmental pollution (Li et al., 2018). Throughout the past few decades, the effects of industrial activity on the environment have resulted in serious ecological issues. This in addition to other human activities resulting in over-exploitation of natural resources and pollution, is a contributory factor to the nearly collapse of the environment in recent time. The sustainability of the economies of nations around the world, especially those in sub-Saharan Africa, has been harmed by the worsening of problems including climate change, air pollution, and hazardous wastes (Nwobu et al., 2018; Ozordi et al., 2018).

Many literatures have documented the potential adverse effect of corporate activities on the operating environment (Ghani et al., 2018; Wilson et al., 2011). The current accounting and corporate finance literature places high priority relating to the requirement for assessments of environmental effects and reporting as a means of effectively reducing the negative effects of various companies' operations (Ghani et al., 2018; Rokhmawati & Gunardi, 2017). To avoid the detrimental effects of corporate activity on the environment, corporate entities are required to conduct themselves responsibly. It was reported for instance that rail, hospital beds, telephones, computer keyboards, and automated teller machines are transmission agents of microorganisms (Wilson et al., 2011). Industries environmental pollution and many incidences of respiratory infections and chronic obstructive lung illnesses have really been linked to climate change difficulties (Nriagu et al., 2016). Increase in domestic and multinational food companies have been characterized with potential negative environmental health impact (Akbas, 2016; Khoiruman & Haryanto, 2017).

Governments and international organizations and other stakeholders are increasingly concerned with the issue of global warming arising from environmental pollution (Kalu et al., 2016). One of the main focuses of the UN's sustainable development goals, which are supported by all nations in the world, is conscientious production that reduces environmental damage. Concerned efforts must be put in place to prevent further deterioration of the environment and restore its stability (Syed & Tollamadugu, 2019). Corporate entities must therefore submit information about their activities in the situated area to demonstrate how fully they uphold their environmental responsibilities. The timely disclosure of considerable information by firms is therefore expected to influence the corporate social image of the firm as it affords the public the opportunity to monitor the sustainability behaviour of the corporate entity effectively. For stakeholders to accurately and rationally assess performance and take necessary action, high-quality environmental information must be published (Global Reporting Initiative, GRI, 2013). Through its impact on social image, environmental disclosure in an organization is linked with the financial and market performance of the firm (Odoemelam & Okafor, 2018).

Given its potential to affect the firm market and financial performance, environmental issues resulting from the corporate activities has been receiving attention from the shareholders

of corporate entities also (Joshi & Li, 2016; Li et al., 2016; Wang, 2016). Hence, policy makers, are particularly being placed under obligation to show more commitment towards achieving an environmentally friendly operations as its benefits to humanity is tremendous (Mulyanto et al., 2018; Votsi et al., 2017). The question that has continued to come up in corporate finance literature in the last decade is therefore centres around the factors that drive the environmental disclosure in corporate firms. Corporate environmental disclosure is the practice of businesses that operate in an environment disclosing accurate and timely relevant data (Bateman et al., 2017). Few business entities often include this information in their annual reports (de Villiers et al., 2017).

Disclosing environmental impact of a company's operations is still optional (Plumlee et al., 2015), many annual reports of corporate firms, particularly in developing nations like Nigeria (Al-Janadi et al., 2012; Odoemelam & Okafor, 2018), severely lack this information. Additionally, when it does exist, such details are usually selective as organizations only disclose information that is favorable (Deegan & Gordon, 1996). Environmental disclosure practice is reportedly weak in developing countries (Biobele & Mefor, 2012) and required data for controlling the environment are often unreliable (Botero et al., 2015). Thus, the relevant data is less visible in the annual reports of the entities, investors and regulators may rely on outside information for their valuation judgments (Asay et al., 2017). One major topic that has been linked with environmental disclosure among corporate entities is corporate governance.

The corporate governance system of the organization will determine what, how, when, and how much information should be disclosed about these environmental issues (e.g. Agyei-Mensah, 2016; Akbas, 2016; Cormier et al., 2015; Elsakit & Worthington, 2014; Liao et al., 2015; Mayorga & Trotman, 2016; Trireksani & Djajadikerta, 2016). Research from developed and developing nations has shown that business governance affects environmental exposure (Akbas, 2016; Umoren et al., 2015; Trireksani & Djajadikerta, 2016). Audit committee characteristics are a significant corporate governance instrument that possibly affecting environmental reporting procedures.

The disclosure of environmental information is strategic choice that is within the purview of the management of the companies. In making this decision, the management relies often in the advice from its various committees including the audit committees. Given its monitoring role, audit committee attributes including its size, independence, gender diversity and meetings may thus find out how much sustainability data the business has disclosed.

Even though there have been number of attempts in literature to assess the effect of corporate governance on environmental disclosure, very few studies focus on the effect attributes of audit committee on firms' environmental disclosure. Theses few studies have produced mixed results especially in Nigeria due to the sectoral coverage and variation in the method of analysis employed. Majority of the existing studies have failed to take endogeneity issue into cognizance. This study does not only test for the endogeneity problem but demonstrated how endogeneity issue observed was addressed. The outcome of this study is expected to be indispensable to the corporate firms in Nigeria and to regulators in the country. Firms that operate in Nigeria and in other developing countries

can leverage on the outcome of this study to achieve a responsible production process that will reduce carbon emissions and other activities that damage the environment.

2 Literature Review

2.1 Conceptual Review

Environmental Disclosure

According to Mamman et al. (2021), environmental disclosure is the process of informing diverse stakeholders about the environmental effects of corporate operations. Environmental disclosure also refers to the dissemination of data to various stakeholder groups regarding the operational performance of businesses that have impact on the environment. Businesses can share their environmental performance through corporate environmental reporting, sometimes called environmental disclosure.

The process through which a business notifies different stakeholders, such as staff, local communities, shareholders, consumers, the government, and environmental groups, about the range of its management of operations impact on environmental is known as environmental disclosure. In Nigeria, environmental information disclosure refers to voluntary disclosures made by businesses more than legal obligations or managerial decisions to give accounting and other information deemed important for annual report readers to make decisions (Tashakor, 2014). In considering the broad nature and extent of the idea, Environmental disclosure, according to Adam et al. (2016), is a strategy for sharing environmental data on an enterprise's impact, effectiveness, and commitment to environmentally sustainable initiatives.

Audit Committee

A sub-committee of board of directors called audit committee (AC) is in charge of confirming the reliability and accuracy of the financial statements that management provides (Kuang, 2007). The objective of the audit committee's monitoring process is to enhance the quality of information disclosure to all relevant stakeholders (Mamman et al., 2021). The audit committee, which oversees financial reporting and other information disclosure, constitutes one of the board of directors' primary operating committees. The audit committee in Nigeria is required to review the company's financial statements, among other things, in accordance with section 359(6) of CAMA (2020), as amended. The statute also mandates that the audit committee assess the scope and findings of external auditors in order to reinforce their objectivity and ensuring that the company keeps up a strong internal control and accounting process. Like this, every year, AC assesses risk management programs, including issues relating to corporate environmental responsibility.

According to Smith (2003), audit committee is required to push management on critical reporting and sustainability concerns, such as the annual report's disclosure's completeness and clarity, and analyses how the organization is incorporating these difficulties into its own corporate goals and business planning (KPMG, 2010). Furthermore, adequate AC has been argued to be crucial for excellent corporate governance (Zaman

et al., 2011). Due to the accounting expertise and experience of the AC, corporate governance is positively and significantly impacted by disclosures on social and environmental issues. In a similar line, AC is best recognised for reducing errors and insisting on regulatory compliance, which strengthens internal control and raises the quality of disclosures (Ho & Wong, 2001).

Audit Committee Size

The term "audit committee size" refers to the total number of members. According to Financial Reporting Council of Nigeria – FRCN (2018), each audit committee must have a significant number of members relative to the size of the board. An audit committee with a larger membership typically has diverse knowledge and experience, which allows it to share more insights during meetings. According to several academic works, a big team size increases the likelihood that individual team members would succumb to the "crowd effect" and be more likely to adopt the opinions of their colleagues without giving the matter more attention. When this occurs, the audit committee members are less likely to bring up accounting report concerns during the internally review process, increasing the likelihood that errors may be created and not be discovered until later (Kipkoech & Rono, 2016).

Audit Committee Independence

An independent member of the audit committee is one who has never worked for the corporation and is not currently doing so. The term "AC independence" refers to a member of the AC not conducting a large amount of business with the organisation on whose board of directors he is serving. The independence of the audit committee, according to Ayuso and Argandona (2007), is "the extent to which board members (audit committee) are the subject of the current CEO or organisation". The board should receive assistance from an independent audit committee to fulfil its legal and fiduciary obligations (Weir & Laing, 2001). The goal is to ensure the committee's independence, which will increase board activity confidence, financial control, and the legitimacy of the committee's work in overseeing the firm's financial statement process (Kibiyaet al., 2016).

Audit committee that is independent board of directors will be in position to objectively perform the statutory duties expected and thereby enhancing corporate governance and promote disclosure of the effect of activities on the immediate environment of a business/organization.

Audit Committee Meeting

DeZoort et al. (2002) state that an auditor committee's level of diligence can be gauged by the number of meetings held. Even though few studies directly link business performance to the frequency of meetings, meeting frequency is a critical component of a company's operations and processes that ensures reliability and efficiency (Ioana & Mariana, 2014). One of the most important aspects of auditor bodies is their meeting frequency. Yatim et al. (2006) was of the view that there is the likelihood that board members will carry out their responsibilities and raised the level of oversight over accounting procedures through external auditing and the existence of audit committee.

The frequency at which the audit committee meets during an accounting year determines the opportunity to reasonably perform their functions as regular meeting will provide platform to critically examine operational process that will affect environment and to confirm the reportage of such in financial statements.

Audit Committee Gender Diversity

In terms of gender diversity, having women on the AC might result in increased reporting discipline and closer supervision (Adams & Ferreira, 2009; Srinidhi, et al., 2011). For numerous reasons, women are especially likely to manage ESG reporting methods more effectively. Women are expected, on the one hand, to supervise environmental disclosures in AC meetings more effectively than men (Galbreath, 2018; Husted & De Sousa-Filho, 2018). However, female directors bring distinct viewpoints and moral principles to the table, which increases awareness of environmental and societal issues. The literature also highlights the ways in which female board members foster more active board discussions, enhancing the AC's ability to discuss and monitor environmental issues (Bear et al., 2010). Because they actively seek out and acquire knowledge about environmental and social concerns.

Literature also emphasises how female board members encourage more engaged board discussion, which improves the audit committee's capacity to debate and track environmental issues (Bear et al., 2010). Women directors rigorously search for and gather knowledge about issues related to society and the environment, so they are more equipped to emphasise the advantages of environmental disclosures at meetings (Huse & Solberg, 2006). (Galbreath, 2018.) Women also take their roles as directors more seriously and actively which may help them perform their duties as members of the audit committee more effectively, such as checking environmental reporting methods. Liao et al. (2015), found that female directors are more inclined to take jobs addressing sustainability and environmental challenges.

Theoretical Framework

The agency theory, which is one of the most often utilized theories in accounting and finance literature to describe firm's strategic behaviour, serves as the foundation for this study. The agent (management) pursues interests that are at odds with the principal (shareholders) and even other stakeholders, creating conflict in the modern corporate environment, according to agency theory.

It is argued that, management need to be socially responsible to attract higher firms' value and thus maximize the wealth of shareholders (Principal) (Jensen & Mecklings, 1976). Ultimately, Stakeholders increasingly demand that businesses disclose their environmental difficulties, and audit committees play a critical role in forming firms strategic decisions leading to the disclosure of higher environmental information. The ability of the audit committees to determine strategic decisions and thus encourage firm to disclose more environmental information is anchored on the audit committees' features which reflects the audit committee effectiveness (Royaie & Ebrahimi, 2015).

Some of these attributes include the size, independent, meetings and gender diversity of audit committee. In particular, it has been argued in several quarters that audit effectiveness of the audit committee is higher with size (Buallay & Aldhaen, 2018), audit

committee meetings (Bicer & Feneira 2019), audit committee independence (Chariri et al., 2018; Odoemelam & Okafor, 2018) and gender diversity of the audit committee (Wang & Sun, 2022).

Empirical Literature

Audit Committee Size and Environmental Disclosure

Sheikh et al. (2019) equally assessed how audit committee qualities influence voluntary disclosure in a study of 150 Pakistan firms. It was reported that voluntary disclosure increases with audit committee size. In a study conducted by Buallay and Aldhaen (2018), the authors looked at the influence of AC traits on the amount of sustainability report disclosure for 59 listed companies in the Gulf Cooperation Council (GCC) between 2013 and 2017. The findings of their investigation showed that the sampled organizations' sustainability disclosure rises with larger audit committee sizes. Royaie and Ebrahimi (2015) reported that audit committee size does not affect voluntary ethics disclosure.

Audit Committee Independence and Environmental Disclosure

Mamman et al (2021) reported in a study of 58 Nigerian non-financial companies using multiple OLS regression that independence and size of audit committee though recorded positive but do not significantly impact on environmental disclosure of the sampled firms. In a research of 150 Pakistani companies, Sheikh, et al. (2019) evaluated equally how audit committee features affect voluntary disclosure. According to a report, audit committee independence and size both boost voluntary disclosure.

Odoemelam and Okafor (2018) reported Nigerian listed non-financial firms using OLS regression that audit committee independence does not drive corporate environmental disclosure. The study was however a cross sectional study of 86 firms. Ofoegbu, Odoemelam et al (2018) found in a study of selected companies in South Africa and Nigeria which was based on data collected from 90 Nigerian companies and 213 South African firms and analysed using OLS that committee independence does not drive environmental disclosure practices. The study was based on cross-sectional data. Naseer and Rashid (2018) in study to interrogate the implication of audit committee independent on environmental reporting of 50 non-financial firms in Pakistan between 2014 and 2015 reported that audit committee independence exerts positive influence on environmental reporting of the firms.

In a study carried out by Chariri et al. (2017) to examine the implication of audit committee independent and meetings on carbon emission disclosure using data from 136 listed firms on Indonesia Stock Exchange between 2009 and 2015, it was revealed that audit committee independence exerts significant positive influence on the environmental performance of the firms. Appuhami and Tashakor (2017) in a study of 300 firms in Australia corporations found that audit committee independence has no discernible consequences for environmental disclosure and that the size of the audit committee considerably boosts the corporate social and environmental disclosure.

Audit Committee Meetings and Environmental Disclosure

The influence of the features of AC on the social and environmental disclosure of Turkish listed companies were studied by Bicer and Feneir (2019). Based on information

gathered from listed banks on Borsa, the size of the audit committee and the frequency of the meetings of the audit committee did not significantly affect environmental disclosure, according to the findings of the OLS model used in the study. Data from 237 environmentally sensitive industries in Malaysia were used by Azman (2019) to examine the impact of audit committee characteristics on the calibre of voluntary disclosure. While the au8dit committee size has a favourable effect on the standard of environmental disclosure, the level of main environmental disclosure was determined to be 45.42%. The quantity of audit committee meetings has no bearing on the quality of environmental disclosure.

In a study conducted by Buallay and AlDhaen (2018), the authors looked at the impact of audit committee traits on the amount of sustainability report disclosure for 59 listed firms in the Gulf Cooperation Council (GCC) between 2013 and 2017. Their analysis' findings showed that the number of AC meetings increases with the amount of sustainability disclosure made by the tested companies.

Audit Committee Diversity and Environmental Disclosure

Wang and Sun (2022) found that having more women on the audit committee stimulates greater disclosure of social and environmental information in their research of publicly traded Chinese companies. According to a related study by Bravo and Reguera-Alvarado (2018), female presence on the audit committee is positively and significantly correlated with disclosure practices of social and environmental data.

3 Methodology

3.1 Data and Technique of Analysis

The study employed ex-post-facto research design. The population of the study is made up of all firms listed non-financial firms between 2011 and 2020. This study utilized purposive sampling technique to select 70 listed non-financial firms. The data collected are from secondary sources from annual report of listed non-financial firms. Three hypotheses were tested through Panel regression analysis. Hence, study employed robust fixed effect panel regression to control for violation of heteroscedasticity and serial correlation assumptions in achieving the objectives.

Table 1: List of Sampled Firms by Sectors

Sector	Number of Sampled Firms	Percent (%)
Oil and Gas	7	10.00
Services	13	18.57
Natural Resources	4	5.71
Industrial	10	14.29
Consumer Goods	16	22.86
ICT	4	5.71
Conglomerate	5	7.14
Health Care	6	8.57
Agriculture	3	4.29
Construction	2	2.86
Total	700	100.00

Source: Authors' Compilation (2023)

3.2 Model

To investigate the influence of audit committee attributes on corporate environmental disclosures, the following regression model was used:

$$ENDI = f(ACS, ACM, ACID, ACD, FP, FS, FLV) - - - \quad (3.1)$$

(3.1) could be represented in linear form as

$$ENDI_{it} = \tau + \sigma ACS_{it} + \vartheta ACM_{it} + \varphi ACID_{it} + \lambda ACD_{it} + \beta FP_{it} + \alpha FS_{it} + \propto FLV_{it} + \pi_{11} IND_{it} + \beta_{11-20} YEAR_{it} \mu_{it} - - - \quad (3.2)$$

Where;

ACS_{it} = size of audit committee

ACM_{it} = audit committee meeting

$ACID_{it}$ = audit committee independent

ACD_{it} = audit committee diversity

FS_{it} = Firm size

FP_{it} = firm performance

FP_{it} = Financial leverage

I = Firms, t = time

Table 2: Variable Measurement

Variables	Description
Dependent Variable	
Environmental disclosure (ENDI)	An index score of the extent of firm disclosure of environmental information based on GRI framework expressed in proportion.
Independent Variables	
Audit Committee Size (ACS)	Number of members on committee
Audit committee meeting (ACM)	Number of times meeting in fiscal year
Audit Committee Independent (ACID)	The proportion of non-board members in the board
Audit committee Diversity (ACD)	Proportion of women in committee
Control Variables	
Firm Performance (FP)	The change in revenue from one year to another
Firm Size (FS)	Natural log of the total asset of the firm
Financial leverage (FLV)	The ratio of liability to equity
Industry Effect (IND)	A binary variable with one use as indicator of environmentally sensitive sectors. Following leads form other literature, this study used oil and gas, construction and industrial sectors to be environmentally sensitive sectors.

Source: Authors' Computation (2023)

The level of environmental disclosure is obtained from the 8 themes relating to environmental disclosure in the Global Reporting Initiatives which include energy, water, material, emission, biodiversity, products and services and effluent and waste disclosure and compliance to environmental law disclosure. A four-level quantitative scale ranging from 0 to 3 (0, 1, 2, 3) is employed in attaching weight to each of the eight indicators. The score of 0 is assigned if no information on a theme is disclosed, 1 is assigned for the disclosure of the theme in general statement, 2 is assigned for qualitative disclosure while 3 is assigned for the quantitative disclosure of the theme. The implication is that the maximum score obtainable by each indicator is 3 and since there are a eight indicators of environmental disclosure being captured, the maximum score is 24. The environmental disclosure index is then obtained as:

$$ENDI = \frac{\sum_1^8 d_i}{24}$$

Where ENDI is environmental disclosure index, d is the weight score (using a four-level quantitative scale) obtain for each of the indicators i.

4 Results and Discussion

Table 3: Summary Statistics of Variables

	Mean	Std. Dev.	min	max	p25	Median	p75	skewness	kurtosis
ENDI	0.309	0.169	0.167	0..958	0.250	0..250	0.250	2.684	9.004
ACID	0.457	0.127	0.000	1.000	4.000	0.500	0.500	0.407	9.087
ACM	3.811	0.756	1.000	9.000	3.000	4.000	4.000	0.247	7.744
ACD	0.106	0.139	0.000	0.667	0.000	0.000	0.167	1.175	3.820
ACS	5.451	1.007	0.000	9.000	4.000	6.000	6.000	-0.590	3.133
FP	2.942	17.268	-179.917	176.267	0.562	3.746	8.249	-1.534	42.608
FS	7.064	0.818	5.093	9.241	6.464	6.997	7.721	0.132	2.449
FLV	1.893	4.624	-28.271	47.923	0.683	1.298	2.282	3.009	39.502

Source: Authors' Computation, (2023)

Table 3 above revealed that the average environmental disclosure index to be 0.309 implying that the extent of environmental disclosure among Nigerian non-financial firms is 30.09 per cent.. The results further revealed the average audit committee size to be 5.451 with a SD of 1.007. The minimum audit committee size was 2 with maximum of 9. The average frequencies of audit committee meetings in a financial year are found to be 3.811 or about four times with SD of 0.756 as well as minimum and maximum meeting time of 1 and 9. Also, the results revealed that the average number of non-executive members of audit committee (Audit committee independence) of Nigerian non-financial firms to be 0.457 with SD of 0.127, minimum of 0 and maximum of 4. Also, the average female representation on the committee is 0.106 with a standard deviation of 0.139, while the average firm performance as represented by the return on asset is 2.942 with standard deviation of 17.268 indicating wide variation in the performance of Nigerian non-financial firms, the firm size, the estimated average is 7.064 with SD of 0.818 and finally, the average of firm financial leverage is 1.893 and it SD is 4.674.

The results suggest that there is no wide variation in the environmental disclosure among Nigerian listed non-financial firms over the period covered as the SDs were found to possess lower value that the means of all elements except for firm performance and financial leverages where the SDs were found with higher value compared with their means.

Table 4: Estimated Pairwise Correlations

Matrix of Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) ENDI	1.000							
(2) ACID	0.126	1.000						
(3) ACM	0.115	0.022	1.000					
(4) ACD	0.121	-0.043	0.063	1.000				
(5) ACS	0.248	-0.002	0.208	0.103	.000			
(6) FP	0.111	0.063	0.039	0.074	0.130	1.000		
(7) FS	0.396	0.046	0.280	0.081	0.542	0.213	1.000	
(8) FLV	-0.056	-0.179	0.033	0.024	0.131	0.015	0.109	1.000

Source: Authors' Computation, (2023)

The results of correlation matrix of the study as shown in Table 4 above shows that the interrelationship between the dependent variable and the explanatory variables in one hand, and in another between the explanation variables shows the absence of multicollinearity as the highest correlation coefficient shows a value of 0.542 for the relationship between the size of audit committee (ACS) and firm size (FS). This value is lower than the threshold of 0.7 as suggested by Kennedy, (2008) for the presence of multicollinearity.

Normality Test

Table 5: Summary of Normality Test

Test	Prob Value	Remarks
Skeweness/Kurtosis	0.000	Normal Distribution Assumption rejected
JaqueBera	0.000	Normal Distribution Assumption rejected

Source: Authors' Computation, (2023)

The results of normality test using skeweness, kurtosis and JaqueBera tests are as shown in Table 5 above which shows that the joint probability value of the skewness and Kurtosis score of 0.000 implies the rejection of the null hypothesis of normal distribution. The results of the JaqueBera test equally indicate that the null hypothesis of normal distribution is rejected. The implication is that the data used in the study are not normally distributed. The graphical representation equally confirms this (see appendix). This may be linked with heteroscedasticity in the data used. The study therefore tests for heteroscedasticity in the subsequent section and the results affirmed existence of heteroscedasticity. The issues are addressed by obtaining the regression results with robust standard error while feasible generalized least square panel regression was used in the alternative.

Unit Root Test

Unit root test was conducted to check for the stationarity of the series used in this study. Given the few years covered in the study, Handri t test for unit root was employed and the results are summarized in Table 6 shown below. It provides that the null hypothesis of no unit root was only rejected for the environmental disclosure index while the null hypothesis of no unit root could not be rejected for all the explanatory variables. By implication, the explanatory variables are stationary while the environmental disclosure index is found to be non-stationary. The non-stationarity of the environmental disclosure may be attributable to its trending over time. Thus, this study controls for time by including year effect in the regression model of the study.

Table 6: Summarised Results of the Handri t Unit Root Test

Variable	Statistic	Prob. Value	Order of Integration	Remarks
ENDI	0.7601	0.841	I(1)	Not Stationary
ACID	0.4578	0.000	I(0)	Stationary
ACM	0.2386	0.000	I(0)	Stationary
ACD	0.508	0.000	I(0)	Stationary
ACS	0.4416	0.000	I(0)	Stationary
FP	0.3261	0.000	I(0)	Stationary
FS	0.2937	0.000	I(0)	Stationary
FLV	0.1984	0.000	I(0)	Stationary

Source: Authors' Compilation, (2023)

To ensure that relative linear regression assumptions are not violated, the study conducts diagnostic tests for serial correlation, heteroscedasticity and cross-sectional dependence. The results obtained are summarized in Table 7. The results of the Pesaran test indicates the presence of cross sectional dependent while Wooldridge test shows that there is existence of firs-order serial correlation. Also, the Breusch-Pagan test for heteroscedasticity revealed the no absence of heteroscedasticity in the study.

Table 7: Summary of Diagnostic Tests

Test	**Results**	**Remarks**
Pesaran Cross Sectional Dependence Test	F = 35.559 Pr = 0.000	Existence of Cross Sectional Dependence at 1 per cent
Breusch-Pagan test for heteroskedasticity	Chi2 = 179.34 Prob> Chi2 = 0.000	Existence of Heteroscedasticity at 1 per cent
Wooldridge test for serial correlation	F stat = 87.173 **Prob> Chi2 = 0.000**	Existence of First-order serial correlation

Source: Authors' Computation, (2023)

In addition, few other post estimation diagnostic tests were conducted and Hausman test to determine whether the fixed or random effect models be selected. Thus, the estimation of the data for this study was be based on the fixed effect panel regression.

From the robust fixed effect panel regression results presented in the second column of Table 8, audit committee size has insignificant effect on the environmental disclosure of listed firms given its coefficient and standard error of 0.0075 and 0.0055 respectively.

These results imply that the size of the audit committee does not matter for the disclosure of environmental information. The estimated slope and corresponding standard error of 0.0074 and 0.00683 respectively in the full model presented in column 6 of Table 9 imply that audit committee's size impact on the environmental disclosure of publicly traded non-financial enterprises in Nigeria is positive but insignificant.

Table 8: Estimated Static Panel Regression Results (Dep = ENDI)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	ACID	ACM	ACGD	ACS	Full Model
ACID	0.107**				0.112**
	(0.0467)				(0.0467)
ACM		-0.0061			-0.0066
		(0.0090)			(0.0082)
ACDn			0.0857**		0.0882**
			(0.0418)		(0.0418)
ACS				0.00754	0.0074
				(0.00550)	(0.0068)
FP	0.000372	0.0004	0.000374	0.000417	0.0003
	(0.000343)	(0.0003)	(0.000343)	(0.000341)	(0.0003)
FS	0.0786***	0.0806***	0.0784***	0.0743***	0.0745***
	(0.00728)	(0.0109)	(0.00729)	(0.0115)	(0.0087)
FLV	-0.00267**	-0.00321***	-0.00329***	-0.00335***	-0.0028**
	(0.00127)	(0.0009)	(0.00125)	(0.000852)	(0.0013)
Ind	0.0125	0.0104	0.00780	0.0101	0.0105
	(0.0115)	(0.0119)	(0.0116)	(0.0118)	(0.0116)
Year Effect	YES	YES	YES	YES	YES
Constant	-0.317***	-0.262***	-0.272***	-0.278***	-0.314***
	(0.0568)	(0.0638)	(0.0533)	(0.0670)	(0.059)
Observations	700	700	700	700	700
R-squared	0.215	0.209	0.214	0.210	0.222

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' Computation (2023)

In column 3 of Table 8, the results (coefficient = -0.0061; standard error = 0.0090) imply that meetings of the audit committee (ACM) have a negative and negligible effect on the environmental disclosure of publicly traded non-financial companies in Nigeria. Inferentially, the frequency of audit committee meetings has little bearing on the depth of environmental disclosure made by Nigerian non-financial enterprises. The coefficient of -0.0066 and standard error of 0.0082 in the full model of column 6 equally confirm that audit committee meetings have a negligible impact on listed non-financial corporations in Nigeria's disclosure of the effect of activities on environment.

Furthermore, he results of column 2 with a coeff. 0.107; stand error = 0.0467 and suggest that audit committee independence has a direct and significant effect on environmental disclosure, indicating that the higher the percentage of independent board members, the higher the tendency of higher environmental disclosure by the Nigerian non-financial. Similar results are recorded in the full model where the coefficient is found to be 0.0112;

stand error = 0.0467demonstrate that environmental disclosure among Nigerian listed non-financial enterprises is positively and significantly impacted by audit committee independence. The results of the fixed effect panel regression summarized in column 4 of Table 8, an estimated coefficient of. 0.0857; stand error = 0.0414 revealed that audit committee diversity has significant positive impact on environmental disclosure of listed Nigerian non-financial firms implying that higher audit committee diversity lead to more environmental disclosure practice in Nigerian corporate environment. The estimated slope and corresponding standard error of 0.088 and 0.0418 respectively in the full model presented in column 6 above equally revealed that audit committee diversity has positive and significant impact at 5 per cent level on environmental disclosure of Nigerian listed non-financial firms. The implication of the results is that higher female representation on the audit committee is expected to facilitate higher corporate environmental disclosure in Nigerian non-financial sector.

According to the estimated results in Table 8 above for the influence of the control variables, performance of the company has a direct but insignificant impact upon the environmental disclosure of the listed non-financial enterprises in Nigeria. The size of the firm on the other hand recorded positive and significant influence on environmental disclosure. This suggests that larger firms are more disposed to disclose more environmental information. The financial leverage (FLV) of firms is found to exert negative influence which is significant on the environmental disclosure, as indicated by the estimated coefficient of -0.0028 and standard error of 0.0013 which implies that a company's financial leverage is irrelevant for corporate social and environmental disclosure.

Robustness Check

The study checks for the robustness of the fixed effect panel results obtained by using a panel feasible generalized least square, which is alternative panel regression technique that is not only autocorrelation and heteroskesdasticity consistent (controls for both serial correlation and heteroskedasticity), but also controls for endogeneity. The results obtained with panel feasible generalized least square are presented in Table 9 where in column 5 it reveals that the size of the audit committee (ACS) has a direct but no significant influence on the environmental reporting procedures of listed non-financial companies in Nigeria with coefficient of 0.0075; stand. error. = 0.0068 respectively, the full model revealed a coefficient of 0.0074 with standard error of 0.0067 which suggest that audit committee size has a direct but no significant impact on environmental disclosure. The estimated coefficient of -0.0061; stand error = 0.0082 shows that frequency of meetings of audit committee has positive and significant influence on environmental disclosure while coef. -0.0066; stand error = 0.0081 in the full model and this indicate that the impact of the frequency of audit committee meetings (ACM) on environmental disclosure is negative but not significant. In addition, the results revealed that audit committee independence (ACID) with coef. 0.107; stand. error = 0.0462 records a positive and significant influence on environmental disclosure among Nigerian listed non-financial firms and the estimated coefficient and standard error of 0.112 and 0.0462 in the full model affirmed independent audit committees have a strong positive impact on environmental disclosure. Similarly, the estimated coefficient of 0.0857 and standard error of 0.0414 reveal that audit committee diversity (ACD) exerts positive and significant

influence on environmental disclosure of listed firms while the coefficient and standard error of 0.088 and 0.0413 respectively in the full model in column 6 confirmed that audit committee diversity has a considerable positive impact on environmental disclosure. The above suggest that the way in which audit committee influence the disclosure of environmental information among Nigerian listed non-financial firms is robust to alternative technique of analysis.

Table 9: Estimated Feasible Generalized Least Square Panel Regression Results

Estimated Pannel Regression Results

	(1)	(2)	(3)	(4)	(5)
VARIABLES	ACID	ACM	ACGD	ACS	Full Model
ACID	0.107**				0.112**
	(0.0462)				(0.0461)
ACM		-0.00610			-0.00664
		(0.00816)			(0.00811)
ACD			0.0857**		0.0882**
			(0.0414)		(0.0413)
ACS				0.00754	0.00737
				(0.00676)	(0.00674)
FP	0.000372	0.000427	0.000374	0.000417	0.000310
	(0.000339)	(0.000340)	(0.000340)	(0.000340)	(0.000339)
FS	0.0786***	0.0806***	0.0784***	0.0743***	0.0745***
	(0.00720)	(0.00746)	(0.00721)	(0.00845)	(0.00854)
FLV	-0.00267**	-0.00321***	-0.00329***	-0.00335***	-0.00282**
	(0.00126)	(0.00124)	(0.00124)	(0.00125)	(0.00126)
Ind (sens =1)	0.0125	0.0104	0.00780	0.0101	0.0105
	(0.0114)	(0.0114)	(0.0114)	(0.0114)	(0.0114)
Years Effect	YES	YES	YES	YES	YES
Constant	-0.317***	-0.262***	-0.272***	-0.278***	-0.314***
	(0.0561)	(0.0546)	(0.0527)	(0.0531)	(0.0579)
Observations	700	700	700	700	700
Number of PID	70	70	70	70	70

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' Computation (2023)

5 Discussion of Findings

This study finds that the audit committee's independence had a positive and substantial impact on environmental exposure in both the fixed effect and FGLS analyses, indicating a connection between greater representation of independent individuals on the board and higher environmentally information disclosure. This demonstrates that higher proportion of non-executive directors have a strong, positive influence on environmental disclosure in the corporate environment of Nigeria.

Also, based on the FGLS results, the study concluded that the audit committee's independence has a favourable and substantial effect on sustainability disclosure,

suggesting that greater participation of independent members in audit committee is related to greater openness about environmental information. This is consistent with the efficient monitoring hypothesis proposed under the agency theory, according to which independent committee with varying ideas and independent mind which ultimately make it easier to make informed decisions, including those involving the release of environmentally sensitive information. This is expected as higher AC independent encourages the audit committee to make independent strategic decision which is fair to all stakeholders including the disclosure of environmental disclosure practices. The results obtained agree with the findings of Chariri et al. (2017) that AC independent exerts positive and significant influence on environmental disclosure. However, the results found here does not agree with the report of literature which submitted that audit committee independence has no bearing on environmental disclosure including Appuhami and Tashakor (2017), Odoemelam and Okafor (2018), and Ofoegbu et al. (2018).

The results of the fixed effect panel regression and the FGLS used in the study also showed that audit committee diversity (ACD) records a positive and substantial effect on environmental disclosure, indicating that the higher the proportion of female audit committee members, the more environmental information disclosure among Nigerian listed non-financial firms. The findings here concur with Wang and Sun (2022) finds that disclosure of environmental and social information is encouraged if there's a large proportion of women on the audit committee. Bravo and Reguera-Alvarado (2018) equally reported that female representation on the board enhances environmental disclosure practices.

According to the panel regression results from the study, frequency of audit committee meetings has a negative but no significant impact on environmental disclosure, including when FGLS, which corrects for endogeneity issues, is used. So, audit committee activeness in terms of how frequently they meet does not have effect on the environmental disclosure of the listed non-financial companies in Nigeria. The non-significant of the audit committee meeting may be linked to the fact that no large variation is observed in the audit committee meetings in the study across firms and time. The results do not agree with the submission in related studies such as those by Buallay and Aldhaen (2018) and Chariri, et al. (2018), which found an association between audit committee meetings and greater environmental disclosure.

In addition, the results found in the study indicate that audit committee size (ACS) records positive but no significant influence on the environmental disclosure practice. The finding here fails to agree with the results of previous studies including Buallay and Aldhaen (2018), and Abdullah and Shah (2019) who found that environmental disclosure increases with higher firm size. The study however agrees with the finding of Mamman et al. (2021) who reported no significant influence of AC size on environmental disclosure, as well as Royaie and Ebrahimi (2015) and Bicer (2019) who reported no influence of AC size on environmental disclosure.

6 Policy Implications

The study found evidence that the attributes of the audit committee matter for the disclosure of the environmental related information by the Nigerian non-financial firms. In particular, the implication of the findings in this study is that neither the size of the audit committee nor the number of times they meet that matters for encouraging disclosure of environmental information but the composition of the committee in a way that give room for more independent members and female on the committee. From this study therefore, policy makers and other concern stakeholders can leverage on the composition of the audit committees to encourage and enhance sustainability practices among Nigerian non-financial firms.

7 Conclusion and Recommendations

This study extensively examined the effect of audit committee characteristics on the amount of corporate environmental disclosure in Nigeria. In this study, a variety of audit committee characteristics were taken into account, including the size, independence, gender diversity, and frequency of meetings. According to empirical findings from both fixed effect and FGLS used in the study, audit committee independence and gender diversity had a favourable and significant impact on environmental disclosure among Nigerian listed non-financial enterprises while the impact of audit committee meetings and size were found to be negligible.

The general conclusion of this study is that the composition of the audit committees in terms of more independent members and female representation play crucial role in attainment more environmental disclosure. Previous studies on the link between audit committee attributes and environmental disclosures have largely failed to incorporate the issue of endogeneity in their studies. This study is different as it tested for the presence of endogeneity and control for the problem using feasible generalized least square panel regression technique.

In line with the results, the study recommends that regulators should lay emphasis on the effectiveness of the audit committees to achieve disclosure of environmental information by these firms. In particular, it is suggested efforts should be made to ensure that the audit committee composition of the Nigeria non-financial firms reflect more independent members. Also, more female representation on the audit committee of the Nigeria non-financial firms should be encouraged.

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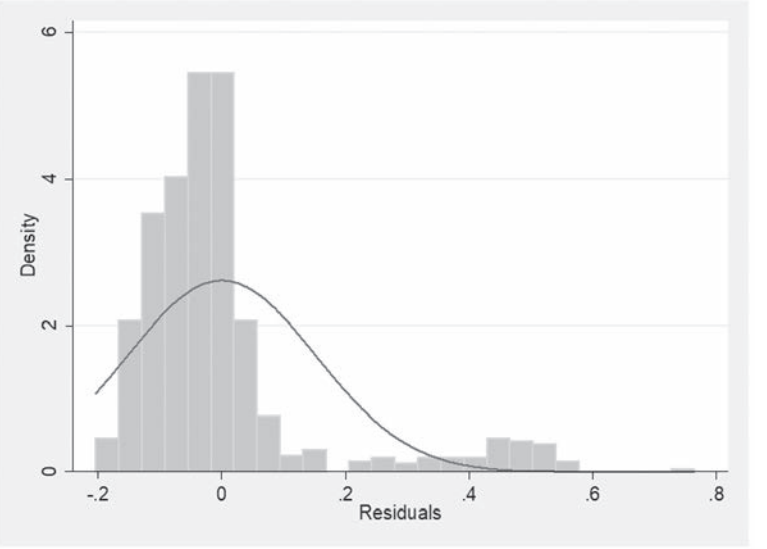
Appendix



Normal distribution graph

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Correlation between the ECB Pandemic Policy and the STOXX Europe 600 Sector Performance Sensitivity

ALEXANDER HÜTTEROTH & PETR BUDINSKÝ

Abstract
In 2022 European equity markets lost some of their value, led by high-growth sectors, which generally have a significantly higher growth rate. The prevailing academic opinion is that the European Central Bank's monetary policy during the COVID-19 pandemic is a key reason and the financial and the technology sectors are defined to be particularly sensitive to interest rates. In this context, a performance sensitivity analysis for the STOXX Euro 600 sectors on European Central Bank interest rates from 2020 to 2022 will be investigated based on the assumption of a significant interest rate sensitivity. The objective is achieved with a Pearson correlation and linear regression. The results confirm a correlation for the selected sectors, indicating a potential general sensitivity for the entire investigation period. On this basis, further research on sectors and variables such as inflation and a comparison with Fed interest rates and the S&P 500 is recommended.

Keywords
STOXX Europe 600, performance sensitivity, mean reversion, interest rates, COVID-19, central banks

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Introduction

In 2022, the European Central Bank (ECB) increased interest rates after two years of Covid 19 pandemic to prevent risk to price stability. The prevailing academic view is that this a rising interest rate environment weighs on high-growth equities such as the technology and the financial sector and that these are particularly affected by interest rate increases (Lange 2022). This is based on the theory that bond yields are more attractive than equities when interest rates rise, impacting the global equity market. Future cash inflows also lose value for faster-growing companies as the discounted present value declines. If these earnings are discounted to the present, the values are significantly lower at higher discount rates. The basis for calculation, the interest rate, melted away even though the companies' fundamentals had not changed. The effects of the discounted cash flow method are particularly strong for technology stocks (Heyden 2021) and traditional

companies, such as utilities or consumer goods, rather less so. In addition, it becomes more expensive for companies to finance themselves with debt (Motley Fool 2021). High inflation led to higher bond yields, whereupon equity markets around the world lost some of their value, led by technology stocks. This dynamic was primarily driven by the rise in bond yields, which are like the average dividend yields in equity indices. In this environment, banks are among the winners, as higher interest rates again create more scope for interest margins (Sullivan 2022). This results in the objective to investigate the hypothesis that the higher the interest rates at the end of the pandemic, the stronger the mean reversion process for the highly capitalized sectors of the STOXX Europe 600. This paper analyses the sensitivity of the sector performance of the STOXX Europe 600 and the ECB interest rate policy during the pandemic from 2020 to 2022. In the first step, the impact on the performance of the highly capitalized technology sector and the financial sector is examined. Key findings are that the STOXX Europe 600 Technology Index outperformed the STOXX Europe 600 during the pandemic and underperformed in 2022 with central bank interest rate change. However, there is no linear correlation between ECB interest rates and the sensitivity of the sector performance of the STOXX Europe 600 in 2021, and a slight sensitivity of the basic resources, retail, and utilities sectors can be seen in 2021 and 2022. Chapter four examines a potential correlation between interest rate increases and the sensitivity of the sector performance of the STOXX Europe 600. To account for the potential interest rate sensitivity, the distribution of performance data is examined. Finally, the question of whether there is a mean reversion process for the STOXX Europe 600 sector is answered through a regression analysis for performance and interest rate data. The paper concludes with the findings compared with the literature review.

1 Literature review

In a first step the current state of science is summarized. There are numerous recent studies on equities and interest rates in relation to the Covid 19 pandemic for Europe, and some of the most important are reviewed in more detail in this chapter. Kanapickiene et al. (2020) analyze the impact of COVID-19 on European financial markets and economic sentiment. The authors examined the performance of stock indices, exchange rates, and government bonds, and experienced sharp declines in March 2020 due to the pandemic. In addition, they examined the impact of the pandemic on economic sentiment in Europe and concluded that it is strongly impacted by the evolution of infection numbers and the measures taken to contain the pandemic. The authors emphasize the need to conduct further research to better understand the impact of the pandemic on the economy and to inform policy decision makers at national and international levels. A paper by Kyriazis (2021) examines the connection between European stock indices (total and on a sector basis), gold, and oil during the COVID-19 pandemic. The author analyses correlations, cointegrations, and Granger causality relationships between the different asset classes and examines how the impact of the pandemic affected the interactions. The results show a stronger correlation was between the different asset classes during the pandemic, especially between gold and the stock indices. In addition, the study shows that the pandemic affected the cointegration and causality relationships between asset classes, especially in the context of oil prices. Assel et al. (2022) defines

the research question whether sustainable stock indices performed more stably and better than conventional indices during the COVID-19 pandemic. The focus is on the European region. The results show that all selected indices, whether sustainable or conventional, responded with abnormal returns considering the selected events. Significant market movements were found up to ten days after the pandemic event.

The studies show that the broad STOXX Europe 600 index provides a good data base for studies on stock market performance and monetary policy in Europe.

Oxford Analytica (2023), in another paper, refers to considerations by some Central and Eastern European countries to raise interest rates due to high inflation and possible implications for indices such as the STOXX Europe 600, arguing that raising interest rates could slow economic growth and increase pressure on governments in the context of rising prices. Instead, lowering interest rates in some countries in the region could be an option to support growth and mitigate the impact of inflation.

The paper by Alfieri et al. (2022) examines the impact of European Central Bank (ECB) communications on financial markets before and during the COVID-19 pandemic. The authors use a variety of methods, including event study and content analysis, to examine the effect of communications on equity and bond markets. They find that ECB communications overall have a significant impact on financial markets, particularly the stock market. Prior to the pandemic, ECB communications had a greater impact on financial markets than during the pandemic. The authors suggest that market participants were less receptive to ECB communications during the pandemic due to uncertainty about the economic impact of COVID-19.

The studies show that the broad STOXX Europe 600 index provides a good data basis for studies on stock market development and money market policy in Europe. With the ECB's interest rate changes in 2022, the prevailing academic view for Europe is that this environment will weigh on high-growth equities such as the technology sector and the financial sector that these will be particularly affected by interest rate hikes (Lange 2022). In this environment, banks are also among the winners in Europe, as higher interest rates again create more room for interest margins (Sullivan 2022). This leads to the objective of testing the hypothesis that the higher interest rates are at the end of the pandemic, the stronger the mean-reversion process is for the highly capitalized sectors of the STOXX Europe 600. This paper analyses the sensitivity of the sector performance of the STOXX Europe 600 sectors and the ECB interest rate policy during the pandemic from 2020 to 2022 with the interest rate changes. To account for the possible interest rate sensitivity, the distribution of performance data is examined. Finally, the question whether there is a mean reversion process for the STOXX Europe 600 Technology is answered by a regression analysis for performance and interest rate data.

2 Data and methods

For this paper, the equity market performance data of the STOXX Europe 600 on sector basis is analyzed in combination with the ECB Deposit Facility Rate, during the pandemic from 2020 to 2021 and with increased interest rates in 2022. The STOXX Europe 600 is

an equity index representing the performance of the 600 largest listed companies in Europe and is calculated by the index provider STOXX Limited, a subsidiary of Deutsche Börse Group. The calculation of the STOXX Europe 600 is based on a weighted average method and is performed in the following steps (Quontigo 2023):

1. Component selection: 600 largest companies from Europe are selected and included in the index based on their market capitalization and liquidity.

2. Calculation of market capitalization: The market capitalization is determined for each selected company by multiplying the current share price of the company by the total number of shares issued. This calculation is performed for each company in the index.

3. Component weighting: The weighting of each company in the index is determined based on its market capitalization. Companies with a higher market capitalization have a greater weight in the index and a greater influence on the index movement, with a cap of 10 percent.

4. Calculation of the index value: the market capitalizations of all companies included in the index are summed up. This sum is divided by a divisor to determine the index value. The divisor is set that the index has an underlying value at a certain point in time, usually 100 points. The divisor is adjusted regularly to ensure that changes in the composition of the index or other adjustments are correctly considered.

The STOXX Europe 600 Index is reviewed regularly to ensure that it reflects current market trends and company changes. This review and adjustment are usually carried out on a quarterly basis (Quontigo 2023). The technology and financial sectors are of particular interest due to their index weightings from 2020 to 2022 as well as the potential sensitivity to interest rate changes during the selected period based on the outcome of the literature review. Table 1 summarizes the observation values for Europe. There are 258 observations values for 2020 and 2021 for the index, all sub-sectors and interest rates and 257 values for 2022 shown in table 1.

Table 1: Examination values Europe

Variable	Name	Observations 2020	Observations 2021	Observations 2022
Y_1	STOXX Europe 600	258	258	257
Y_2	STOXX Europe 600 Automobiles & Parts	258	258	257
Y_3	STOXX Europe 600 Banks	258	258	257
Y_4	STOXX Europe 600 Basic Resources	258	258	257
Y_5	STOXX Europe 600 Chemicals	258	258	257
Y_6	STOXX Europe 600 Construction & Materials	258	258	257
Y_7	STOXX Europe 600 Financial Services	258	258	257
Y_8	STOXX Europe 600 Food & Beverage	258	258	257
Y_9	STOXX Europe 600 Health Care	258	258	257
Y_{10}	STOXX Europe 600 Industrial Goods & Services	258	258	257
Y_{11}	STOXX Europe 600 Insurance	258	258	257
Y_{12}	STOXX Europe 600 Media	258	258	257
Y_{13}	STOXX Europe 600 Oil & Gas	258	258	257
Y_{14}	STOXX Europe 600 Personal & Household Goods	258	258	257
Y_{15}	STOXX Europe 600 Real Estate	258	258	257
Y_{16}	STOXX Europe 600 Retail	258	258	257
Y_{17}	STOXX Europe 600 Technology	258	258	257
Y_{18}	STOXX Europe 600 Telecommunications	258	258	257
Y_{19}	STOXX Europe 600 Travel & Leisure	258	258	257
Y_{20}	STOXX Europe 600 Utilities	258	258	257
X	ECB Interest Rate	258	258	257

Source: Own representation based on Qontigo & ECB data

The entire paper is calculated with Excel and all graphics are created by the author. The first part of the research is based on descriptive statistical methods used to evaluate a potential correlation between the central bank's pandemic policy and the stock market sector performance. The objective of this paper is fulfilled using Pearson correlation. The usage of correlation for the analysis is relevant as it allows for the examination of the relationship between the sector performance and interest rates and therefore an indication for the contribution to the entire market. By calculating the correlation coefficient, one can assess the extent to which performance for both regions is related. If there is a strong correlation, it would support the prevailing academic opinion that rising interest rates negatively impact high-growth sectors and that there is a sensitivity for financial stocks. Based on this, the working hypothesis will be evaluated. Furthermore, examining the correlation at the sector level can provide additional valuable insights for investors. Interest rates are defined as independent variables that influence the dependent variable stock market performance. The correlation analysis assesses both the strength and direction of the relationship between the variables on a scale ranging from -1 to +1. A correlation coefficient of +1 indicates a perfect positive correlation, -1 indicates a perfect negative correlation and 0 indicates no correlation. Additionally, the potential interest rate sensitivity is calculated with a simple linear regression analysis. It is applied to test whether there is a relationship between two of the interval-scaled

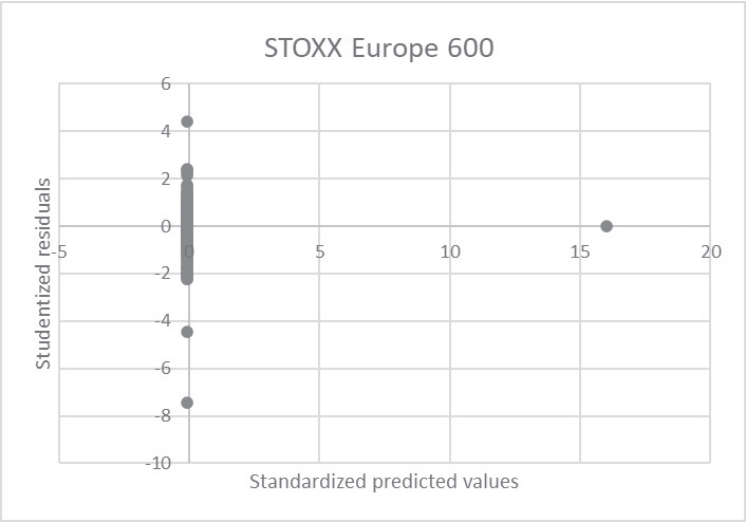
variables performance and interest rates. The significance is determined with the t-test. A result with a p-value below 0.05 is significant. The performance data of the index is analyzed during the pandemic from 2020 to 2022. It is applied to test whether there is a significant correlation between the stock performance in Europe and interest rates during the investigation period.

3 Homoscedasticity of data

In the context of regression analysis and the estimation of statistical models for this paper, heteroskedasticity from an econometrics point of view is of importance. This refers to the situation in which the variance of the confounding variables or residuals in a regression model are not constant, but change depending on the independent variables (Baltes-Götz 2018). Heteroskedasticity can affect the efficiency and consistency of the estimates of a regression model and therefore be problematic. presence of heteroscedasticity may bias the standard errors of the coefficient estimates, leading to spurious inferences. T-tests and F-tests may be inaccurate, and confidence intervals may be too wide or too narrow. Linear regression model with constant variance and homoscedastic assumptions, have the best properties in terms of statistical tests as the estimates of the regression coefficients are efficient (Regorz 2021).

For this paper, the analysis with a residuals diagram is used. Standardized predicted values are plotted on the x-axis and the studentized residuals are plotted on the y-axis for the STOXX Europe 600 first and afterwards for the S&P 500. Figure 1 shows the STOXX Europe 600 plot for 2020. The residuals scatter unsystematically around their zero point and demonstrating homoscedasticity. The small variation of the variances between the different x-values can be explained with low interest rate values during the year 2020. The single outlier is not irritating. The data set has been generated with completely homogeneous variances, but due to random influences there is always some variation of the variances between the different x-values.

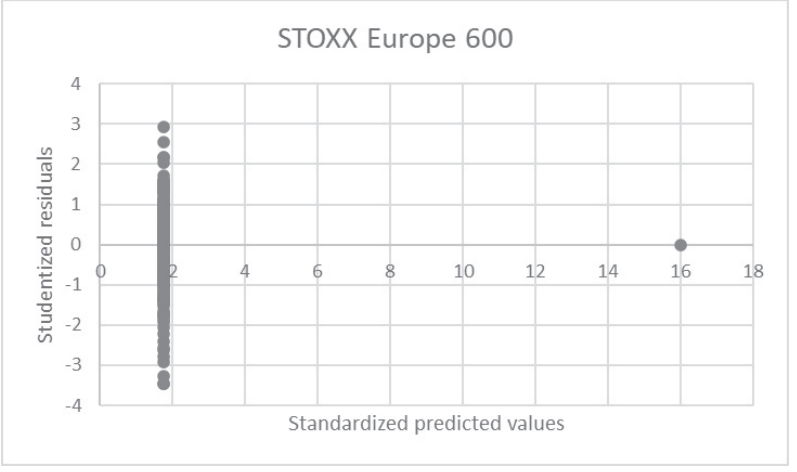
Figure 1: STOXX Europe 600 distribution for 2020



Source: Own representation based on Qontigo & ECB data

The STOXX Europe 600 plot for the year 2021 is shown in figure 2. The plot shows a similar picture than for 2020 with residuals scatter unsystematically around their zero point, demonstrating homoscedasticity. The variation of the variances between the different x-values is similar to 2020 because of the low interest rate values during the year 2021.

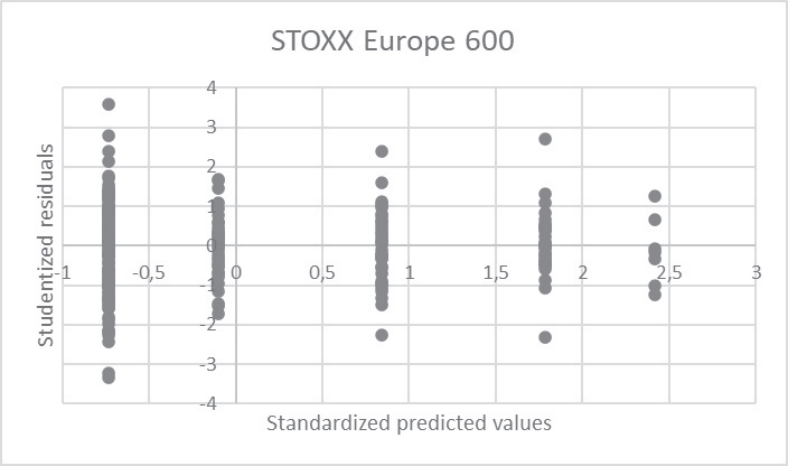
Figure 2: STOXX Europe 600 distribution for 2021



Source: Own representation based on Qontigo & ECB data

Figure 3 shows the STOXX Europe 600 plot for the year 2022. The plot shows a s residuals scatter less unsystematically around their zero point for the STOXX Europe 600, demonstrating homoscedasticity 2022. The variation of the variances between the different x-values is higher because of the higher interest rate values during the year 2022.

Figure 3: STOXX Europe 600 distribution for 2022



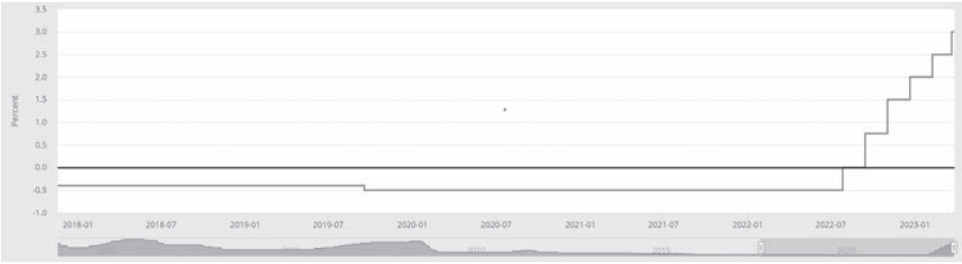
Source: Own representation based on Qontigo & ECB data

The data analysis for the STOXX Europe 600 for the years 2020, 2021 and 2022 does not indicate possible heteroskedasticity. This also includes a statement about the population sample to estimate whether the variances are homogeneous in the population. An examination of the scatter plots demonstrates that the residuals for all years and indices scatter unsystematically around their zero point and therefore demonstrates homoscedasticity.

4 European interest rates and stock markets development from 2020 to 2022

The following figure 4 illustrates the historical ECB Deposit Facility Rate for a 5 Year period. The data shows that the ECB monetary environment shifted from negative interest rates to zero interest rates and to the positive interest rates during the period of investigation. Based on this, the performance of the STOXX Europe 600 is analysed for the period 2020 to 2022 in the following chapters of this paper.

Figure 4: 5 Years ECB interest rate



Source: macrotrends

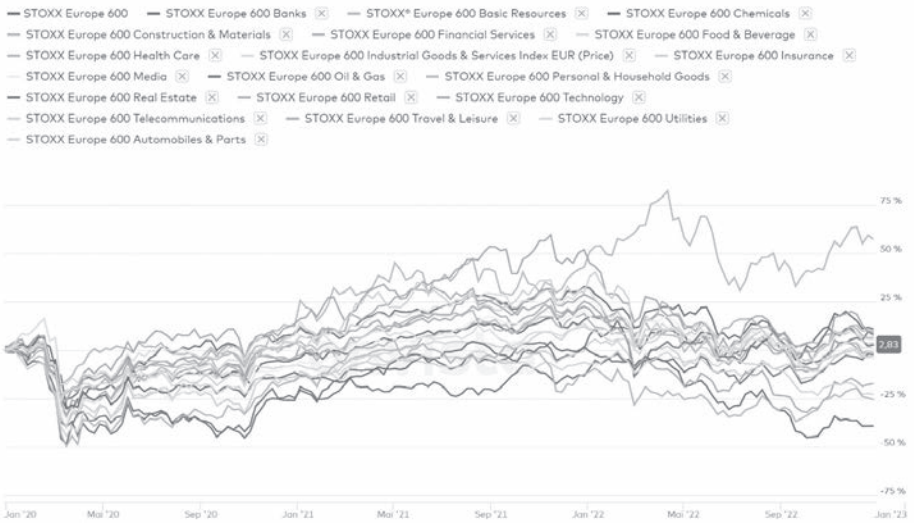
Official STOXX Europe 600 performance data shows that the performance is higher during the pandemic and lower in 2022 with increased ECB interest rates (TradingView 2022). In the next step, the STOXX Europe 600 sector performance is analyzed graphically to illustrate a potential contribution of the high-growth sectors to the overall index performance from 2020 to 2022. Figure 5 highlights the historical STOXX Europe 600 performance from January 2020 to December 2022.

Figure 5: STOXX Europe 600 performance from Jan 2020 to December 2022

Source: TradingView

Figure 6 highlights the historical STOXX Europe 600 sector performance from January 2020 to December 2022.

Figure 6: STOXX Europe 600 performance from January 2020 to December 2022



Source: Own representation based on Onvista

Figure 5 and 6 show that the performance of the index and the underlying sectors is higher during the pandemic and lower in 2022 with higher interest rates which supports the assumptions for this paper.

In the next step the STOXX Europe 600 sector performance is analyzed in absolute performance to identify contribution of the high-growth technology and the financial sector. Table 2 illustrates the significant performance contribution of the technology sector during the pandemic in 2020 and 2021. Furthermore, the data shows a significant underperformance of the sectors in 2022. In addition, the data shows a significant negative contribution of the financial sector in 2020 and a positive in 2021.

Table 2: STOXX Europe 600 sector performance from 2020 to 2022

	2020	2021	2022
STOXX Europe 600 Automobiles & Parts (SXAP)	3,7	25,1	-20,1
STOXX Europe 600 Banks (SX7P)	-24,5	34,0	-3,2
STOXX Europe 600 Basic Resources (SXPP)	8,2	20,3	4,3
STOXX Europe 600 Chemicals (SX4P)	8,2	22,7	-16,5
STOXX Europe 600 Construction & Materials (SXOP)	-3,9	31,1	-21,1
STOXX Europe 600 Financial Services (SXFP)	3,9	24,3	-25,2
STOXX Europe 600 Food & Beverage (SX3P)	-7,6	21,6	-14,3
STOXX Europe 600 Health Care (SXDP)	-3,4	23,1	-7,9
STOXX Europe 600 Industrial Goods & Services (SXNP)	4,6	26,7	-20,1
STOXX Europe 600 Insurance (SXIP)	-13,5	15,4	-1,0
STOXX Europe 600 Media (SXMP)	-7,7	31,7	-12,3
STOXX Europe 600 Oil & Gas (SXEP)	-25,8	17,1	24,4
STOXX Europe 600 Personal & Household Goods (SXQP)	3,5	18,1	-12,9
STOXX Europe 600 Real Estate (SX86P)	-11,5	14,8	-40,1
STOXX Europe 600 Retail (SXRP)	9,4	12,4	-32,6
STOXX Europe 600 Technology (SX8P)	13,9	33,7	-28,4
STOXX Europe 600 Telecommunications (SXKP)	-16,1	11,8	-17,7
STOXX Europe 600 Travel & Leisure (SXTP)	-15,5	3,7	-15,1
STOXX Europe 600 Utilities (SX6P)	7,9	5,4	-11,1
STOXX Europe 600 (SXXP)	-4,0	22,3	-12,9

Source: Qontigo

Based on the sector performance data the following hypothesis is defined:

H1: There is a significant correlation for ECB interest rate policy and high-growth sectors and financial sector performance of European equities during the COVID-19 pandemic from 2020 to 2021. For further research Pearson correlation and linear regression is used to evaluate a potential correlation between the ECB pandemic policy and the STOXX Europe 600 sector performance.

Correlation and Regression Analysis

H1 will be answered with the help of a Pearson correlation and linear regression for the index and ECB interest rate data. Data points and periods are the same as for the distribution and boxplot analysis. In the first step, a simple regression analysis for the pandemic observation is conducted with 258 data points. In the next step the performance sensitivity for all 19 sectors of the STOXX Europe 600 is conducted based on regression analysis and Pearson correlation for the same periods to identify a potential impact of the ECB policy on the performance sensitivity of the other STOXX Europe 600 sectors.

Table 3 shows the correlation between STOXX Europe 600 sub-sectors and interest rates in 2020

Table 3: Correlation between STOXX Europe 600 sub-sectors and interest rates in 2020

	r	P-value
STOXX Europe 600 Automobiles & Parts (SXAP)	0,03	0,44
STOXX Europe 600 Banks (SX7P)	0,04	0,48
STOXX Europe 600 Basic Resources (SXPP)	0,02	0,78
STOXX Europe 600 Chemicals (SX4P)	0,02	0,80
STOXX Europe 600 Construction & Materials (SXOP)	0,02	0,79
STOXX Europe 600 Financial Services (SXFP)	0,03	0,62
STOXX Europe 600 Food & Beverage (SX3P)	0,02	0,81
STOXX Europe 600 Health Care (SXDP)	0,02	0,80
STOXX Europe 600 Industrial Goods & Services (SXNP)	0,03	0,65
STOXX Europe 600 Insurance (SXIP)	0,02	0,72
STOXX Europe 600 Media (SXMP)	-0,01	0,92
STOXX Europe 600 Oil & Gas (SXEP)	0,02	0,73
STOXX Europe 600 Personal & Household Goods (SXQP)	0,03	0,65
STOXX Europe 600 Real Estate (SX86P)	0,02	0,72
STOXX Europe 600 Retail (SXRP)	0,04	0,57
STOXX Europe 600 Technology (SX8P)	0,06	0,36
STOXX Europe 600 Telecommunications (SXKP)	0,03	0,61
STOXX Europe 600 Travel & Leisure (SXTP)	0,03	0,67
STOXX Europe 600 Utilities (SX6P)	0,02	0,71
STOXX Europe 600 (SXXP)	0,03	0,60

Source: Own representation based on Qontigo & ECB data

The correlation in table 3 ranges between r = -.01 to r = .04. The p-values range from .36 to .92.

None of those correlations are significant, with all p-values being above .05. Table 3 Pearson values demonstrate that there is no significant correlation between interest rates and the performance of the STOXX Europe 600 sub-sectors in 2020. Therefore, the outperformance of the high-growth sectors cannot be explained with the low interest rate environment. This rejects H1, that there is a significant correlation between ECB interest rate policy and high-growth sectors and financial sector performance of European equities during the COVID-19 pandemic from 2020 to 2021.

Table 4 highlights the relationship between STOXX Europe 600 sub-sectors and interest rates for 2020.

Table 4: Relationship between STOXX Europe 600 sub-sectors and interest rates in 2020

	Coefficients	P-value	F	R Square	Multiple R
STOXX Europe 600 Automobiles & Parts (SXAP)	1,1E+14	0,66	0,19	0,00	0,03
STOXX Europe 600 Banks (SX7P)	1,8E+14	0,48	0,51	0,00	0,04
STOXX Europe 600 Basic Resources (SXPP)	5,9E+13	0,78	0,08	0,00	0,02
STOXX Europe 600 Chemicals (SX4P)	4,0E+13	0,80	0,06	0,00	0,02
STOXX Europe 600 Construction & Materials (SXOP)	5,1E+13	0,79	0,07	0,00	0,02
STOXX Europe 600 Financial Services (SXFP)	8,5E+13	0,62	0,24	0,00	0,03
STOXX Europe 600 Food & Beverage (SX3P)	3,2E+13	0,81	0,06	0,00	0,02
STOXX Europe 600 Health Care (SXDP)	3,3E+13	0,80	0,06	0,00	0,02
STOXX Europe 600 Industrial Goods & Services (SXNP)	8,0E+13	0,65	0,21	0,00	0,03
STOXX Europe 600 Insurance (SXIP)	8,3E+13	0,72	0,13	0,00	0,02
STOXX Europe 600 Media (SXMP)	-1,6E+13	0,92	0,01	0,00	0,01
STOXX Europe 600 Oil & Gas (SXEP)	8,7E+13	0,73	0,12	0,00	0,02
STOXX Europe 600 Personal & Household Goods (SXQP)	5,9E+13	0,65	0,20	0,00	0,03
STOXX Europe 600 Real Estate (SX86P)	6,0E+13	0,72	0,13	0,00	0,02
STOXX Europe 600 Retail (SXRP)	7,5E+13	0,57	0,32	0,00	0,04
STOXX Europe 600 Technology (SX8P)	1,6E+14	0,36	0,86	0,00	0,06
STOXX Europe 600 Telecommunications (SXKP)	8,0E+11	0,60	0,28	0,00	0,03
STOXX Europe 600 Travel & Leisure (SXTP)	1,1E+14	0,67	0,18	0,00	0,03
STOXX Europe 600 Utilities (SX6P)	6,1E+13	0,71	0,14	0,00	0,02
STOXX Europe 600 (SXXP)	8,0E+13	0,60	0,28	0,00	0,03

Source: Own representation based on Qontigo & ECB data

Table 4 shows a p-value range between .36 to .92. None of those relationships are significant, with all p-values being above .05. The coefficients range from 1,1E+14 to 8,7E+13. This can be explained by the low variance for the interest rate values during the year 2020. In summary, it can be said that there is no significant relationship between STOXX Europe 600 sub-sectors performance and interest rates for 2020. This rejects H1, that there is a high correlation between ECB interest rates and high-growth and financial sector sectors of the STOXX Europe 600 for 2020.

Table 5 shows the correlation between STOXX Europe 600 sub-sectors and interest rates in 2021. Correlation values range between r = -.10 to r = .14. The p-values range from .03 to .81. The value for the basic resources sector is significant, with a p-value of .03. None of the other correlations are significant, with all p-values being above .05. In table 5, Pearson values demonstrate that there is one significant correlation between interest rates and the performance of basic resources in 2021. Therefore, the outperformance

of the high-growth sectors cannot be explained by the low interest rate environment. This rejects H1, that there is a significant correlation between ECB interest rate policy and high-growth and financial sector sectors performance of European equities during the COVID-19 pandemic from 2020 to 2021.

Table 5: Correlation between STOXX Europe 600 sub-sectors and interest rates in 2021

	r	P-value
STOXX Europe 600 Automobiles & Parts (SXAP)	-0,05	0,39
STOXX Europe 600 Banks (SX7P)	-0,07	0,28
STOXX Europe 600 Basic Resources (SXPP)	0,14	0,03*
STOXX Europe 600 Chemicals (SX4P)	0,07	0,27
STOXX Europe 600 Construction & Materials (SXOP)	0,08	0,21
STOXX Europe 600 Financial Services (SXFP)	0,04	0,51
STOXX Europe 600 Food & Beverage (SX3P)	0,02	0,69
STOXX Europe 600 Health Care (SXDP)	0,05	0,42
STOXX Europe 600 Industrial Goods & Services (SXNP)	0,03	0,60
STOXX Europe 600 Insurance (SXIP)	-0,04	0,48
STOXX Europe 600 Media (SXMP)	-0,03	0,63
STOXX Europe 600 Oil & Gas (SXEP)	-0,05	0,44
STOXX Europe 600 Personal & Household Goods (SXQP)	-0,03	0,58
STOXX Europe 600 Real Estate (SX86P)	-0,09	0,14
STOXX Europe 600 Retail (SXRP)	-0,10	0,11
STOXX Europe 600 Technology (SX8P)	0,06	0,81
STOXX Europe 600 Telecommunications (SXKP)	0,07	0,28
STOXX Europe 600 Travel & Leisure (SXTP)	0,00	0,04
STOXX Europe 600 Utilities (SX6P)	0,13	0,73
STOXX Europe 600 (SXXP)	0,02	0,33

Note: * significance with value P<0.05

Source: Own representation based on Qontigo & ECB data

Table 6 shows the relationship between STOXX Europe 600 sub-sectors and interest rates for 2021.

Table 6: Relationship between STOXX Europe 600 sub-sectors and interest rates in 2021

	Coefficients	P-value	F	R Square	Multiple R
STOXX Europe 600 Automobiles & Parts (SXAP)	1,8E+14	0,39	0,73	0,00	0,05
STOXX Europe 600 Banks (SX7P)	-1,3E+14	0,28	1,16	0,00	0,07
STOXX Europe 600 Basic Resources (SXPP)	3,2E+14	0,03*	4,97	0,02	0,14
STOXX Europe 600 Chemicals (SX4P)	8,5E+13	0,27	1,24	0,00	0,07
STOXX Europe 600 Construction & Materials (SXOP)	1,1E+14	0,21	1,60	0,01	0,08
STOXX Europe 600 Financial Services (SXFP)	5,7E+13	0,51	0,44	0,00	0,04
STOXX Europe 600 Food & Beverage (SX3P)	2,5E+13	0,69	0,16	0,00	0,02
STOXX Europe 600 Health Care (SXDP)	5,7E+13	0,42	0,66	0,00	0,05
STOXX Europe 600 Industrial Goods & Services (SXNP)	4,5E+13	0,60	0,28	0,00	0,03
STOXX Europe 600 Insurance (SXIP)	-6,3E+13	0,47	0,51	0,00	0,04
STOXX Europe 600 Media (SXMP)	-3,8E+13	0,63	0,23	0,00	0,03
STOXX Europe 600 Oil & Gas (SXEP)	-9,2E+13	0,44	0,60	0,00	0,05
STOXX Europe 600 Personal & Household Goods (SXQP)	-4,2E+13	0,58	0,31	0,00	0,03
STOXX Europe 600 Real Estate (SX86P)	-1,2E+14	0,14	2,17	0,01	0,09
STOXX Europe 600 Retail (SXRP)	-1,7E+14	0,11	2,59	0,01	0,10
STOXX Europe 600 Technology (SX8P)	2,9E+13	0,81	0,06	0,00	0,03
STOXX Europe 600 Telecommunications (SXKP)	2,2E+11	0,28	1,19	0,00	0,07
STOXX Europe 600 Travel & Leisure (SXTP)	-3,9E+12	0,98	0,00	0,00	0,00
STOXX Europe 600 Utilities (SX6P)	1,8E+14	0,04*	4,39	0,02	0,13
STOXX Europe 600 (SXXP)	2,2E+13	0,73	0,12	0,00	0,02

Source: Own representation based on Qontigo & ECB data

Table 6 shows a p-value range between .03 to .98. The value for the basic resources sector is significant, with a p-value of .03. Furthermore, the value for the utilities sector is significant, with a p-value of .04. None of the other relationships are significant, with all p-values being above .05. The coefficients range from -9,2E+13 to 8,5E+13. The high values can be explained by the low variance for the interest rate values during the year 2021. To summarize, it can be said that there is no significant relationship between STOXX Europe 600 high-growth sub-sectors and financial sector performance and interest rates for 2021. This rejects H1, that there is a significant correlation between ECB interest rate policy and high-growth sectors performance of European equities during the COVID-19 pandemic from 2020 to 2021.

Table 7 shows the correlation between STOXX Europe 600 sub-sectors and interest rates in 2022.

Table 7: Correlation between STOXX Europe 600 sub-sectors and interest rates in 2022

	r	P-value
STOXX Europe 600 Automobiles & Parts (SXAP)	0,03	0,60
STOXX Europe 600 Banks (SX7P)	0,06	0,30
STOXX Europe 600 Basic Resources (SXPP)	0,06	0,34
STOXX Europe 600 Chemicals (SX4P)	0,05	0,47
STOXX Europe 600 Construction & Materials (SXOP)	0,06	0,37
STOXX Europe 600 Financial Services (SXFP)	0,05	0,40
STOXX Europe 600 Food & Beverage (SX3P)	0,01	0,89
STOXX Europe 600 Health Care (SXDP)	0,01	0,85
STOXX Europe 600 Industrial Goods & Services (SXNP)	0,07	0,28
STOXX Europe 600 Insurance (SXIP)	0,06	0,33
STOXX Europe 600 Media (SXMP)	0,04	0,52
STOXX Europe 600 Oil & Gas (SXEP)	0,01	0,86
STOXX Europe 600 Personal & Household Goods (SXQP)	0,06	0,34
STOXX Europe 600 Real Estate (SX86P)	0,04	0,53
STOXX Europe 600 Retail (SXRP)	0,10	0,09
STOXX Europe 600 Technology (SX8P)	0,08	0,22
STOXX Europe 600 Telecommunications (SXKP)	-0,06	0,30
STOXX Europe 600 Travel & Leisure (SXTP)	0,04	0,52
STOXX Europe 600 Utilities (SX6P)	0,02	0,76
STOXX Europe 600 (SXXP)	0,06	0,73

Note: * significance with value P<0.05

Source: Own representation based on Qontigo & ECB data

The correlation in table 7 ranges between r = -.06 to r = .10. The p-values range from .09 to .89. None of those correlations are significant, with all p-values being above .05. In table 7, Pearson values demonstrate that there is no significant correlation between interest rates and the performance of the STOXX Europe 600 sub-sectors in 2022. Therefore, the performance of the STOXX Europe 600 sub-sectors cannot be explained by the low interest rate environment.

Table 8 highlights the relationship between STOXX Europe 600 sub-sectors and interest rates for 2022. The p-value ranges between .09 to .89. None of the relationships are significant, with all p-values being above .05. The coefficients range from .00 to .18. The values are lower compared to 2020 and 2021 examinations. This can be explained by the high variance for the interest rate values during the year 2022.

Table 8: Relationship between STOXX Europe 600 sub-sectors and interest rates in 2022

	Coefficients	P-value	F	R Square	Multiple R
STOXX Europe 600 Automobiles & Parts (SXAP)	0,08	0,60	0,28	0,00	0,03
STOXX Europe 600 Banks (SX7P)	0,12	0,36	0,85	0,00	0,06
STOXX Europe 600 Basic Resources (SXPP)	0,13	0,34	0,90	0,00	0,06
STOXX Europe 600 Chemicals (SX4P)	0,08	0,47	0,52	0,00	0,05
STOXX Europe 600 Construction & Materials (SXOP)	0,10	0,37	0,82	0,00	0,06
STOXX Europe 600 Financial Services (SXFP)	0,10	0,40	0,70	0,00	0,05
STOXX Europe 600 Food & Beverage (SX3P)	0,01	0,89	0,02	0,00	0,01
STOXX Europe 600 Health Care (SXDP)	0,01	0,85	0,03	0,00	0,01
STOXX Europe 600 Industrial Goods & Services (SXNP)	0,07	0,28	1,19	0,00	0,07
STOXX Europe 600 Insurance (SXIP)	0,00	0,47	0,53	0,00	0,05
STOXX Europe 600 Media (SXMP)	0,06	0,52	0,42	0,00	0,04
STOXX Europe 600 Oil & Gas (SXEP)	0,02	0,86	0,03	0,00	0,01
STOXX Europe 600 Personal & Household Goods (SXQP)	0,09	0,34	0,90	0,00	0,06
STOXX Europe 600 Real Estate (SX86P)	0,09	0,53	0,40	0,00	0,04
STOXX Europe 600 Retail (SXRP)	0,23	0,09	2,81	0,01	0,10
STOXX Europe 600 Technology (SX8P)	0,18	0,22	1,53	0,01	0,08
STOXX Europe 600 Telecommunications (SXKP)	0,00	0,34	1,07	0,00	0,06
STOXX Europe 600 Travel & Leisure (SXTP)	0,09	0,52	0,41	0,00	0,04
STOXX Europe 600 Utilities (SX6P)	0,03	0,76	0,10	0,00	0,02
STOXX Europe 600 (SXXP)	0,08	0,34	0,92	0,00	0,06

Source: Own representation based on Qontigo & ECB data

To summarize, the performance of the STOXX Europe 600 sub-sectors in 2022 cannot be explained by the low interest rate environment. This rejects the assumption that there is a mean reversion process for European equities with the shift of ECB interest rate policy after the pandemic in 2022.

5 Conclusion

This paper shows the different sensitivity of STOXX Europe 600 sectors during the Covid19 pandemic from 2020 to 2022 with the ECB interest rates. The technology sector contributed significantly to the positive performance in the low interest rate environment and led the negative contribution in 2022 with raising interest rates.

Interestingly, there is an outperformance of the STOXX Europe 600 Technology over the STOXX Europe 600 during the pandemic and an underperformance in 2022 with increased interest rates. But the regression analysis of this paper shows that that there is no linear correlation between ECB interest rates and the performance of the technology sector and proves that that there is no mean reversion process in 2022.

Therefore, the aim of this paper results in the important conclusion that the hypothesis that the higher the interests at the end of the pandemic the higher the mean reversion process for the highly capitalized STOXX Europe 600 sectors is wrong. Since traditional companies, such as utilities or consumer goods and banks, are less affected by the mechanism of discounted cash flow this paper expresses further dedicated research on these sectors.

One limitation of this study is the focus on interest rate changes as the key variable influencing stock market performance during the COVID-19 pandemic. While this variable is significant, other relevant variables, such as political events, economic indicators, and global trade relationships, could have been included to provide a more comprehensive analysis. The exclusion of these variables limits the findings and prevents a comprehensive understanding of the complexities of stock market performance.

Overall, this paper provides an overview of the complex interplay between interest rates and stocks and shows the relevance of an investigation into the relationship during a period of extraordinary economic circumstances from 2020 to 2022. The results contribute to a better understanding of the relationships between interest rate policy changes, COVID-19 pandemic and European stock market performance. Although no significant effects on sector performance were found, this suggests that other factors may play a larger role. Further research is needed to identify these factors in more detail and understand their impact on equity markets. The findings of this study can be used by investors to make more informed decisions regarding their investment strategies and business plans.

The paper also recommends conducting research based on S&P 500 sector sensitivity data to analyze a potential correlation with Fed interest rates in comparison to the ECB.

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Linkages Between Property Prices and Macroeconomic Determinants: Evidence from Germany

FREDERIK SCHRÖDER

Abstract

The global financial and economic crisis has led to significant efforts to better integrate property price channels into macroeconomic models and to improve models. This paper deals with property prices in Germany and their determinants in the period Q1 2000–Q4 2022. Since then, property prices in Germany have risen considerably. The models regularly use indicators that are aligned with the specificities of property, but less macroeconomic determinants. From economic models, theoretical modes of action between macroeconomic determinants and property prices are generally known. Regarding Germany, there are only limited studies on the direct influences of economic determinants. In the context of a regression analysis, this paper examines the relationship between the selected variables that directly drive house prices.

On the one hand the results confirm a positive relationship between property prices and real GDP. On the other hand, a negative correlation was found for real short-term interest rates and inflation. In this study, no significant relationships were found between house prices and unemployment rate and long-term interest rates, despite a culture of long-term fixed interest rates in Germany.

Keywords

Real Estate Markets, Housing Demand, Business Fluctuations

JEL Codes

R31, R21, E32

DOI

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Introduction

Since the global financial crisis, the property prices have begun to be investigated (Wetzstein, 2017; Haffner and Hulse, 2021). Previous pre-crisis macroeconomic models have not taken into account satisfactory links between the real economy and asset prices (Duca et al., 2021). The IMF found that house prices are synchronized across countries, and they claimed that this is caused by global interest rate shocks (Hirata et al., 2013; Katagiri, 2018; Andrle and Plašil, 2019). It is therefore reasonable to assume that property prices and interest rates could also be negatively correlated in Germany. Since the beginning of 2020, a contagious disease of a new coronavirus called COVID-19 by the WHO has been spreading around the world. It has led to many deaths and a global recession. Many companies also have significant difficulties in maintaining proper business operations due to supply chain problems. As a result, economic growth has fallen significantly behind the good results of recent years. The unemployment rates of many developed economies have risen noticeably for the first time in years because of the pandemic. The unemployment rate in Germany rose to 6,3% in 2020, as reported by the Federal Statistical Office. Contrary to general expectations, however, property prices in many countries, including Germany, have increased rather than fallen in this catastrophic event.

Opposite to the traditional theoretical prediction of a negative impact of a pandemic on the housing market (Francke and Korevaar, 2021) house prices rose significantly in many countries after the outbreak of COVID, including Germany. The development was also observed when business operations were disrupted, GDP growth rates were negative and unemployment rates were unprecedentedly high (Wang, 2021). During the movements of these macroeconomic determinants, a fall in property prices was generally to be expected. Instead, property prices initially continued to rise. Property prices didn't start declining until after Russia's invasion of Ukraine, which was followed by a shortage of construction supplies and an energy crisis in Germany. Thus, the question arises whether a bubble formation could be present. This paper examines the development of several determinants influencing house prices from long-established models using multivariate regression analysis. The aim is to see which determinants are strongly correlated with property prices.

The paper is structured as follows. In the introduction a literature review of studies on the monetary policy hypotheses was shown. Section 1 outlines the research materials and methods used. The following section reports on the results of the empirical tests. Section 3 discusses the results and implications. The end of the paper accomplishes with a conclusion.

1 Methodology

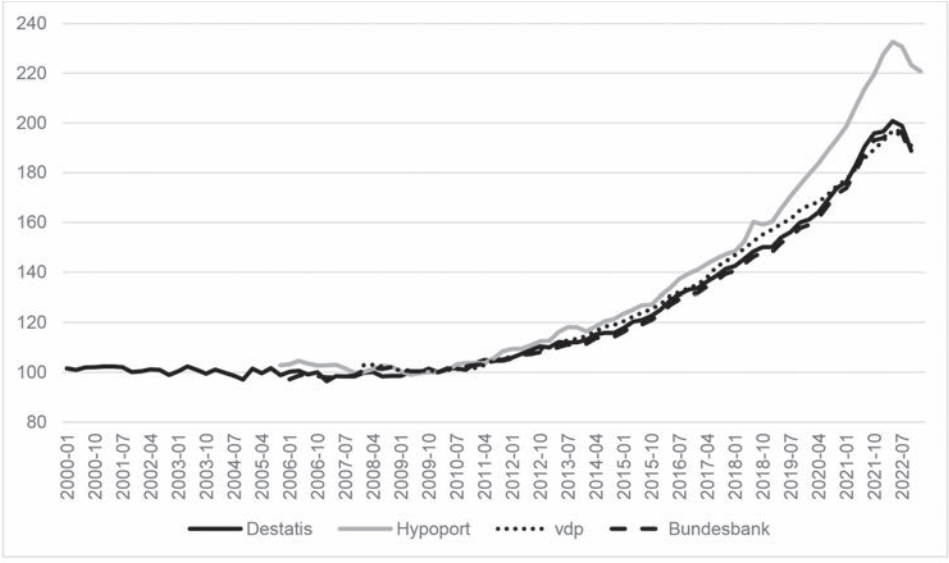
The aim of this paper is to analyze how short-term and long-term real interest rates, unemployment rate, consumer price index (inflation) and real gross domestic product influence the level of property prices in Germany. The goal of the paper is to find determinants that describe property prices in Germany. The study is based on the following two hypotheses: I expect a positive relationship between house prices, inflation

and real gross domestic product. And I assume a negative relationship between house prices, real short- and long-term real interest rates and unemployment.

1.1 Data

House prices are not easy to generate due to the lack of a public register in Germany. In principle, property price indices are compiled by four established institutions: The German Central Bank (Deutsche Bundesbank), the German Federal Statistical Office (Destatis), the Association of German Bond Banks, which represents the interests of the majority of credit institutions issuing bonds in Germany (vdp), and one of the two central brokers of real estate financing (Hypoport AG). These house price indices are generally published quarterly and are indexed as 2010=100 and shown in the following figure.

Figure 1: Indexed prices for residential real estate in Germany



Source: (Deutsche Bundesbank, 2022); (Europace AG, 2022)

Overall, the development of three out of four institutions is quite uniform. The only difference in Figure 1 is the price development of Hypoport AG. From 2017 onwards, there will be a higher increase in property prices, which will intensify again from 2019. Hypoport AG does not claim to record the development of the market as a whole, but only calculates the index on the basis of data from the transactions it supports, which account for around 20% of the transactions in the market as a whole. As a result, the development of the property market is not presented holistically. As an amplifying explanatory approach, the urban-rural divide in the use of financing intermediaries in connection with the stronger increase in property prices in cities could play a role.

As a result, the data from Hypoport AG will not be used further, as there is a suspicion that the data is not representative.

For the study period from the beginning of 2000 to the end of 2022, only the time series with continuous data from the German Federal Statistical Office is available. Since the data of the vdp and the Deutsche Bundesbank differ only marginally, the logarithm of the data series of the German Federal Statistical Office is used for this paper as the property price index and thus also as a dependent variable.

First of all, the real interest rate is considered as an independent variable. However, the determination of the real interest rate is not without problems, since in Germany, in contrast to many other developed economies, property is regularly financed not variably with short-term interest rates, but property is usually financed with long-term fixed interest rates. Against this background, a short-term real interest rate may have only a limited effect on the property market and both a short-term and a long-term real interest rate, as well as a combination in this model, are examined. The following list provides an overview of the variables that capture the basic determinants included in the empirical analysis based on the literature review.

Short-term interest rates (SIR): When setting short-term real interest rates by using short-term nominal interest rates adjusted for inflation, there is a risk of distortion when nominal interest rates approach the lower bound of zero. Therefore, the short-term real interest rate is defined as the shadow rate. This model was originally elaborated by Fischer Black (Black, 1995) in his work "Interest as Options". The shadow interest rate derives from Fischer Black's insight that currencies are an option. If someone has money, they can either spend it today or not spend it and have money tomorrow. So, if less money were repaid on loans than was originally borrowed, investors will choose to exercise this option and not lend their money. Thus, the nominal short-term interest rate is always greater than or equal to zero. In this model, the nominal short-term shadow interest rate is equal to what the nominal short-term interest rate would be if it were allowed to fall below the lower zero bound. But if the short-term shadow interest rate is negative – as during deflation or a severe recession with low inflation – the nominal short-term interest rate will diverge and remain above zero. In Black's model, long-term nominal interest rates can be well above zero, even if nominal short-term interest rates remain close to zero. There is also an ECB shadow rate. The real shadow interest rate is equal to the nominal shadow interest rate minus expected inflation. Due to the option effect, the shadow interest rate is not directly observable on the market. The value of the shadow interest rate depends on assumptions about how interest rates move, so different models may calculate different values for it. The model by Jing Cynthia Wu and Fan Dora Xia was published in "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound" and applied in the context of the work (Wu and Xia, 2016). To eliminate trends, the change in the previous period is considered.

Long-term interest rates (LTIR): The long-term real interest rate is defined as the expected real interest rate in Germany for government securities with a residual maturity of 10 years. In order to eliminate trends, the change in the previous period is taken into account. It is published monthly by the Deutsche Bundesbank. Since the analysis is based

on quarterly figures, the arithmetic mean of the monthly values is formed for the quarter. There is no risk of a distortion at the zero-line analogous to short-term interest rates in the case of long-term interest rates, since the expectations of market participants are queried independently of each other for both the ten-year nominal interest rate and the long-term inflation rate. Thus, the zero line does not form a de facto barrier.

Unemployment rate (UNE): The Federal Employment Agency publishes meaningful time series of the unemployment rate on a monthly basis. Since the analysis is based on quarterly figures, the arithmetic mean of the monthly values is formed for the quarter. Labour market time series are influenced by annually recurring seasonal effects, which make it difficult to assess current trends in the labour market. Seasonal influences can be eliminated by means of statistical methods to enable a better assessment of current developments. In addition to the seasonal adjustment core, the Census X-12 ARIMA method used in the statistics of the Federal Employment Agency for seasonal adjustment contains a module for pre-processing the time series as well as key figures for assessing the results of the seasonal adjustment. The methodological report presents the main features of this seasonal adjustment procedure.

Gross Domestic Product (GDP): As a measure of the economic performance of an economy, the gross domestic product is included. GDP measures the value of domestically produced goods and services and is calculated on a price-adjusted basis (deflation with annually changing prices and chaining of the previous year) and calculated logarithmic returns. The rate of change in price-adjusted gross domestic product is a regular measure of economic growth in national accounts, making it the most important measure of national accounts and one of the indicators of the International Monetary Fund's (IMF) dissemination standard. Data from the Federal Statistical Office (Destatis) are used for the survey on a quarterly basis.

Inflation (CPI): Inflation is defined as the Consumer price index. For Germany, the Harmonised Index of Consumer Prices (HICP) is calculated. The HICP was developed in the European Union (EU) to be able to compare price developments internationally and to combine them into an overall inflation rate for Europe and for the euro area. The index is compiled by the Federal Statistical Office on a monthly basis. Since the analysis is based on quarterly figures, the arithmetic mean of the monthly values is formed for the quarter.

The following table describes the central tendency of the respective variables as well as the distribution of the values of the variables.

Table 1: Descriptive statistics Q2 2000–Q4 2022

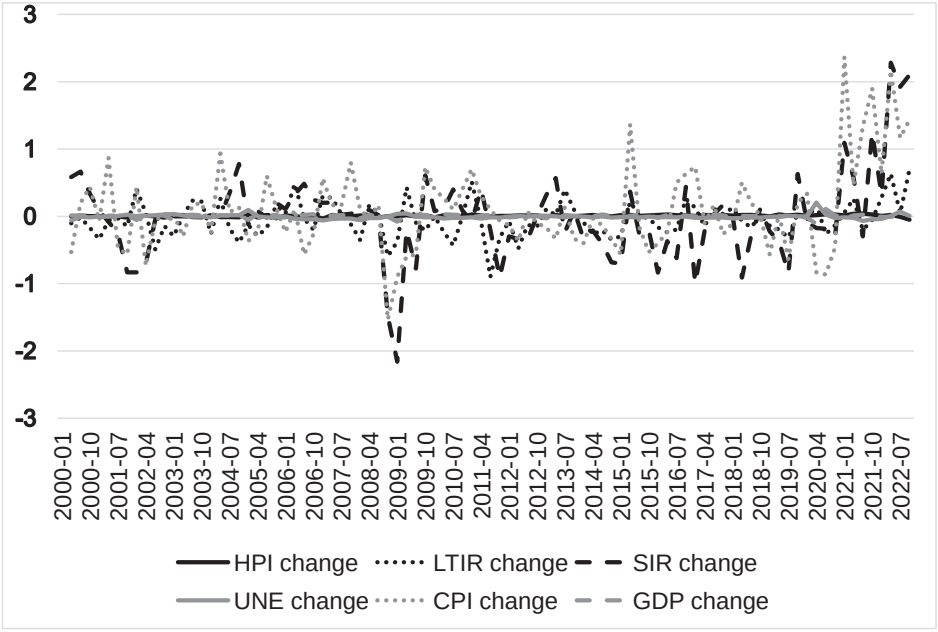
		HPI	LTIR	SIR	UNE	CPI	GDP
N	Valid	91	91	91	91	91	91
	Missing	0	0	0	0	0	0
Mean		.0069	-.0467	-.0064	-.0067	.1015	.0030
Median		.0080	-.0680	.0000	-.0100	.0330	.0100
Std. Deviation		.01628	.26500	.64186	.03364	.64512	.02732
Range		.10	1.59	4.44	.27	3.90	.22
Minimum		-.05	-.90	-2.16	-.07	-1.53	-.11
Maximum		.04	.70	2.28	.20	2.37	.11

Sources: SPSS, own work

1.2 Research Design

First, the data set was compiled. The data has been prepared in such a way that the percentage returns have been converted into logarithmic returns to eliminate possible trends. Only in the case of interest rates, this method is not applicable, since the data contain positive and negative values. Consequently, the absolute change is used to take out a trend.

Figure 2: Time series with trend elimination



Source: Own work

The ordinary least squares method is used. In this process, a function is determined for a set of data points that runs as close as possible to the data points and thus summarizes the data in the best possible way. A straight line, the regression line, is used as a function, especially since a linear relationship between the variables is obvious. The parameters of the function to be estimated are determined in such a way that the sum of the squared residuals becomes minimal. The estimators for α, β and $\sigma^2 = \mathrm{Var}(\epsilon_n)$ using the principle of ordinary least squares will be found. Here, α and β is chosen in such a way that

$$S(\alpha, \beta) = \sum_n (Y_n - \alpha - \beta X_n)^2 = \sum_n \epsilon_n^2$$

becomes minimal, so that the straight line is optimally adapted to the data points (X_n, Y_n).

So the least squares method allows, under certain conditions, to calculate the most probable of all model parameters. To do this, a correct model must have been selected, a sufficient number of measured values must be available and the deviations of the measured values from the model system must form a normal distribution. In practice, the method can be used for various purposes even if these requirements are not met. However, it should be noted that under certain unfavorable conditions, the method of least squares can give completely undesirable results. For example, there should be no outliers in the measured values, as these distort the estimation result. In addition,

multicollinearity between the parameters to be estimated is unfavorable as it causes numerical problems. Incidentally, even regressors that are far away from the others can strongly influence the results of the adjustment calculation.

During the regression, a collinearity diagnostics indicator was used to check whether the independent variables are too strongly correlated. There are no values that indicate multicollinearity problems. Next, the regression coefficient variance decomposition matrix was considered. For each regression coefficient, its variance is distributed over the different eigenvalues. No values were found in the condition index, which assume that there is a collinearity problem.

Furthermore, a Durbin-Watson test was used to check the autocorrelation of the residuals. It is monitored whether the respective previous month's values are suitable for forecasting the current values, i.e. whether the correlation between two consecutive residual variables is non-zero in a regression analysis. When looking at the residuals, the standardized residuals are examined as a function of the forecast value. There are no values of residuals that indicate too high a correlation. This concludes the first phase of the investigation.

Linear regression is performed using the backward elimination method. In this procedure, the independent variables that no longer have a significant influence on the dependent variable are excluded. Thus, all variables are first recorded and a model with all five independent variables is created in this investigation. Subsequently, the independent variables with the highest significance value are successively eliminated, up to a value of < 0.1.

Compared to stock markets, the property market is sluggish. The change in macroeconomic determinants could therefore have a delayed effect. The processing of property transactions in Germany via a notary as well as the time required to approve financing could slow down immediate reactions. Therefore, time lags up to a period of one year are examined in four different steps, each with a further quarter time offset.

2 Results

In the first linear regression model, all independent variables are successively eliminated. Thus, there is no immediate significant effect on property prices in the event of a change in the determinants. In a model with the shadow interest rate and inflation, a significance value of 0.104 is determined, but the unstandardized beta has different signs for independent variables and should therefore not be overinterpreted. When looking at the shadow interest rate alone, the regression coefficient is lower, which could indicate an overfitting of the model. In this model, the significance value is 0.176 and therefore there is no significance.

In the next step, a time lag of one quarter is integrated into the model. Consequently, the number of observations is reduced by one. The next table shows the results.

Table 2: Coefficients from regression model time lag 1 quarter

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	.007	.002		3.678	.000		
	LTIR_chg	.001	.007	.013	.113	.910	.826	1.211
	SIR_chg	-.008	.004	-.301	-2.224	.029	.574	1.741
	UNE_chg	-.061	.058	-.127	-1.062	.291	.740	1.351
	CPI_chg	.002	.004	.084	.602	.549	.541	1.847
	GDP_chg	-.105	.069	-.177	-1.510	.135	.771	1.297
2	(Constant)	.006	.002		3.772	.000		
	SIR_chg	-.008	.004	-.299	-2.254	.027	.594	1.682
	UNE_chg	-.061	.057	-.126	-1.065	.290	.742	1.348
	CPI_chg	.002	.004	.087	.642	.523	.564	1.773
	GDP_chg	-.106	.069	-.178	-1.537	.128	.778	1.285
3	(Constant)	.007	.002		3.945	.000		
	SIR_chg	-.007	.003	-.246	-2.379	.020	.971	1.030
	UNE_chg	-.074	.053	-.153	-1.378	.172	.844	1.185
	GDP_chg	-.116	.067	-.195	-1.742	.085	.823	1.215
4	(Constant)	.007	.002		4.217	.000		
	SIR_chg	-.007	.003	-.246	-2.366	.020	.971	1.030
	GDP_chg	-.080	.062	-.135	-1.301	.197	.971	1.030
5	(Constant)	.007	.002		4.075	.000		
	SIR_chg	-.007	.003	-.268	-2.614	.011	1.000	1.000

a. Dependent Variable: HPI chg. (time lag: 1 quarter)

Source: SPSS, own work

With a time lag of one quarter, a significant result is achieved. The more the shadow interest rate rises, the more the house price index in Germany decreases. Already in the first, saturated model, the value of the shadow interest rate is significant, and the significance increases with the successive elimination of the remaining variables that cause distortion here. The results of the Durbin-Watson test for the model with a time lag of one quarter are presented in table 3.

Table 3: Durbin-Watson from regression model time lag 1 quarter

Model Summary[f]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.337[a]	0,114	0,061	0,01580	
2	.337[b]	0,114	0,072	0,01571	
3	.331[c]	0,109	0,078	0,01566	
4	.300[d]	0,090	0,069	0,01574	
5	.268[e]	0,072	0,062	0,01580	1,783

a. Predictors: (Constant), GDP_chg, CPI_chg, LTIR_chg, UNE_chg, SIR_chg

b. Predictors: (Constant), GDP_chg, CPI_chg, UNE_chg, SIR_chg

c. Predictors: (Constant), GDP_chg, UNE_chg, SIR_chg

d. Predictors: (Constant), GDP_chg, SIR_chg

e. Predictors: (Constant), SIR_chg

f. Dependent Variable: HPI chg. (time lag: 1 quarter)

Source: SPSS, own work

In the next step, a time lag of two quarters is considered. There will be no significant independent variable. When extending the time lag to three quarters, significant results are achieved using a model of two independent variables. The change in GDP has a high significance of 0.011 and there is a positive relationship between real GDP and house price Index. The SIR has a significance value of 0.090 and with a directed hypothesis, a significance would still have to be stated here. However, the effect is not as clear as with the time lag of a quarter. This method with backward elimination is listed in the table below.

Table 4: Coefficients from regression model time lag 3 quarter

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.006	.002		3.143	.002		
	LTIR_chg	-.008	.007	-.117	-1.056	.294	.882	1.134
	SIR_chg	-.006	.004	-.192	-1.538	.128	.697	1.435
	UNE_chg	.059	.062	.119	.950	.345	.689	1.451
	CPI_chg	.003	.004	.117	.887	.378	.620	1.614
	GDP_chg	.188	.071	.315	2.638	.010	.759	1.317
2	(Constant)	.006	.002		3.318	.001		
	LTIR_chg	-.007	.007	-.099	-.907	.367	.914	1.094
	SIR_chg	-.005	.004	-.143	-1.278	.205	.869	1.150
	UNE_chg	.038	.058	.077	.665	.508	.804	1.244
	GDP_chg	.174	.069	.292	2.509	.014	.796	1.256
3	(Constant)	.006	.002		3.263	.002		
	LTIR_chg	-.007	.007	-.100	-.918	.361	.915	1.093
	SIR_chg	-.005	.004	-.152	-1.382	.171	.885	1.130
	GDP_chg	.156	.063	.262	2.455	.016	.946	1.057
4	(Constant)	.006	.002		3.527	.001		
	SIR_chg	-.006	.003	-.181	-1.715	.090	.962	1.039
	GDP_chg	.163	.063	.274	2.597	.011	.962	1.039

a. Dependent Variable: HPI chg. (time lag: 3 quarters)

Source: SPSS, own work

During a further extension of the time lag to four quarters, a significant result is achieved. There is a negative relationship between inflation and house prices. In the model, the remaining independent variables only contributed to distortion and were removed from the model during backward elimination, as shown in the following table.

Table 5: Coefficients from regression model time lag 4 quarter

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.008	.002		4.183	.000		
	LTIR_chg	.008	.008	.119	1.061	.292	.889	1.125
	SIR_chg	-.003	.004	-.090	-.707	.481	.701	1.426
	UNE_chg	.021	.064	.043	.333	.740	.688	1.454
	CPI_chg	-.006	.004	-.225	-1.676	.098	.627	1.595
	GDP_chg	-.024	.073	-.041	-.336	.738	.755	1.325
2	(Constant)	.008	.002		4.199	.000		
	LTIR_chg	.008	.008	.122	1.094	.277	.893	1.119
	SIR_chg	-.003	.004	-.087	-.691	.491	.704	1.420
	CPI_chg	-.007	.003	-.241	-1.954	.054	.730	1.370
	GDP_chg	-.035	.065	-.059	-.545	.587	.943	1.060
3	(Constant)	.008	.002		4.182	.000		
	LTIR_chg	.009	.007	.129	1.166	.247	.904	1.106
	SIR_chg	-.003	.004	-.102	-.838	.405	.741	1.349
	CPI_chg	-.007	.003	-.238	-1.935	.056	.732	1.366
4	(Constant)	.008	.002		4.402	.000		
	LTIR_chg	.008	.007	.116	1.060	.292	.923	1.083
	CPI_chg	-.008	.003	-.284	-2.605	.011	.923	1.083
5	(Constant)	.007	.002		4.278	.000		
	CPI_chg	-.007	.003	-.252	-2.404	.018	1.000	1.000

a. Dependent Variable: HPI chg. (time lag: 4 quarters)

Source: SPSS, own work

As mentioned above, a significant relationship is established with different time lags between property prices and short-term interest rates, GDP and inflation. The models show that the relationship between house prices and short-term interest rates or inflation is negative, with a positive relationship with GDP. No significance was found on long-term interest rates and the unemployment rate.

The adjusted R-squared value is quite low in all three models with significant variables and lies between .053 and .067 (time lag 1 quarter .062; time lag 3 quarters .067; time lag 4 quarters .053). R-squared is a measure of how much of the variation in the dependent variable is explained by the independent variables in the model. It ranges from 0 to 1, with higher values indicating a better fit. Adjusted R-squared is similar like R-squared, but it considers the number of independent variables in the model. It is a more conservative estimate of the model's fit, as it penalizes the addition of variables that do not improve the model's performance. The low R-squared could result from the fact that the data set also has only a small number of predictors and asset prices are generally difficult

to predict from data. The highest R-squared is achieved in the model with a time lag of three quarters. In principle, the result is also plausible, since it is the only model in which two significant variables have remained in the model, even though one of the variables is only one-sidedly significant. The R-squared values are quite low, making it difficult to make an exact forecast of real estate prices. However, the creation of a real estate price model is not the subject of this work, but the comparison of different determinants and their influence on real estate prices. Thus, the low R-squared values do not fundamentally affect the significance of the paper. There is no indication of multicollinearity in the model.

3 Discussion

In the first linear regression, no significant associations were found between the dependent and independent variables. However, this fact is not implausible, since property is neither traded as fungible nor can its trading be observed as transparently as, for example, stocks. Even in the case of informed market participants, the effects of the determinants would take time before an effect could unfold. For this reason, the application of time lags makes sense.

With a time lag of one quarter, a significant result is achieved. The more short-term real interest rates rise, the more the house price index in Germany decreases. In principle, this correlation had been expected, since on the one hand the interest rate is an extremely relevant determinant in property transactions and their financing and on the other hand the real interest rate describes the opportunity for a property investment. This result also confirms the use of the shadow interest rate, which tracks negative real interest rates almost continuously from 2011 to 2022. With a value of 1.783, the Durbin-Watson test is in the range between 1.5 and 2.5 and thus does not indicate the presence of autocorrelation.

A significant correlation between property prices and short-term interest rates can no longer be determined with a time lag of two quarters. However, this fact was also to be expected, since although a time delay is needed before the breakthrough, there are quite fast-reacting markets and a high level of transparency among all market participants. Other asset classes, such as share prices, for example, are also traded on the stock exchange and are therefore much more transparent, but interest rate changes also react almost immediately. Consequently, a delay of two quarters in the effect of the interest rate was not expected.

There is a positive relationship between real GDP and the house price Index with a time lag of three quarters. This delay until the effect on property prices is also plausible, as the impulses from GDP seem quite sluggish. Furthermore, with a delay of three quarters, this approach reveals a further negative relationship to short-term interest rates, but only in the case of a directed hypothesis. This relationship can also be meaningfully derived from macroeconomic models, since when GDP rises and interest rates fall, property prices generally rise.

With a four-quarter time lag, a high significance value between inflation, expressed by the consumer price index, and property prices is diagnosed. However, contrary to expectations, the relationship is negative, regardless of the observation of actual events. For example, inflation has already recorded significant increases in the second half

of 2021, while the central bank has not initially developed any activity. It wasn't until July 2022 that the European Central Bank's interest rates were raised to counter inflation. As a result, asset prices have subsequently fallen. If there had been a direct effect through the inflation channel, a positive relationship would have been expected, although rising inflation would have led to rising property prices. The observation period of this study was characterized by a long-lasting bull market. In this market environment, it is plausible that inflation, as measured by consumer price inflation, has an influence on asset price inflation and is thus positively correlated with property prices. This correlation could thus be further made plausible, as investors anticipate a downturn in an ongoing bull market and invest in asset classes such as property, which are widely regarded as less susceptible to crises. The high stability of the real value of property would also reinforce the significant link with inflation.

Similarly, no significant correlation has been found between house prices and unemployment figures. It could have been expected that as unemployment fell, property prices would rise. One explanation could be that unemployment rate may be a bad predictor, since it only measures whether a person is in work or unemployed. Initially, no statement is made about the nature of the employment relationship. As a result, the quality of the working conditions could have changed and a distortion could have occurred. Similarly, no negative relationship was found between long-term interest rates and property prices. In contrast to various other cited studies in developed economies, a real long-term interest rate was deliberately integrated into the model. However, a positive correlation was not found even with the use of lime lags. The initially assumed culture of long-term fixed interest rates in Germany seems to have only a very limited influence, if at all, on the development of property prices. As part of further investigations, the different explanatory variables with different time lags could be systematically examined. The aim of this study would be to find a model with several significantly correlated variables. It should also be examined whether higher R-squared values can be observed in a model with several highly significant variables.

Given that short-term interest rates can explain property prices with a time lag of a quarter of a year, as can the shadow rate, there is a fundamental explanation for the significant increase in real estate. On this basis, there is no direct evidence of a property price bubble.

4 Conclusions

Using a time series regression model, this study aims to test the hypothesis of the influence of different macroeconomic determinants on the change in property prices. Various studies, including a publication by the IMF, have found cross-border correlations between property prices and interest rates. Since nominal interest rates can lead to distortions at low interest rates, the real interest rate to be used as a basis was determined in two variants, as a long-term interest rate and as a shadow rate. The investigations led to quite different results. Although this correlation is equally plausible and obvious from the macroeconomic models, only the hypothesis of a negative relationship between property prices and short-term interest rates was confirmed. A significant correlation between house prices and long-term interest rates was not found. On the other hand,

the hypothesis of a positive relationship between property prices and real GDP was stated. In this study, no significant relationships were found between house prices and unemployment and the hypothesis cannot be confirmed. Furthermore, a significant correlation between house prices and inflation was found. However, contrary to the hypothesis, there is an underlying negative relationship. A positive effect was expected, so as inflation rises, so do property prices. The effect via the interest rate channel could be an explanation, as interest rates rise, and property prices fall as inflation rises. The results of this study show that the significant increase in property prices in Germany from 2000 to 2022 is related to some meaningful macroeconomic determinants of interest rates, GDP and inflation. Since connections between macroeconomic determinants and property prices with corresponding time lags have been established and there is consequently a fundamental justification for the significant increase in property prices, there is currently no evidence of bubble formation.

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Appendix

Collinearity Diagnostics

Collinearity Diagnostics

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions					
				(Constant)	LTIR_chg	SIR_chg	UNE_chg	CPI_chg	GDP_chg
1	1	1.993	1.000	.00	.07	.09	.03	.09	.01
	2	1.549	1.134	.11	.09	.01	.15	.00	.14
	3	.955	1.444	.56	.01	.00	.03	.03	.23
	4	.661	1.737	.05	.06	.16	.48	.02	.28
	5	.560	1.886	.24	.77	.08	.01	.11	.09
	6	.283	2.654	.03	.00	.66	.32	.74	.26
2	1	1.963	1.000	.00	.09	.11	.02	.10	
	2	1.323	1.218	.30	.09	.01	.24	.01	
	3	.798	1.569	.48	.00	.02	.59	.00	
	4	.578	1.843	.17	.81	.22	.03	.04	
	5	.338	2.410	.05	.01	.65	.13	.85	
3	1	1.931	1.000	.00	.10	.12		.11	
	2	1.117	1.315	.65	.09	.00		.04	
	3	.584	1.819	.26	.80	.17		.06	
	4	.368	2.291	.09	.00	.72		.80	
4	1	1.627	1.000	.02		.18		.19	
	2	1.005	1.272	.89		.04		.00	
	3	.368	2.102	.09		.78		.81	
5	1	1.010	1.000	.49		.49			
	2	.990	1.010	.51		.51			
6	1	1.000	1.000	1.00					

a. Dependent Variable: HPI_chg

Relations between Development of E-Government and Government Effectiveness, Control of Corruption and Rule of Law in 2010–2020: a Cluster Analysis

JIŘÍ SLEZÁK

Abstract

Nowadays, an increasing number of citizens use information and communication technologies to interact with the government, and therefore it is necessary for the public sphere to constantly innovate and meet the expectations placed on it under the pressure of an ever-changing environment. The aim of the article is to compare the progress of e-government between 2010 and 2020 in the member states of the European Union based on selected global indices of e-government development. The article examines the relationship between the E-Government Development Index (EGDI) and selected indices within the Worldwide Governance Indicators. The goal of the article is achieved through correlation and cluster analysis. The results of these countries vary from state to state. It was found that according to the level of digitization of public administration and the quality of public services, EU countries can be divided into 5 groups. However, within the monitored period, the EU states achieved progress in the field of digitization and the quality of public administration. The average value of EGDI increased by about 34% between 2010 and 2022 and the share of countries at a very high level EGDI in 2010 was approx. 11% and in 2022 even 100%. The best results in this area are achieved by the states in the north of the EU (for example, Denmark, Finland and Sweden), on the contrary, the worst results are achieved by the states in the east of the EU (for example, Bulgaria and Romania). The results also showed that countries that were in the best cluster and the worst cluster in individual years are still in those clusters.

Keywords

digitization, governance indicators, cluster analysis, e-government development index, European Union countries, public administration

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Introduction

The aim of the European Union in the framework of the digital transformation of Europe is to ensure that 100% of services are provided to citizens in a digital form in the field of public administration. As part of electronic healthcare, 100% of citizens will also have access to medical records. 80% should be able to log in via digital identity (European Commission, 2023).

The significant development of information and communication technologies (ICT) changes current standards in all areas and their use leads to the emergence of the so-called information society. The information society is characterized by certain characteristics, such as the ability to access information; the subject is at the same time a means in the communication process; processes take place virtually, for example communication between public administration bodies Szewczyk (2021).

ICT provides access to information through the Internet, wireless networks, mobile phones, computers, etc. ICT also provides online services and applications. Their use has a number of advantages and disadvantages, see more in Bosamia (2013).

Public administrations are increasingly using ICT-based means to communicate with subjects (for example, in the case of electronic filing of tax returns) Hamza et al (2021). Governments are introducing new and new information systems to meet the needs of citizens. However, their implementation is often not optimal Sanda, MacDonald & Ferrer (2019). According to Krishnan, Teo & Lim (2013), a high level of e-government has an impact on the economic prosperity of a country. At the same time, citizens are expected to be part of the strategic decision-making process of the government through e-government Bindu, Prem Sankar & Satheesh Kuma (2019).

E-government uses information and communication technologies to provide public services at all levels, both local and national Carter, Yoon & Liu (2022). It empowers citizens by improving human capital, making ICT accessible to citizens, and improving and increasing connectivity between government and citizens through digital public services (Silal, Jha, & Saha, 2023).

Among the main principles based on which the provision of public services through e-government should take place include transparency in the provision of public services; access to public services for all subjects; the efficiency of the use of public funds; protection of confidentiality of personal data; availability of public services Andronicean & Georgescu (2021).

The goal of the European Union is for all state services to be provided digitally by 2030. Currently (year 2022), more than 80% of government services are available digitally European Commission (2022). However, several challenges related to e-governance need to be resolved by 2030. for example: economic, technological and social challenges and legal/regulatory, institutional/operational/environmental, political, financial, qualitative, processual, structural, organizational, development, technical, managerial, contextual, political and training, data and information, interested, etc. Arshad & Asghar (2020).

The presented article is structured in 5 parts. The introduction is followed by an overview of research studies and their conclusions regarding e-government. The next part

is devoted to the characteristics of the data and methods used in the empirical part. In the application part, the EU states are grouped into clusters through correlation and cluster analysis. The individual results of the article are summarized in the discussion and conclusion, including limits and possibilities for future research.

1 Literature review

E-government is a term that represents the use of ICT in public administration. E-government can represent the use of such tools through ICT that lead to the provision of more efficient public services to entities. Another definition of e-Government is focused on the implementation of ICT by public administration bodies with the aim of transforming the relations between all subjects that participate in this process Lehner (2013). E-government represents an effective tool that connects all entities that are involved in this process and thus replaces traditional public services Fan et al. (2022).

E-government includes the general process of digitization of the public sector. In addition to the network infrastructure itself, e-government also includes the entire infrastructure of the authorities. E-Government can ensure the use of wider public services and reduce bureaucracy for all subjects, not only in the European Union. E-government can be used to improve the transparency of the administrative system Androniceanu & Georgescu (2021). E-government does not only involve certain technologies but also rules and procedures. E-government thus functions within the framework of the rule of law, and general rules are protected at the same time, such as the protection of the rights of all subjects Eger & Maggipinto (2009). The rule of law thus represents an important link in the development of e-government.

For e-government services to be provided effectively, it is necessary to ensure their quality, as this affects the satisfaction of end users and thus the entire system. In addition to high-quality and reliable public services, entities require security and simplicity along with usefulness when using them (Mingyue et al., 2022). The success of e-government also depends on the trust of citizens in the government itself.

It is advisable for states not only of the European Union to invest in their e-government services and to try to maintain or increase the trust of subjects within their political measures Pérez-Morote, Pontones-Rosa & Núñez-Chicharro (2020). The reason is, among other things, that the number of users of services is increasing and they are creating new requirements that satisfy their needs and thus expectations from new ICTs are also growing (Shouran, Priyambodo and Rokhman, 2019).

According to several research for example Srivastava & Teo (2007), there is a positive relationship between the level of e-government and the efficiency of public administration. The performance of public administration and the level of e-government are interrelated, but the dynamics of these parameters is caused by other indicators, according to research by Dobrolyubova, Klochkova & Alexandrov (2019). If e-government and government efficiency are correlated, they can represent a tool for influencing corruption Kim (2014).

According to a study by Garcia-Murillo (2013), e-government influences reducing corruption in the country. Also, for example, in Park & Kim (2019); Shim & Eom (2009).

Also, according to Mistry & Jalal (2012), e-government and thus an increase in spending in this area leads to a reduction in corruption in the country, especially in developing countries. The use of ICT by governments is currently essential to the effectiveness of government. Corruption is the abuse of public power for private gain and usually occurs in situations where the public and private sectors collide. In situations where a public entity must transfer revenues or costs to the private sector, the probability of bribery arises. At the same time, however, e-government can lead to the emergence of new types of corruption Adam & Alhassan (2021). The use of ICT creates a more transparent system and increases the accountability of public administration bodies and elected politicians for their performance. By reducing physical contact, ICTs reduce undue bargaining and abuse. Government systems can be more transparent and allow subjects to access government data more easily Zheng (2016). The positive impact of e-government on corruption is also mentioned by Kim (2014).

E-government, focused on the interested entities themselves, leads to the fact that citizens cooperate more effectively with the government. Adherence to the rule of law leads to the development of the given state and, through e-government, to the control of possible corruption, thereby increasing the effectiveness of the government. E-government helps government address the needs and wants of citizens Agbozo & Asamoah (2019).

Government effectiveness includes the quality and scope of services provided, policy formulation and implementation. The effectiveness and efficiency of the government varies in different states, for example, according to the number of citizens or according to political stability. For the optimal use of e-government, it is necessary to ensure a suitable infrastructure and the skills of all interested subjects Dobrolyubova, Klochkova & Alexandrov (2019). Likewise, E-government itself varies in different countries Hodžić, Ravšelj & Alibegović (2021).

The goal of e-government is to provide public services by reducing bureaucracy in their use. This will build trust in the actions of the government. It is appropriate for e-government that its services are aimed directly at the citizen (not only at the infrastructure itself), because if these services are accepted and optimally implemented, they can increase the efficiency of public services. For e-government to function optimally, various factors such as: citizen satisfaction, security, government support and initiative, required ICT skills, efficiency, innovative thinking, rule of law, availability of ICT infrastructure and ICT equipment need to be positively influenced.

For the development of e-government, governments need to develop ICT initiatives and increase the digital skills of citizens. ICT is currently a trend that is one of the important means that lead to success, both in the private and public sectors. For that reason, the availability, access and use of ICT is a tool for the effectiveness of e-government, and it is therefore appropriate that EU states ensure this for their citizens.

Public authorities using ICT can be more effective in implementing their policies. For citizens to have access to ICT, they need to be equipped with the necessary technologies that they will use to access public information and to interact more effectively with public administration bodies. A higher level of e-government thus represents a tool for transparency with lower corruption in the state.

Government efficiency will ensure a higher level of e-government Adam & Alhassan (2021). Countries that do not use ICT at all levels of the economy, including public administration, will not be able to compete in these areas in the future. The reconstruction of public administrations towards the use of ICT is essential and should become a long-term permanent concern of governments Androniceanu & Georgescu (2022).

ICT can be used within all interested entities. Government to Government (G2G) represents relationships between public institutions. Government and Civil Servants (G2E) represents the relationship between government and government employees. Government to Citizens (G2C) enables the exchange of information between government and citizens. Government and business (G2B) represent the relationship between government and business, mainly in the field of public procurement, etc. Androniceanu & Georgescu (2021).

E-government implementation is not always successful, especially in developing countries. For example, Furuholt & Wahid (2008) found that about 60% of e-government initiatives in developing countries did not meet the desired results.

According to Pérez-Morote, Pontones-Rosa & Núñez-Chicharro (2020), a higher level of citizen trust leads to a greater use of e-government, but its use cannot prevent a decrease in trust. At the same time, the growth of investments in e-government leads to the growth of the use of e-government. At the same time, differences between countries were found to be due to digital skills, income and education, based on the division of EU countries into 3 clusters.

2 Research methods

The aim of the article is to compare the progress of e-government between 2010 and 2020 in the member states of the European Union based on selected global indices of e-government development. The purpose of the article is to find out whether the position of the state's changes in the monitored years or not. The assumption is that the EU states show internally homogeneous elements and are externally heterogeneous, which makes it possible to create groups of countries.

The article draws on the literature that deals with e-government mainly in the countries of the European Union. The empirical part uses data and selected indicators from the United Nations and the World Bank.

The selected set consists of 27 countries of the European Union, namely: Austria; Belgium; Bulgaria; Croatia; Cyprus; Czechia; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Ireland; Italy; Latvia; Lithuania; Luxembourg; Malta; Netherlands; Poland; Portugal; Romania; Spain; Slovakia; Slovenia; Sweden.

The empirical analysis was carried out for the period 2010–2020. The year 2020 is the last year for which all values of the selected indicators are available.

The level of government digitization is measured through the E-Government Development Index (EGDI). The e-Government Development Index (EGDI) looks at the

level of e-Government in the countries of the United Nations. It is an indicator that consists of three areas, namely the provision of online e-government services, telecommunication connectivity dealing with the quality and availability of the Internet, and human capacity dealing with literacy and education. Its values range from 0 to 1, while: 0.75–1 means very high values; 0.5–0.7499 means high values; 0.25–0.499 means medium values; 0–0.2499 indicates low values. Government effectiveness (GE), Control of corruption (CC) and Rule of Law (RL) are used to evaluate the quality of public administration. Their index reaches 0–100 and the larger the value, the more effective this indicator is, see Table 1.

Table 1: Definition of variables

Indicators	Definition	Unit	Source
E-Government Development Index (EGDI)	It represents the status of e-government level including online service delivery, telecommunication connectivity and human capacity	Index (0–1)	United Nations
Government effectiveness (GE)	It represents the perception of the quality of public services, the civil service and its degree of independence, the quality of policy formulation and implementation, and the credibility of the government's commitment to that policy	Index (1–100)	World Bank
Control of corruption (CC)	Represents the perception of how public power is used for private purposes, including corruption and interest groups and their influence on public power	Index (1–100)	World Bank
Rule of Law (RL)	It represents the perception in which subjects trust the rules and how they comply with them, including the quality of enforcement of contracts, property rights, etc.	Index (1–100)	World Bank

Source: United Unions (2023); World Bank (2023), own processing

The evaluation of selected indicators in EU countries for the period 2010–2020 is carried out using correlation analysis and hierarchical cluster analysis.

Correlation analysis is used to assess the degree of relationship between the selected indices, see the formula (1):

$$r = \frac{\sum_{i=1}^{n}(x_i - x)\,(y_i - y)}{\sqrt{\sum_{i=1}^{n}(x_i - x)^2 \;\sum_{i=1}^{n}(y_i - y)^2}} \tag{1}$$

where: r represents Pearson's correlation coefficient, x_i a y_i represent the values of x and y for the ith individual (Mukaka, 2012). The significance level is chosen at 5%.

Through cluster analysis, objects (in this case countries) are divided into clusters based on their similarities. Individual clusters are more like each other than other clusters (Frades & Matthiesen, 2010). It is a method that uses multidimensional and quantitative measurements to group objects according to similar properties (Jaeger & Banks, 2022). A cluster is an object whose distance is smaller than the distance shown by objects that do not belong to the given cluster.

Clustering is done through hierarchical clustering, which is done by dividing larger clusters and it is not necessary to know the number of clusters in advance with this method. This method makes it possible to create a so-called dendrogram, which shows how the clusters are related to each other. Ward's method was chosen as the clustering method, which uses the analysis of variance approach to evaluate the distances between clusters. Through this method, the sum of squares of any two clusters that can be formed at each step is minimized. The disadvantage of this method is that it creates clusters with a small number (Frades & Matthiesen, 2010). Ward's method uses the Euclidean distance defined by the formula (2):

$$d_{ij} = \sqrt{\sum_{k=1}^{n} \left(x_{ik} - x_{jk}\right)^2}, \tag{2}$$

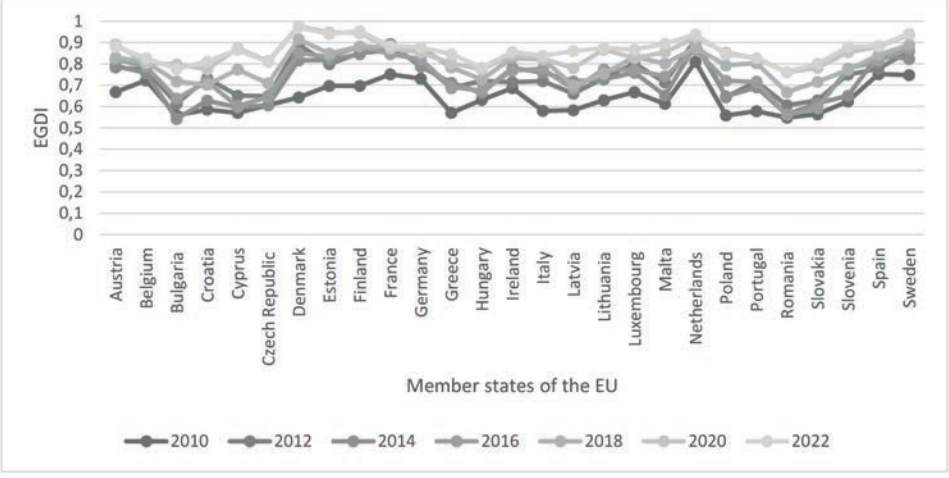
where: x_{ik} is the value of k variable for $i-th$ object and x_{jk} is the value of k variable for $j-th$ object (Frades & Matthiesen (2010); Everitt (2011).

All the calculations and outputs of the analysis were generated in the IBM SPSS Statistics program.

3 Solutions and Results

The development of the EGDI index can be seen in Figure 1.

Figure 1: The progress of the EGDI between the years 2010–2022

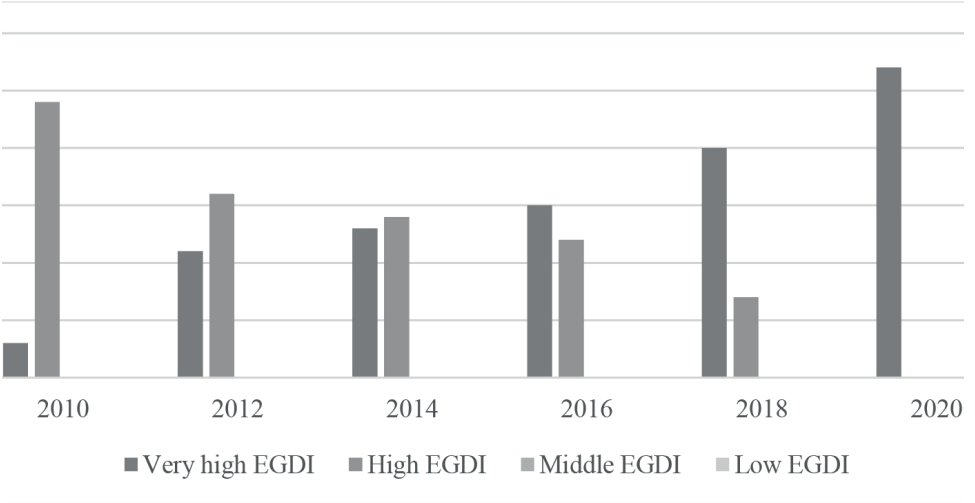


Source: United Nation (2023)

The average value of EGDI increased by about 34% between 2010 and 2022 and the range of variation decreased by about 18%, which may indicate that the differences between EU countries have decreased over the years. The average EGDI value in 2010 was 0.64, in 2012 it was 0.74, in 2014 it was 0.72, in 2016 it was 0.75, in 2018 it was 0.8 and in 2020 it was 0.85. The countries that do not reach the average value are mainly from Southern, Eastern and some Central European countries. On the contrary, the states that achieve higher than average levels are mainly states in the north and west of the European Union.

Based on the EGDI, countries are classified according to the level of e-government development: very high, EGDI > 0.75; high, 0.50 < EGDI < 0.75; medium, 0.25 < EGDI < 0.50; low, EGDI < 0.25 Yerina, Demydiuk & Demydiuk (2021). Figure 2 shows the distribution of the number of countries according to their achieved EGDI values.

Figure 2: Distribution of countries according to EGDI in the years 2010–2020



Source: United Nation (2023)

As can be seen, every year there was an increase in the number of countries moving from a high level to a very high level. The share of countries at a very high level in 2010 was approx. 11%, in 2012 approx. 41%, in 2014 approx. 48%, in 2016 approx. 56%, in 2018 approx. 74% and in 2022 even 100%. According to Yerin, Demydiuk & Demydiuk (2021), the reasons for these shifts were investments in ICT infrastructure and the transformation of public services into digital services..

3.1 Correlation of variables

A correlation analysis was performed to identify the correlation between selected indicators that characterize the level of public administration and its digitization. The results of the correlation analysis in individual years can be seen in Table 2.

Through the correlation analysis, a strong positive correlation was found with all the selected indicators that characterize the level of public administration and EGDI. These indicators show a statistically significant correlation with EGDI.

Table 2: Correlation analysis between EGDI, GE, CC and RL in 2010. 2012, 2014, 2016, 2018 and 2020

2010	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.690	0.784	0.744
GE	0.690	1	0.948	0.951
CC	0.784	0.948	1	0.958
RL	0.744	0.951	0.958	1
2012	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.774	0.814	0.767
GE	0.774	1	0.964	0.949
CC	0.814	0.964	1	0.965
RL	0.767	0.949	0.965	1
2014	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.767	0.732	0.731
GE	0.767	1	0.939	0.954
CC	0.732	0.939	1	0.965
RL	0.731	0.954	0.965	1
2016	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.783	0.772	0.711
GE	0.783	1	0.937	0.934
CC	0.772	0.937	1	0.939
RL	0.711	0.934	0.939	1
2018	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.783	0.859	0.704
GE	0.783	1	0.943	0.927
CC	0.859	0.943	1	0.918
RL	0.704	0.927	0.918	1
2020	**EGDI**	**GE**	**CC**	**RL**
EGDI	1	0.716	0.730	0.677
GE	0.716	1	0.913	0.921
CC	0.730	0.913	1	0.937
RL	0.677	0.921	0.937	1

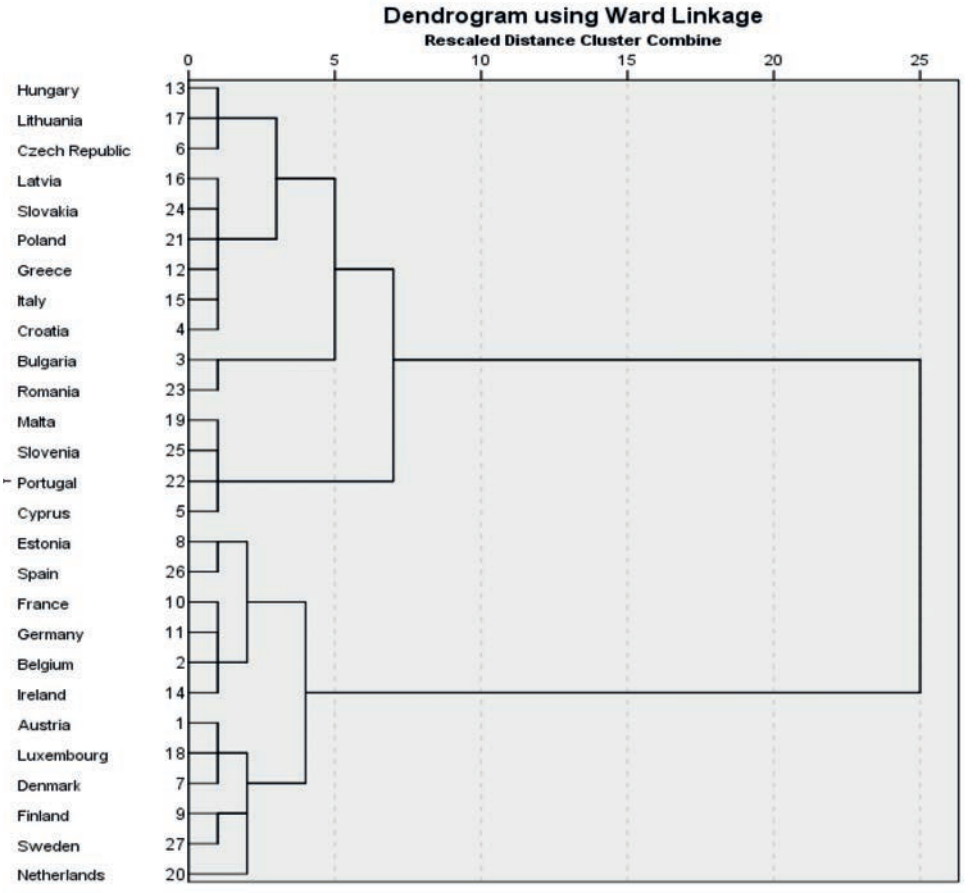
Source: own processing

The strongest correlation is mainly between EGDI and government effectiveness and corruption control, which corresponds to other research that was mentioned in the theoretical background. There is therefore a statistically significant positive correlation between government digitization and public administration performance.

3.2 Evaluation of the Similarities of EU Countries using Hierarchical Cluster Analysis

Hierarchical cluster analysis was used to create clusters of EU countries. EGDI, GE, CC, RL indices were used as inputs for hierarchical cluster analysis. Through cluster analysis, all 27 EU states were divided into groups characterized by similar behaviours according to the indices. The result of the hierarchical clustering process is displayed in individual years through a dendrogram (Figure 3–8), according to which the probable number of clusters can be deduced. Average cluster values can be seen in tables 3–8.

Figure 3: Dendrogram of Similarities in EU Countries in 2010



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises six countries (Austria, Denmark, Finland, Luxembourg, Netherlands, Sweden). These are the states that are characterized by the highest average level of GE, CC and RL and a very high level of EGDI. The greatest similarity can be found between all states within these indicators. Further between Austria, Luxembourg, Denmark and Finland in the EGDI indicator. The Netherlands and Sweden exceed the average value of EGDI within this cluster.

Cluster 2 comprises six countries (Belgium, Estonia, France, Germany, Ireland, Spain). These are the states that are characterized by the highest average level of EGDI and a very high level of GE, CC and RL. The greatest similarity can be found between France, Ireland, Germany and Belgium in the areas of GE, CC and RL, and further between Estonia and Spain. In the EGDI, there is the greatest similarity between Belgium, France, Germany and Spain, and also between Estonia and Ireland.

Cluster 3 comprises two countries (Bulgaria, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 4 comprises eight countries (Croatia, Czech Republic, Greece, Hungary, Italy, Latvia, Lithuania, Poland, Slovakia). After the previous cluster, these are the countries with the second worst EGDI level. Croatia, Greece and Italy show the most similar characteristics in GE. Within this indicator, the Czech Republic and Slovakia show above-average values. Latvia, Italy, Hungary and Slovakia have similar characteristics in CC. In contrast, Poland shows above-average values in this area. Hungary, Latvia and Lithuania are similar in the area of RL. On the contrary, the Czech Republic shows an above-average value compared to the average of the cluster. Croatia, the Czech Republic and Latvia are most similar in EGDI.

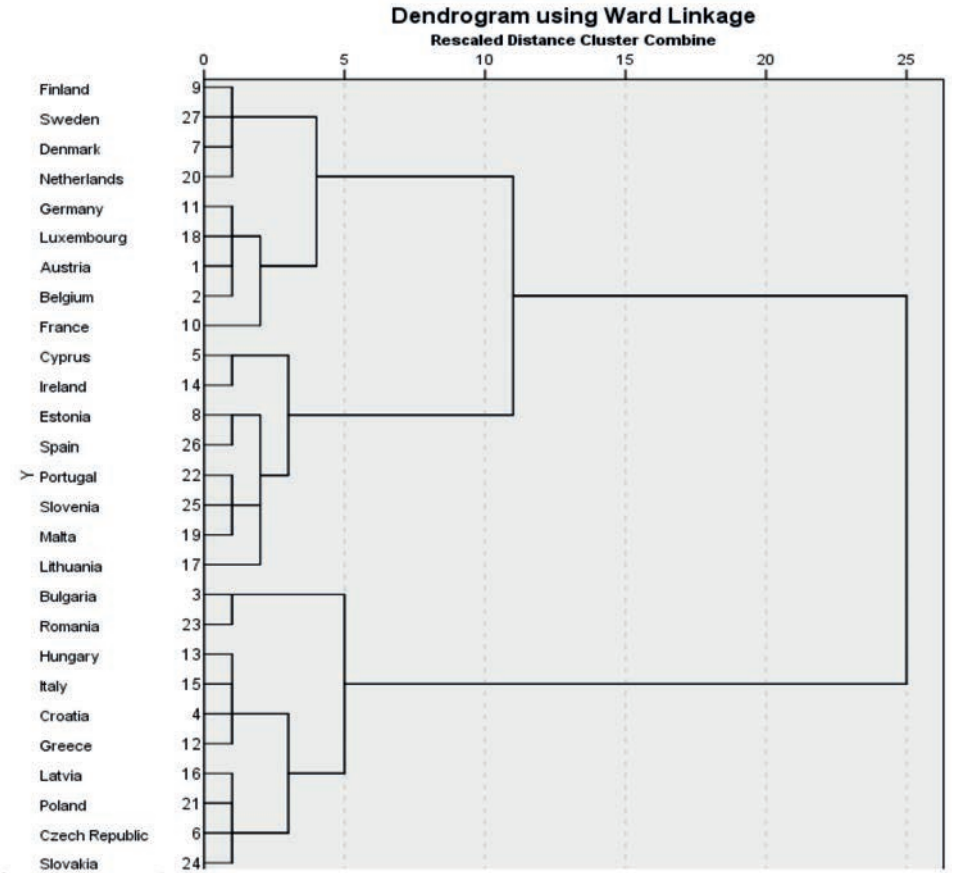
Cluster 5 comprises four countries (Cyprus, Malta, Portugal, Slovenia). These are states that are characterized by high values in GE, CC and RL and rather low values in EGDI. Portugal and Slovenia have the highest similarities in GE, CC and RL. Conversely, Portugal and Cyprus are similar in EGDI.

Table 3: Average cluster values in 2010

Cluster	EGDI	GE	CC	RL
1. cluster	0.71	97.29	97.06	98.34
2. cluster	0.72	86.76	88.57	89.97
3. cluster	0.55	52.87	48.57	54.98
4. cluster	0.59	72.04	64.55	68.72
5. cluster	0.60	83.85	78.81	85.19

Source: own processing

Figure 4: Dendrogram of Similarities in EU Countries in 2012



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises five countries (Austria, Belgium, France, Germany, Luxembourg). This is a cluster characterized by the second highest average values in all indicators. In the field of GE, Austria, Belgium and Germany are most similar. In CC, all countries are the most similar except for the Netherlands, which shows above-average values. Belgium, France and Germany as well as Austria and Luxembourg are most similar in RL. In the EGDI, Austria and Belgium are most similar, followed by Germany and Luxembourg.

Cluster 2 comprises two countries (Bulgaria, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 3 comprises eight countries (Croatia, Czech Republic, Greece, Hungary, Italy, Latvia, Poland, Slovakia). The Czech Republic, Latvia and Slovakia are most similar in GE, followed by Croatia, Hungary and Poland. In Area CC, the Czech Republic, Hungary and Latvia are most similar, as well as Slovakia and Croatia. The most similar in RL

are Latvia and Poland and then Greece with Italy and Slovakia. The most similar in EGDI are Hungary, Croatia and Italy, followed by the Czech Republic, Latvia, Poland and Slovakia.

Cluster 4 comprises eight countries (Cyprus, Estonia, Ireland, Lithuania, Malta, Portugal, Slovenia, Spain). These are the countries with the third highest values in all indicators. Slovenia, Spain and Portugal are the most similar in GE. Estonia and Portugal are most similar in CC. The most similar in RL are Cyprus, Estonia, Spain and Portugal. In the EGDI, Estonia and Spain are most similar, followed by Ireland, Lithuania, Portugal and Slovenia. In GE, CC and RL areas, Ireland achieves above average values and in EGDI it is Estonia.

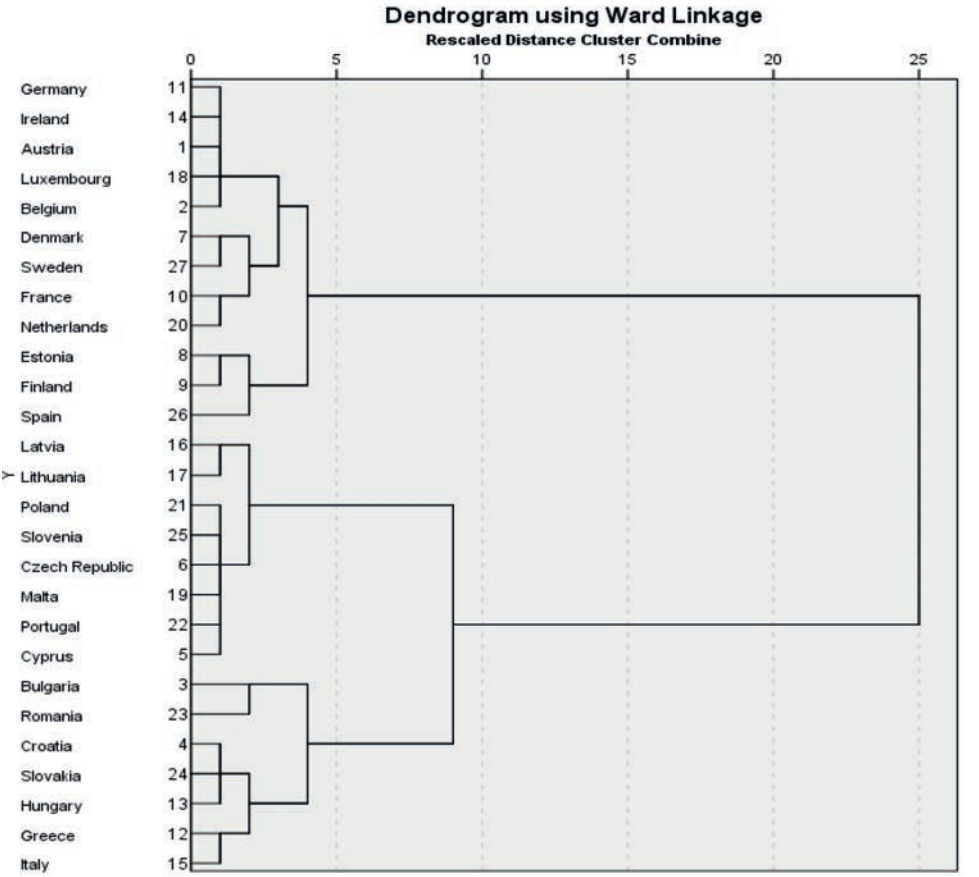
Cluster 5 comprises four countries (Denmark, Finland, Netherlands, Sweden). This is the best cluster with the highest values. All states are similar in all indicators.

Table 4: Average cluster values in 2012

Cluster	EGDI	GE	CC	RL
1. cluster	0.81	92.32	92.51	93.15
2. cluster	0.61	52.13	46.68	54.69
3. cluster	0.68	70.73	62.74	68.31
4. cluster	0.73	82.35	80.39	84.27
5. cluster	0.88	98.70	98.34	98.47

Source: own processing

Figure 5: Dendrogram of Similarities in EU Countries in 2014



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises nine countries (Austria, Belgium, Denmark, France, Germany, Ireland, Luxembourg, Netherlands, Sweden). These states are characterized by the highest values in GE, CC and RL and very high values in EGDI. The greatest similarity in GE is between Austria, Belgium, Germany, Ireland and Luxembourg, and further between Denmark, France, the Netherlands and Sweden. The greatest similarity in CC is between Austria, Belgium, Germany and Ireland, and further between Denmark, France, Luxembourg, the Netherlands and Sweden. In RL, the greatest similarity is between Austria, Luxembourg, France, the Netherlands and Sweden. The greatest similarity in EGDI is reported in Germany, Ireland and Luxembourg, and further between Austria, Denmark and Sweden. Cluster 2 comprises two countries (Bulgaria, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 3 comprises five countries (Croatia, Greece, Hungary, Italy, Slovakia). This is the cluster that is the second worst in GE, CC and RL. In GE and CC, the greatest similarities are between Croatia, Hungary and Slovakia. In RL, the greatest similarities are between Italy, Slovakia and Greece.

Cluster 4 comprises eight countries (Cyprus, Czech Republic, Latvia, Lithuania, Malta, Poland, Portugal, Slovenia). These are the states that are the second worst in the EGDI. Within GE, all countries except Poland are the most similar. In CC, the most similar states are the Czech Republic and Latvia, followed by Poland, Slovenia and Lithuania, and finally Malta and Portugal. Cyprus, the Czech Republic, Malta and Portugal are most similar in RL, as well as Slovenia, Poland, Latvia and Lithuania. In the EGDI, Cyprus, the Czech Republic, followed by Latvia and Lithuania and finally Malta, Poland and Slovenia are most similar.

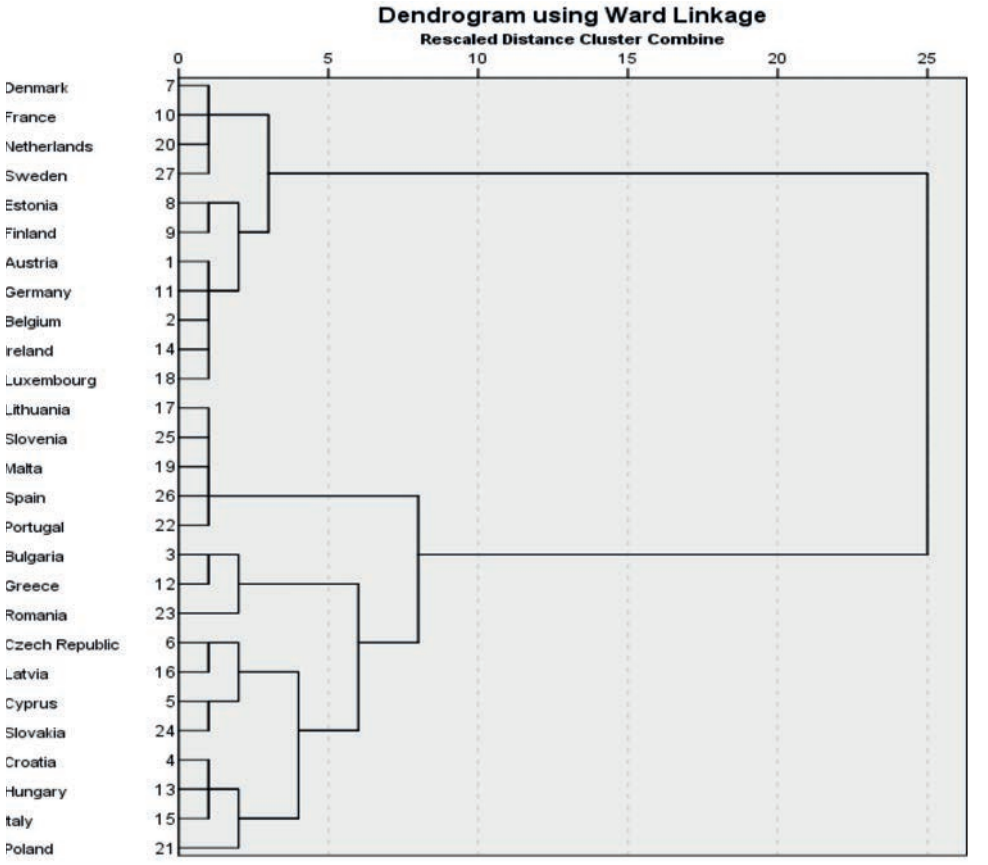
Cluster 5 comprises three countries (Estonia, Finland, Spain). These states are characterized by the largest level of EGDI and very high values in the other indicators.

Table 5: Average cluster values in 2014

Cluster	EGDI	GE	CC	RL
1. cluster	0.81	94.28	95.25	95.78
2. cluster	0.55	55.53	49.76	59.62
3. cluster	0.68	71.35	58.65	67.5
4. cluster	0.66	79.57	73.92	81.67
5. cluster	0.83	84.62	82.85	85.26

Source: own processing

Figure 6: Dendrogram of Similarities in EU Countries in 2016



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises eleven countries (Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden). These are the states that are characterized by the greatest level in all indicators. In GE, the most similar countries are Austria, Belgium, Finland and Ireland, followed by Denmark, France and the Netherlands, and finally Germany, Luxembourg and Sweden. Within the CC, Austria, Belgium, Ireland, Finland and Estonia are most similar, followed by Denmark, France, Luxembourg and Sweden. In RL, Austria, Denmark, France, the Netherlands and Sweden are the most similar, followed by Estonia, Finland, Belgium and Ireland. In the EGDI, Finland, Sweden and the Netherlands are most similar, followed by Estonia, Denmark, Austria, Germany and France.

Cluster 2 comprises three countries (Bulgaria, Greece, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 3 comprises four countries (Croatia, Italy, Hungary, Poland). These are the states with the second lowest values in GE, CC and RL indicators. In GE, Croatia and Hungary are most similar, followed by Italy and Poland. Croatia, Hungary and Italy show the most similar characteristics in CC and RL. Croatia and Poland are most similar in EGDI.

Cluster 4 comprises four countries (Cyprus, Czech Republic, Latvia, Slovakia). These are the states that are the second worst in the EGDI. The greatest similarities in GE are between all states. In CC it is the Czech Republic, Latvia and Slovakia. In RL, the Czech Republic and Latvia are most similar, followed by Cyprus and Slovakia. Slovakia and Cyprus are most similar within the EGDI.

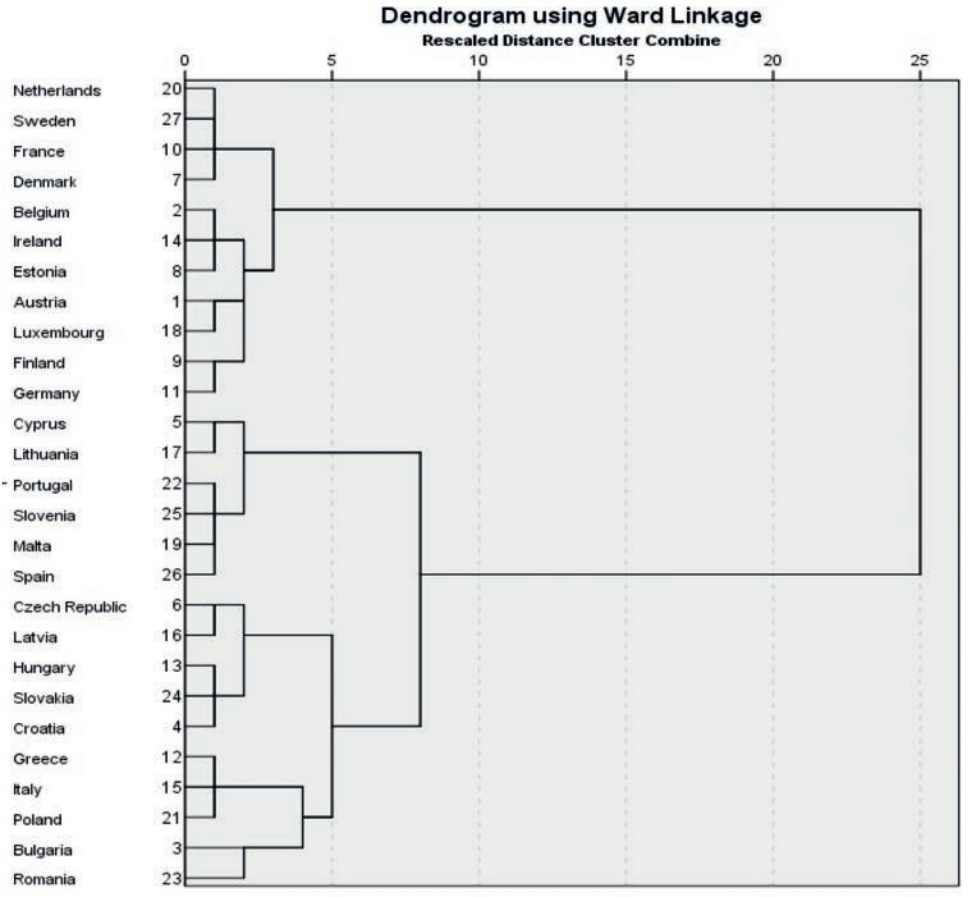
Cluster 5 comprises five countries (Lithuania, Malta, Portugal, Slovenia, Spain). After cluster 1, it is the group of countries with the best values in all indicators. Except for Malta, these states are most similar in GE. A great similarity is also reported in CC (except for Spain). In RL, all states are very similar. Lithuania and Slovenia are most similar in EGDI.

Table 6: Average cluster values in 2016

Cluster	EGDI	GE	CC	RL
1. cluster	0.83	92.70	94.32	93.71
2. cluster	0.63	56.09	52.4	58.97
3. cluster	0.72	70.91	65.26	66.35
4. cluster	0.63	78	69.11	77.76
5. cluster	0.76	82.4	75.29	82.69

Source: own processing

Figure 7: Dendrogram of Similarities in EU Countries in 2018



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises eleven countries (Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden). These are the states that are characterized by the greatest level in all indicators. The most similar countries in GE are Austria, Belgium, Finland, Germany, Belgium and Ireland, as well as Denmark, France and the Netherlands, Luxembourg and Sweden. Within CC, Austria, Belgium, Ireland, Finland and Estonia are most similar, followed by Denmark, France, Luxembourg, Germany, the Netherlands and Sweden. In RL, Austria, Denmark, France, the Netherlands, Luxembourg and Sweden are most similar, as well as Estonia, Finland, Belgium and Ireland. In the EGDI, Denmark, Finland, Sweden, France, Germany and the Netherlands are most similar, followed by Estonia, Austria, Ireland and Luxembourg.

Cluster 2 comprises two countries (Bulgaria, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 3 comprises five countries (Croatia, Czech Republic, Hungary, Latvia, Slovakia). These are the countries that are the second worst in the EGDI. In GE, the Czech Republic and Latvia are most similar, followed by Croatia, Hungary and Slovakia. Croatia and Hungary and then Latvia and Slovakia are the most similar in CC. In RL, Hungary and Slovakia are most similar, followed by the Czech Republic and Latvia.

Cluster 4 comprises six countries (Cyprus, Lithuania, Malta, Portugal, Slovenia, Spain). These are the states that are ranked second in terms of values in GE, CC and RL. The greatest similarity in GE is between Cyprus, Malta and Spain and also between Lithuania and Slovenia. Cyprus, Spain and Malta and Lithuania are most similar in CC. Lithuania, Malta, Spain and Slovenia are most similar in RL. The greatest similarity in EGDI is between Cyprus, Slovenia and Lithuania and then Malta and Portugal.

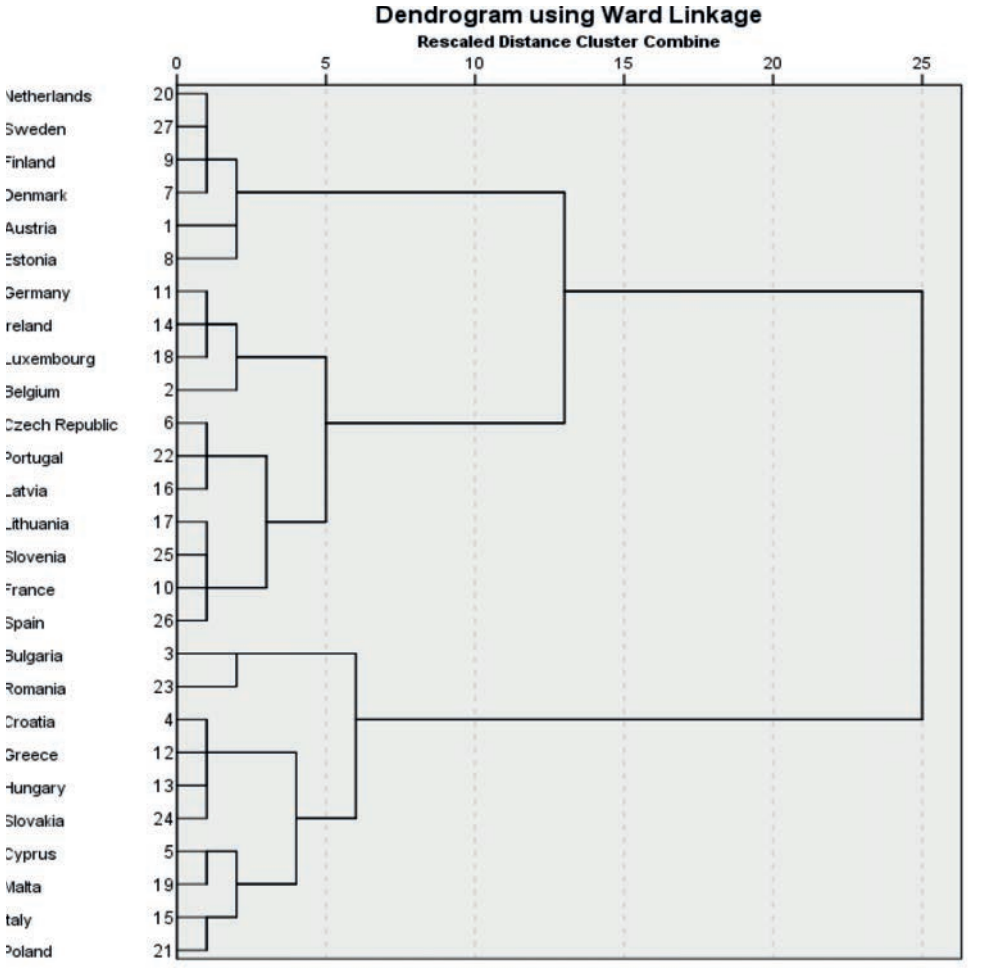
Cluster 5 comprises three countries (Greece, Italy, Poland). These are the second-ranked states within the EGDI, within which they are all similar. The greatest similarity in the remaining indicators is mainly between Greece and Italy.

Table 7: Average cluster values in 2018

Cluster	EGDI	GE	CC	RL
1. cluster	0.86	92.79	94.18	93.53
2. cluster	0.69	53.37	50	58.17
3. cluster	0.71	74.62	63.37	73.27
4. cluster	0.79	81.09	74.28	81.41
5. cluster	0.80	68.43	64.42	61.22

Source: own processing

Figure 8: Dendrogram of Similarities in EU Countries in 2020



Source: own processing

The dendrogram shows the possible division of states into 5 clusters.

Cluster 1 comprises six countries (Austria, Denmark, Estonia, Finland, Netherlands, Sweden). These are the states that achieve the highest values in all indicators. Denmark, Finland, the Netherlands and Sweden are most similar in GE, CC and EGDI. Austria, Denmark, Finland and Sweden are most similar in RL.

Cluster 2 comprises four countries (Belgium, Germany, Ireland, Luxembourg). This is the second-best cluster in the GE, CC and RL indicators, in which, including EGDI, the countries Germany, Ireland and Luxembourg are most similar.

Cluster 3 comprises two countries (Bulgaria, Romania). This is a cluster characterized by the worst values in all indicators.

Cluster 4 comprises eight countries (Croatia, Cyprus, Greece, Hungary, Italy, Malta, Poland, Slovakia). It is the second worst cluster in GE, CC and RL. Croatia, Greece, Italy, Poland and Slovakia are most similar in GE. Croatia, Greece, Hungary and then Cyprus, Italy, Malta and Slovakia are the most similar in CC. Croatia, Greece, Italy, Poland, followed by Cyprus, Poland and Hungary are most similar in RL. In the EGDI, Malta, Poland, Cyprus and Italy are most similar, followed by Croatia, Hungary and Slovakia.

Cluster 5 comprises seven countries (Czech Republic, France, Latvia, Lithuania, Portugal, Slovenia, Spain). It is the second-best cluster in EGDI. France, Slovenia and then the Czech Republic, Latvia, Lithuania, Portugal and Spain are most similar in GE. Spain, Slovenia, Portugal, Latvia are most similar in CC. In RL, the Czech Republic, Latvia, Lithuania, Slovenia and Spain are most similar. France and Lithuania, Spain and Slovenia, and the Czech Republic and Portugal are the most similar in EGDI.

Table 8: Average cluster values in 2020

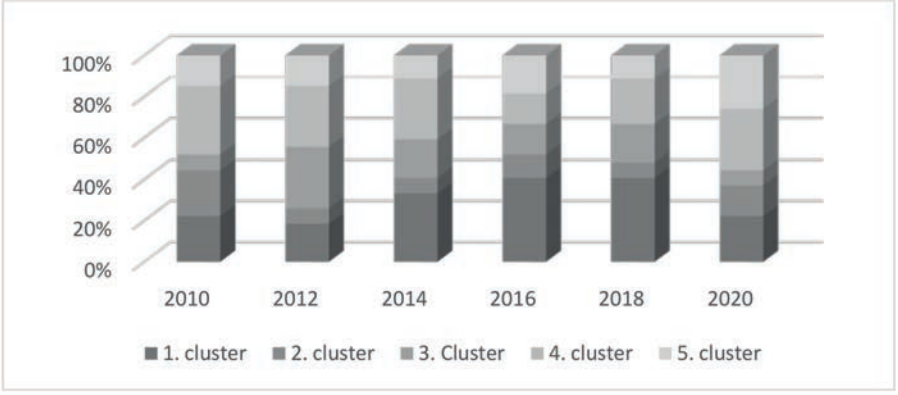
Cluster	EGDI	GE	CC	RL
1. cluster	0.94	95.6	96.15	95.99
2. cluster	0.83	90.14	93.27	91.47
3. cluster	0.78	43.51	49.28	57.45
4. cluster	0.82	70.91	64.84	67.43
5. cluster	0.84	81.46	77.54	82.97

Source: own processing

4 Discussion

Figure 9 shows the distribution of countries into individual clusters.

Figure 9: Distribution of countries by individual clusters between 2010–2020



Source: own processing

In 2010 a total of 5 clusters were created through cluster analysis. Cluster No. 1 includes countries that represent northern and central Europe. All countries except Sweden are members of the Eurozone. This cluster is characterized by the highest values of GE, CC and RL and the second highest level of EGDI. Cluster No. 2 includes countries that represent the North, the West and, in the case of Estonia, the East of Europe. This cluster is characterized by the highest level of EGDI and the second highest level of GE, CC and RL indicators. All countries are members of the Eurozone. Cluster 3 includes countries that are in the east of Europe, and it is a cluster that shows the worst values in all monitored indicators. Cluster 4 includes countries that represent central, southern and south-eastern Europe. According to the average values of all indicators, these are the countries that are the second worst. The last cluster 5 includes countries that represent the south and south-east of Europe. In terms of average values, this is a cluster that ranked 3rd.

In 2012, a total of 5 clusters were created through cluster analysis. Cluster No. 1 includes countries that represent central and western Europe. All countries are members of the Eurozone. This cluster is characterized by the second highest overall GE, CC and RL values. Cluster 2 includes countries that are in the east of Europe, and it is a cluster that shows the worst values in all monitored indicators. Cluster No. 3 includes countries that represent central, southern, eastern and south-eastern Europe. This cluster is characterized by the worst values after the previous one. Cluster 4 includes countries that represent them and the south-east of Europe. According to the average values of all indicators, these are the countries that are the third worst. The last cluster 5 includes countries that represent the north of Europe. In terms of average values, this is the best cluster.

In 2014, a total of 5 clusters were created through cluster analysis. Cluster No. 1 includes countries that represent northern, central and western Europe. All countries except Sweden are members of the Eurozone. This cluster is characterized by the highest values of GE, CC and RL and the second highest level of EGDI. Cluster 2 includes countries that are in the east of Europe, and it is a cluster that shows the worst values in all monitored indicators. Cluster #3 includes countries that represent South, Southeast and Central Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the second worst, and in the case of EGDI it is in 3rd place. All countries are members of the Eurozone. Cluster 4 includes countries that represent central, southern and south-eastern Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the third worst, and in the case of EGDI, it is even the penultimate place. The last cluster 5 includes countries that represent the south, south-east and north of Europe. In terms of mean values, it is the second-best cluster for GE, CC and RL and the best cluster for EGDI. All these countries are members of the Eurozone.

In 2016, a total of 5 clusters were created through cluster analysis. Cluster #1 includes countries that represent North, Central, West and South-East Europe. All countries except Sweden are members of the Eurozone. This cluster is characterized by the highest values of all indicators. Cluster 2 includes countries that are in the east and south of Europe and is the cluster that shows the worst values in all monitored indicators. Cluster #3 includes countries that represent South, Southeast and Central Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the second worst, and in the case of EGDI it is in 3rd place. All countries are members of the Eurozone.

Cluster 4 includes countries that represent central, southern and south-eastern Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the third worst, and in the case of EGDI, it is even the penultimate place. The last cluster 5 includes countries that represent the south and south-east of Europe. In terms of average values, it is the second-best cluster for all indicators. All these countries are members of the Eurozone. In 2016, compared to 2014, 8 states changed their cluster. These are Greece, Lithuania, Malta, Poland, Portugal, Slovenia, Estonia, Finland.

In 2018, a total of 5 clusters were created through cluster analysis. Cluster #1 includes countries that represent North, Central, West and South-East Europe. All countries except Sweden are members of the Eurozone. This cluster is characterized by the highest values of all indicators. Cluster 2 includes countries that are in the East and is the cluster that shows the worst values in all monitored indicators. Cluster #3 includes countries that represent South, Southeast and Central Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the third worst and in the case of the EGDI it is the 4th place. Cluster 4 includes countries that represent them and the south-east of Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the second best, and in the case of EGDI it is a close third place. The last cluster 5 includes countries that represent southern and central Europe. In terms of average values, it is the second best cluster in the case of EGDI and the 4th worst in the case of other indicators. All these countries are members of the Eurozone. In 2018, compared to 2016, 11 states changed their cluster. These are the Czech Republic, Latvia, Slovakia, Lithuania, Malta, Portugal, Slovenia, Spain, Greece, Italy, Poland.

In 2020, a total of 5 clusters were created through cluster analysis. Cluster #1 includes countries that represent North, Central, West and South-East Europe. All countries except Sweden are members of the Eurozone. This cluster is characterized by the highest values of all indicators. Cluster No. 2 includes countries that primarily represent western Europe. According to the average values of the GE, CC and RL indicators, these are the countries that are the second best and in the case of EGDI it is the 3rd place. Cluster 3 includes countries that are in the East and this is the cluster that shows the worst values in all monitored indicators. Cluster 4 includes countries that represent them and south-east and central Europe. According to the average values of the indicators of all indicators, this is the cluster that is the penultimate. The last cluster 5 includes countries that represent central, western and eastern Europe. In terms of average values, it is the second-best cluster in the case of EGDI and the 3rd best in the case of other indicators. In 2018, compared to 2016, 17 states changed their cluster. These are Belgium, Germany, Ireland, Luxembourg, Croatia, Greece, Hungary, Italy, Poland, Slovakia, Czech Republic, France, Latvia, Lithuania, Portugal, Slovenia, Spain.

Cluster No. 1 is relatively homogeneous in the analysed years and mostly consists of Eurozone countries and states in the west and north of Europe, which corresponds to, for example, Yerina, Demydiuk & Demydiuk (2021) or Androniceanu & Georgescu (2023). The EU member states in Central and Eastern Europe did not show any significant progress in the development of e-government during the evaluated years. Occasional exceptions in different years were the Czech Republic, Poland, Lithuania and Slovenia. it can be stated that the cluster with high EGDI value is also the cluster with the highest average values of GE, CC and RL. Furthermore, it can be stated that Romania and Bulgaria

in all monitored years were always the worst in terms of the analysed indicators. Similar results were found in Andronicean & Georgescu (2023) and Pakhnenko & Kuan (2023).

It is worth noting that individual states did not differ much in their levels in uniform years. In the same clusters, there were mostly states that have something in common (for example, from a geographical point of view or history). Another finding is that, in comparison between 2010 and 2020. there was an increase in the GE indicator in most countries, especially in Belgium, Bulgaria, Cyprus, Poland, Romania, and Slovakia. Within the CC indicator, there was a slight increase in this indicator, especially in Bulgaria, Cyprus, France, Hungary, Malta and Spain, but at the same time there was also a significant decrease in some countries such as Estonia, Latvia and Lithuania. There was also a slight increase in the RI indicator, namely in countries such as Cyprus, Greece, Malta and Spain, on the contrary, there was a decrease in Latvia, Lithuania, Romania and Slovakia. Significant changes in these indicators occurred mainly in clusters characterized by worse values.

5 Conclusion

E-government represents a revolutionary area that should be given a lot of attention at the moment. This trend is accompanied by an increase in the number of initiatives that lead to the improvement of public service delivery as well as to the improvement of interaction between citizens and therefore businesses and the government. Over the past 10 years, significant changes have taken place in the EU member states in the area of digitization of public administration.

Based on data from 27 EU countries, the article analysed the relationship between the digitization of countries (based on the E-Government Development Index) and the quality of public administration (based on Government effectiveness, Control of corruption and Rule of Law). It was found that the digitization of EU countries through the EGDI indicator increases over time for all countries, however significant differences can be found between countries. In 2020. all states belong to the group of countries with a very high EGDI, which is 24 more countries than in 2010. Through correlation analysis, it was found that there is a statistically significant positive correlation between government digitization and public administration performance. Through cluster analysis, 5 clusters were created in individual years. Countries such as Finland, Sweden, Denmark, the Netherlands, and Luxembourg appeared in the leading clusters. On the contrary, Bulgaria and Romania were in the worst clusters. Membership in the best and worst clusters does not change much in the monitored years. The results also indicate that countries with a high level of the EGDI indicator also show a high level of the other indicators and vice versa. The results of this research can help economic policy makers to monitor, evaluate their development and compare it with other countries.

The article allows countries with a similar level to be singled out. The limit of this research is that the methodology used for selected indicators, for example EGDI, does not capture all dimensions of digitalization of public administration. Future research could increase the sample set by adding additional countries or could analyse individual countries, especially those that changed from one servant to another within the monitored years.

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