1/2025
volume 19

ACTA VŠFS

Economic Studies and Analyses

SCIENTIFIC ARTICLES

UNIVERSITY OF FINANCE AND ADMINISTRATION
VYSOKÁ ŠKOLA FINANČNÍ A SPRÁVNÍ

REVIEWED JOURNAL

ACTA VŠFS **reviewed scientific journal**

PUBLISHER:
University of Finance and Administration / Vysoká škola finanční a správní, a.s.

EDITORIAL OFFICE:
VŠFS, Estonská 500, 101 00 Praha 10
https://acta.vsfs.eu
acta@vsfs.cz

The journal is indexed in these databases: CEEOL, DOAJ, EBSCO,
Elektronische Zeitschriftbibliothek, ERIH PLUS, Index Copernicus, RePEc.

Prepress:	VŠFS
Evidence number:	MK ČR–E 17745
eISSN:	1802-7946
DOI:	http://dx.doi.org/10.37355/acta
Periodicity:	2 issues per year
Volume:	**XIX**
Number:	**1**
Issued on:	30. 6. 2025

1/2025 **ACTA VŠFS** Volume 19

Economic Studies and Analyses

EDITORIAL

SCIENTIFIC ARTICLES

Editorial

JAN MERTL

Dear readers,

It is with great pleasure that I introduce the latest issue of *Acta VŠFS*, where we proudly present five scholarly contributions that reflect both the evolving landscape of economic analysis and our journal's commitment to rigorous, forward-thinking research. This issue exemplifies how diverse methodological approaches – from econometric modeling to stakeholder analysis – can illuminate the economic realities of today while offering tools to shape policy and enterprise for tomorrow.

Our issue opens with a study by **Jannik Schumann**, who explores the financial effects of inflation on young adult households in Germany. Anchored in a comprehensive literature review and empirical data, this article offers an incisive view into how inflationary pressures from 2015 to 2023 have impaired wealth accumulation and exacerbated generational disparities. By focusing on a demographic often overlooked in macroeconomic analyses, Schumann contributes to an urgently needed policy conversation – one that extends far beyond the German context to all economies grappling with intergenerational inequality.

In the second paper, **Jiří Slezák** presents a comparative analysis of personal income tax progressivity across the Visegrad Group. Using both interval and global progressivity methods, the article provides a nuanced understanding of how Czech, Slovak, Polish, and Hungarian tax systems handle redistributive mechanisms. The study identifies structural variations in effective tax burdens across income levels and household compositions, including cases with children, and offers critical insights for policymakers seeking to balance fairness with fiscal efficiency.

Forecasting accuracy takes center stage in the third contribution, authored by **Manuel Rosinus**, which compares classical ARIMA models and Long Short-Term Memory (LSTM) neural networks for predicting movements in the DAX® 50 ESG Index. The empirical results demonstrate LSTM's superior performance in both static and expanding window frameworks. However, the study also underscores the limits of AI-driven prediction in highly liquid and efficient markets – highlighting that while technological innovation offers powerful tools, its application must be guided by market context and behavioural complexity.

Turning to the Czech capital market, **Adam Černohorský** introduces a novel dual-index methodology for benchmarking real estate investment fund performance. Their model distinguishes between retail and qualified investor funds, and leverages both arithmetic and NAV-weighted approaches to capture key differences in return dispersion, market concentration, and capital flow dynamics. This study not only advances index design but also provides a transparent tool for fund evaluation and investor decision-making – one that may have practical utility for regulators, analysts, and fund managers alike.

Our final article, led by **Miroslav Pavlák**, investigates Czech participation in the reconstruction of Ukraine's housing sector – a topic where economics intersects with

geopolitics, international development, and post-conflict recovery. Blending stakeholder interviews, institutional analysis, and investment scenario modelling, the paper identifies tangible pathways and structural barriers that Czech enterprises face in entering Ukraine's rebuilding efforts. It also presents an illustrative case study involving Karazin University in Kharkiv, revealing both the promise and the complexity of international academic collaboration during these difficult times.

Taken together, these articles capture the breadth of economic inquiry – from fiscal systems and asset markets to international engagement and crisis response. They embody the mission of *Acta VŠFS*: to promote research that is not only methodologically sound but also socially relevant, analytically ambitious, and responsive to contemporary challenges.

I extend my sincere thanks to all contributing authors and peer reviewers for their dedication and scholarly rigor. I also encourage our readers – whether practitioners, researchers, or students – to engage with these articles thoughtfully and critically. May they inspire new questions, collaborative solutions, and meaningful action in academia and beyond.

With appreciation for your continued readership, and warm wishes for an intellectually rich and rewarding summer,

Doc. Ing. Jan Mertl, Ph.D.

editor-in-Chief

Financial Impact of Inflation on Young Adults' Household Assets between 2015-2023 in Germany

JANNIK SCHUMANN

Abstract

Background: Between 2015 and 2023, young adults in Germany faced significant financial challenges due to escalating inflation, peaking at 10.6% between 2021 and 2023.

Aim: This study aims to investigate the financial impacts of inflation on the household assets of young adults in Germany compared to other age groups.

Methods: Employing a structured literature review of studies, reports, and statistical data from institutions like the European Central Bank and the Deutsche Bundesbank.

Results: The findings reveal that high inflation eroded net asset returns for young households, delayed wealth accumulation, and exacerbated generational wealth disparities.

Recommendations: The study recommends targeted policy actions to enhance financial resilience among young adults, such as financial education and support for wealth-building initiatives.

Practical Relevance/Social Implications: Addressing the unique financial vulnerabilities of young adults during inflationary periods is essential for reducing wealth inequality and promoting economic stability.

Originality/Value: This research contributes originality by focusing on an underexplored demographic, shedding light on how recent inflation has specifically impacted the wealth development of young German households.

Keywords

Inflation, Young Adults, Household Assets, Germany, Wealth Accumulation

JEL Codes

E31, D14, D31

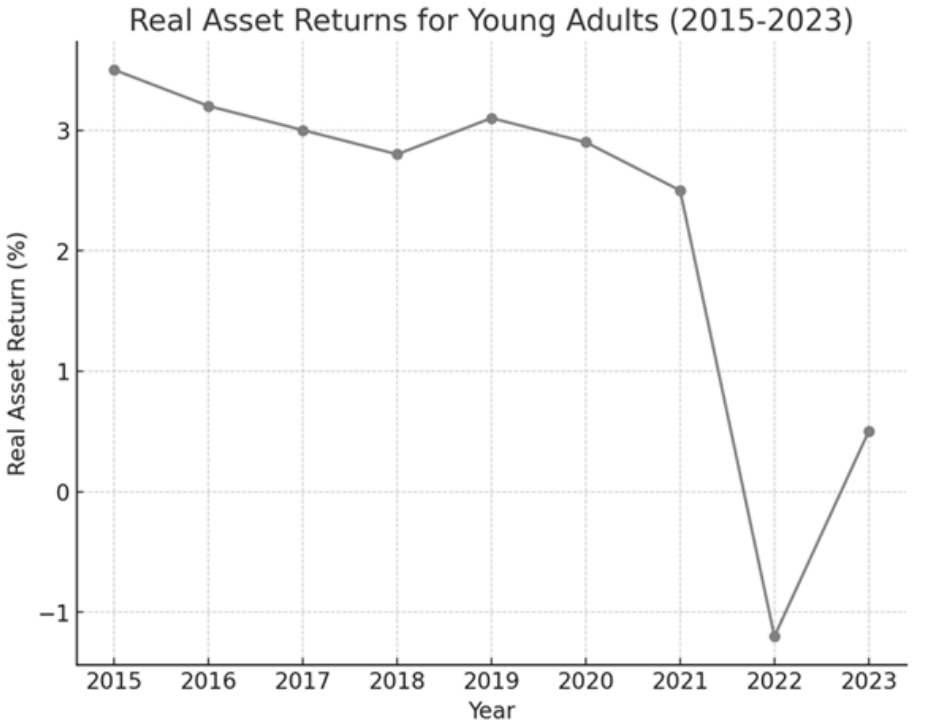
DOI

http://dx.doi.org/10.37355/acta-2025/1-01

Introduction

In Germany, the years 2021 to 2023 were marked by extraordinary inflationary pressures, with young adults among the most affected by rising costs. The inflation rate peaked at 10.6% in 2022, primarily driven by escalating energy and food prices (European Central Bank, 2022). Although inflation decreased to 6.0% in 2023, it remained significantly elevated compared to pre-2021 levels (Deutsche Bundesbank, 2023a). These economic conditions have influenced the financial behaviour of young households, particularly concerning asset allocation and wealth accumulation. Young adults were compelled to adjust their investment strategies, shifting from traditional low-risk assets like bonds and savings accounts to real assets such as real estate. This shift was driven by the need to hedge against inflation, as tangible assets like property typically appreciate during inflationary periods (Deutsche Bundesbank, 2023b). Additionally, there was a noticeable increase in risk appetite among younger investors, who turned to equities to compensate for the real losses incurred in safer asset classes (European Central Bank, 2022).

Figure 1: Real Asset Returns for Young Adults (2015-2023)



Source: Author's Compilation (2024)

The central problem is that young households are particularly vulnerable to the negative effects of high inflation due to smaller asset bases and greater income fluctuations. While

older generations often benefit from inflation-induced increases in the value of real assets and hold long-term liabilities that decrease in real terms, young adults face the challenge of building wealth in an economically volatile environment (European Central Bank, 2022). Inflation thus delays the long-term wealth accumulation processes of this age group and exacerbates income and wealth disparities between generations. The aim of the contribution is to investigate the financial impacts of inflation on the household assets of young adults in Germany from 2015 to 2023, compared to other age groups. The following research questions will be addressed: How has inflation influenced the asset allocation of young adults? To what extent do the real and nominal returns on the assets of young adults differ from those of other age groups? What are the long-term effects of the high inflation between 2021 and 2023 on the wealth development of young households? The methodology involves a comprehensive review of current studies, reports, and statistical data from relevant institutions such as the European Central Bank and the Deutsche Bundesbank. By analysing these sources, well-founded insights into the financial challenges and adaptation strategies of young adults in times of high inflation will be gained.

The remainder of this paper is structured to provide a comprehensive analysis of the topic. It begins with a detailed explanation of the methodology of the literature review and the data sources employed. Following this, an analysis of the income trajectories and household wealth of young Germans between 2015 and 2023 is presented. The investigation then delves into the consumption patterns, saving and investment behaviours, and the debt profiles of young adults during this period. A comparative analysis of the financial impacts of inflation on young adults vis-à-vis other age groups is offered to highlight the disparities. The paper then summarizes the key findings, discusses long-term implications, and provides recommendations for policymakers and practitioners. Finally, conclusions are drawn, and avenues for future research are outlined. Through this structured approach, we endeavour to furnish a comprehensive overview of the subject and to make a meaningful contribution to the ongoing scientific discourse.

1 Method

The methodology followed a structured literature review based on Webster and Watson (2002) and Tranfield et al. (2003) to systematically assess research on income development and household wealth of young adults in Germany from 2015 to 2023. A comprehensive search was conducted in databases such as EconLit, Social Science Citation Index, and Google Scholar, with criteria including publication dates (2015–2023), German focus, and relevance to income, wealth formation, consumption, saving, investment, and indebtedness of young adults. Key search terms included "Income development young people Germany," "Household wealth," "Consumption behaviour adolescents," and others, ensuring inclusion of both quantitative and qualitative studies. Leading sources were the German Institute for Economic Research (DIW Berlin), the Federal Statistical Office (EVS data), and the Deutsche Bundesbank's PHF study, which provided foundational data on income distribution, wealth, and consumption. Studies by the Institute for Employment Research (IAB) and insights from BaFin (2020) on fintech's impact further contextualized

financial behaviours. This structured approach highlighted significant insights and research gaps relevant for future studies and policy measures.

2 Theoretical Background

The following background on underlying fundamental publications aims to discover the propriate research within the topic of inflation, household's asset return rate and in specific the young households' contributation to that.

2.1 Fundamentals of Inflation Theory: Presentation of Relevant Economic Theories

Inflation theory deals with the causes and effects of general price level increases in an economy. A central approach is the Quantity Theory of Money, which traces back to Irving Fisher. Fisher (1911) postulated that an increase in the money supply, given a constant velocity of circulation, leads to proportional price increases. Milton Friedman (1963) built upon this idea and emphasized in Monetarism that inflation is always a monetary phenomenon caused by an excessive expansion of the money supply by the central bank. In contrast stands the Keynesian theory developed by John Maynard Keynes (1936). Keynes argued that inflation arises from excess demand in the economy, particularly when aggregate demand exceeds aggregate supply. Expectations and wage-price spirals also play a decisive role here. The New Keynesian theory expands this approach by integrating price rigidities and imperfect market information (Mankiw & Reis, 2002). The theory of rational expectations, represented by Robert Lucas (1972), criticizes Keynesian models for their assumption of adaptive expectations and emphasizes that economic agents anticipate future policy changes and act accordingly. This has implications for the effectiveness of economic policy measures to combat inflation.

2.2 Effects of Inflation on Households: Theoretical Mechanisms and Models

Inflation affects households by reducing purchasing power and distorting relative prices. Modigliani and Brumberg (1954) developed the life-cycle hypothesis, which states that individuals smooth their consumption over their lifespan. Inflation can disrupt this planning by altering the real values of savings and debts. Friedman's (1957) permanent income hypothesis suggests that consumption decisions are based on expected average income. However, unexpected inflation can reduce real disposable incomes, leading to adjustments in consumption. Additionally, inflation influences wealth distribution; households with nominally fixed assets lose purchasing power, while debtors may benefit from the real devaluation of their debts (Doepke & Schneider, 2006). Behavioural economics complements these models by considering money illusion, where individuals focus on nominal rather than real values (Shafir et al., 1997). This can lead to suboptimal financial decisions if households do not correctly incorporate inflation into their planning.

2.3 Specifics of Young Households: Socioeconomic Characteristics and Vulnerabilities

Young households exhibit specific socioeconomic characteristics that make them particularly susceptible to the negative effects of inflation. According to the Federal Statistical Office (Destatis, 2021), young adults under 30 often have lower incomes and are more frequently employed in atypical or precarious jobs. This results in increased income uncertainty and limited opportunities for wealth accumulation. The German Institute for Economic Research (DIW Berlin) has found that young people are disproportionately affected by income losses, especially in crisis times like the COVID-19 pandemic (Grabka et al., 2021). Precarious employment and fixed-term contracts increase the risk of financial instability, which is further exacerbated by inflation. Studies by the Deutsche Bundesbank (2022) show that young households possess less wealth compared to older age groups and have difficulties building long-term assets. Rising living costs and higher expenses for education reduce disposable income and saving capacity. Additionally, young households are more frequently indebted, which diminishes their financial resilience to price increases. The Institute for Employment Research (IAB) emphasizes that regional disparities influence the economic opportunities of young people (IAB, 2020). In structurally weak regions, young adults are more affected by unemployment and lower wages, increasing their vulnerability to inflation. These factors lead to young households being less able to build financial buffers and respond to economic shocks.

3 Literature Review

Between 2021 and 2023, Germany experienced a significant surge in inflation that notably influenced the financial behaviours of its young adult population. This period of economic fluctuation prompted a reassessment of traditional asset allocation strategies among young adults, who sought to preserve their wealth amid rising costs and diminishing real returns on safer investments. The literature indicates a marked shift from conventional assets like bonds and savings accounts toward equities and real estate, as young investors aimed to mitigate the adverse effects of inflation on their financial portfolios. Achieving real returns became increasingly challenging for this demographic, with nominal interest rates failing to keep pace with inflationary pressures. While equity markets and real estate provided some avenues for inflation-adjusted gains—particularly through significant price appreciations in real estate—the overall wealth accumulation for young adults showed signs of deterioration. Comparative studies highlight that young adults were more adversely affected by inflation than older age groups, due to smaller asset bases and greater sensitivity to income fluctuations. Older households often benefited from holding more real assets and nominal liabilities that appreciated or became less burdensome during inflationary times. Empirical research underscores the long-term implications of this inflationary period on the wealth-building trajectories of young adults in Germany. The erosion of disposable income led to reduced investment rates in both financial and tangible assets, suggesting potential enduring consequences on their financial stability and growth. This literature review synthesizes key findings from recent studies to explore the multifaceted impact of the 2021–2023 inflation surge on

the asset allocation, real and nominal returns, and overall wealth development of young adults in Germany.

3.1 Income Development and Household Wealth of Young People in Germany (2015–2023)

The income trajectories and household wealth of young people in Germany between 2015 and 2023 have been pivotal subjects in contemporary social science research. Various studies have analysed the influencing factors, highlighting the roles of labour market conditions, educational investments, and economic frameworks. The German Institute for Economic Research (DIW Berlin) has extensively examined income and wealth distribution in Germany. In particular, the works of Markus M. Grabka and colleagues provide a detailed analysis of income inequality trends. For instance, DIW's Weekly Report No. 18/2021 illustrates that income inequality remained relatively stable despite the impacts of the COVID-19 pandemic. However, it emphasizes that young people were disproportionately affected by income losses, attributed to precarious employment conditions and temporary contracts. Data from the Federal Statistical Office's Income and Expenditure Survey (EVS) offer crucial insights into the income situations of young households. Publications on income and living conditions in Germany reveal that adults under 30 tend to have lower incomes and are more likely to work in atypical employment arrangements. These factors not only influence current income but also affect the potential for wealth accumulation. The Deutsche Bundesbank's study "Private Households and Their Finances" (PHF) provides essential findings on wealth building. The results indicate that young households possess less wealth compared to older age groups and face difficulties in building long-term assets. Contributing factors include rising living costs, higher educational expenses, and uncertainties in the labour market. Research by the Institute for Employment Research (IAB) sheds light on the labour market situation of young people. The findings suggest that temporary contracts and insecure employment negatively impact income and hinder wealth accumulation. Moreover, regional disparities significantly influence the economic opportunities available to young individuals. Collectively, these studies demonstrate that the income development and wealth building of young people in Germany depend on a multitude of factors. The unique challenges they face shape their financial situations and necessitate targeted policy measures to reduce income inequalities and promote wealth accumulation.

3.2 Consumption Behaviour: Effects on Spending Habits and Expenditure Patterns

The consumption behaviour of young people in Germany has undergone significant changes between 2015 and 2023. Various studies have analysed these developments, each focusing on different aspects. According to the Federal Statistical Office (2021), there has been a marked increase in online purchases among young people. This trend is facilitated by advancing digitalization and the widespread use of smartphones. Mobile commerce has influenced spending habits, as purchases can be made anytime and anywhere. The Federal Agency for Civic Education (2019) highlights the impact of social media on consumption habits. Platforms like Instagram and TikTok serve as marketing channels where influencers promote products, leading to increased willingness to purchase and influencing young consumers' preferences. The German Youth Institute (DJI) emphasizes

that sustainability and environmental awareness have gained importance among young people (DJI, 2020). They show a heightened interest in sustainable products and are willing to spend more on them. This shift in values affects their consumption decisions and their household wealth. A study by the Bertelsmann Foundation argues that a lack of financial literacy leads to impulsive spending behaviour and lower savings rates (Bertelsmann Foundation, 2018). Promoting financial competence is therefore deemed crucial for fostering healthy financial behaviour. The Deutsche Bundesbank points out that rising living costs and rents reduce the disposable income of young people (Deutsche Bundesbank, 2022). These economic factors necessitate adjustments in consumption behaviour and can lead to shifts in expenditure priorities. In summary, technological advancements, social media influence, changing values, and economic conditions significantly contribute to the evolving consumption behaviour of young people in Germany.

3.3 Saving and Investment Behavior: Influence on Savings Rates and Investment Decisions

Between 2015 and 2023, the saving and investment behaviour of young people in Germany has garnered increased attention in research. Various studies analyse the factors influencing their savings rates and investment decisions. The Deutsche Bundesbank observed that young adults often exhibit lower savings rates than older generations (Deutsche Bundesbank, 2019). This is attributed to lower incomes, higher consumption expenditures, and less financial education. Financial insecurity and temporary employment contracts may lead young people to hesitate in long-term saving. A study by Börsch-Supan and colleagues at the German Institute for Economic Research underscores the importance of financial education (Börsch-Supan et al., 2016). The authors argue that a lack of financial knowledge leads to conservative investment decisions, with young people preferring low-risk savings products. Increased financial literacy boosts the willingness to invest in higher-yield assets like stocks. Lusardi and Mitchell highlight the global relevance of financial education for saving and investment behaviour (Lusardi & Mitchell, 2017). Although their focus is not exclusively on Germany, their findings underscore that financial competence is crucial for effective financial decisions. The Federal Financial Supervisory Authority (BaFin) analysed the influence of technological innovations. They found that fintech platforms and mobile apps ease access to financial services, leading to increased participation in capital markets among young adults (BaFin, 2020). This has the potential to sustainably change saving and investment habits. A study by Deloitte examines the influence of social media on investment decisions (Deloitte, 2021). It concludes that young investors increasingly obtain information from social networks, which can positively influence their investment decisions through increased market participation but also negatively through misinformation. KfW Research analysed the effects of the COVID-19 pandemic on the saving behaviour of young people (KfW Research, 2022). They found that uncertainty during the pandemic led to increased savings rates but also to more conservative investment strategies as risks were avoided. Overall, financial education, technological developments, and social media play central roles in shaping the saving and investment behaviour of young people in Germany, impacting their household wealth.

4 Discussion

The literature review reveals that young households in Germany between 2015 and 2023 faced significant financial challenges exacerbated by rising inflation. The findings indicate that young adults possess less wealth, earn lower incomes, and are more susceptible to economic fluctuations compared to older age groups. Interpreting these results suggests that inflation substantially impairs the financial stability of young households. Due to lower incomes and higher expenditures—particularly for education and increasing living costs—there is less financial leeway for wealth accumulation and savings activities. The erosion of purchasing power caused by inflation adds further strain, as real disposable incomes decline, necessitating adjustments in consumption expenditures. This can have long-term effects on the financial resilience and wealth-building opportunities of young people. Comparing the studies reveals both concordances and discrepancies in the literature. There is consensus that young households are financially more vulnerable and less able to accumulate wealth (Deutsche Bundesbank, 2022; DIW Berlin, 2021). Additionally, the influence of precarious employment and regional disparities on income situations is emphasized (IAB, 2020). However, contradictions emerge regarding the role of financial education and technological influences. While Lusardi and Mitchell (2017) stress the importance of financial literacy for better investment decisions, other studies point to risks associated with a lack of financial education and impulsive consumption behaviour (Bertelsmann Stiftung, 2018). Identifying research gaps highlights that the long-term effects of inflation on the wealth accumulation of young households are insufficiently explored. There is a lack of empirical longitudinal studies that analyse the interactions between inflation, consumption, and savings behaviour in detail. Furthermore, the impact of technological developments, such as fintech and social media, on the financial decisions of young people has not been adequately investigated. Additional research is necessary to develop targeted measures for promoting financial resilience. In terms of methodological critique, many studies rely on quantitative data from surveys and official statistics, which, while providing comprehensive insights, often overlook the individual experiences and subjective perceptions of young people. Qualitative approaches could complement this by offering a deeper understanding of the motives and barriers to wealth accumulation. Additionally, variations in study periods and sample sizes limit the comparability of the studies. Some research utilizes outdated datasets or insufficiently considers current economic developments, such as the COVID-19 pandemic. In conclusion, the discussion underscores that young households in Germany are disadvantaged in their financial development due to inflation and associated economic factors. There is an urgent need for further research and targeted policy measures to address the financial challenges faced by young people and to enhance their opportunities for wealth accumulation and financial security.

Conclusion

This study highlights how high inflation from 2021 to 2023 disproportionately affected the financial stability and wealth development of young adults in Germany. Due to smaller asset bases and volatile incomes, young households faced intensified inflationary

pressures, prompting shifts in investment strategies from low-risk assets to real assets like real estate and equities to counteract purchasing power loss. However, high entry barriers in real estate and risks in equity markets limited the benefits of these adjustments. Future research should examine long-term inflation effects on wealth accumulation among young adults, accounting for socioeconomic diversity. The potential impact of fintech and digital platforms on young adults' investment behaviour should also be explored. Policies addressing structural barriers, promoting financial literacy, supporting home ownership, and incentivizing long-term savings can help alleviate inflation's impact and support sustainable wealth building for younger generations.

References

BaFin (Federal Financial Supervisory Authority). (2020). *Digitalization and fintechs: Impacts on the financial market* [Digitalisierung und Fintechs: Auswirkungen auf den Finanzmarkt]. BaFin.

Becker, L., & Wolf, M. (2022). *Digitalization and financing behavior* [Digitalisierung und Finanzierungsverhalten]. Springer.

Bertelsmann Stiftung. (2018). *Financial education in Germany* [Finanzielle Bildung in Deutschland]. Bertelsmann Stiftung.

Börsch-Supan, A., Coppola, M., & Reil-Held, A. (2016). *Pension knowledge and retirement savings behavior in Germany* [Rentenwissen und Altersvorsorgeverhalten in Deutschland]. Deutsches Institut für Wirtschaftsforschung (DIW Berlin).

Bundeszentrale für politische Bildung (bpb). (2019). *Influence of social media on the consumption behavior of adolescents* [Einfluss sozialer Medien auf das Konsumverhalten Jugendlicher]. bpb.

Deloitte. (2021). *Influence of social media on the investment behavior of young investors* [Einfluss sozialer Medien auf das Anlageverhalten junger Investoren]. Deloitte.

Deutsche Bundesbank. (n.d.). *Private households and their finances (PHF): Results of the wealth surveys* [Private Haushalte und ihre Finanzen (PHF): Ergebnisse der Vermögensbefragungen].

Deutsche Bundesbank. (2019, March). *Asset formation in Germany: Results of the Bundesbank study* [Vermögensbildung in Deutschland: Ergebnisse der Bundesbank-Studie]. Monthly Report.

Deutsche Bundesbank. (2022). *Monthly report: Financial situation of private households* [Monatsbericht: Finanzielle Lage privater Haushalte].

Deutsches Institut für Wirtschaftsforschung (DIW Berlin). (2021). *Income inequality in Germany remains stable despite the corona crisis* [Einkommensungleichheit in Deutschland bleibt trotz Corona-Krise stabil]. DIW Weekly Report, 18.

Deutsches Jugendinstitut (DJI). (2020). *Youth study: Sustainability and consumption behavior* [Jugendstudie: Nachhaltigkeit und Konsumverhalten]. DJI.

Fischer, T., & Lange, S. (2019). *Social media and consumption pressure* [Soziale Medien und Konsumdruck]. Oldenbourg Scientific Publishing.

Fisher, I. (1911). *The purchasing power of money: Its determination and relation to credit, interest, and crises.* Macmillan.

Friedman, M. (1957). *A theory of the consumption function.* Princeton University Press.

Friedman, M. (1963). *Inflation: Causes and consequences.* Asia Publishing House.

Grabka, M. M., Goebel, J., & Schröder, C. (2021). *Einkommensungleichheit trotz Corona-Krise stabil – Sozialstaat schützt vor Verwerfungen* [Income inequality remains stable despite the corona crisis – Welfare state protects against upheavals]. DIW Wochenbericht, 18, 291–302.

Hoffmann, A., & Richter, F. (2021). *Financial impacts of COVID-19 on young adults* [Finanzielle Auswirkungen von COVID-19 auf junge Erwachsene]. Campus Verlag.

Institut für Arbeitsmarkt- und Berufsforschung (IAB). (n.d.). *Various studies on the labor market situation of young people* [Verschiedene Studien zur Arbeitsmarktsituation junger Menschen].

Keller, S., & Braun, H. (2018). *Household wealth and debt burden* [Haushaltsvermögen und Schuldenlast]. Social Science Publishing.

Keynes, J. M. (1936). *The general theory of employment, interest and money.* Macmillan.

KfW Research. (2022). *Savings behavior during the pandemic: Young adults between caution and opportunity* [Sparverhalten in der Pandemie: Junge Erwachsene zwischen Vorsicht und Chancen]. KfW Bankengruppe.

Lehmann, P., & König, T. (2023). *The future of youth debt* [Zukunft der Jugendverschuldung]. UTB.

Lucas, R. E., Jr. (1972). *Expectations and the neutrality of money. Journal of Economic Theory*, 4(2), 103–124.

Lusardi, A., & Mitchell, O. S. (2017). Financial literacy and economic outcomes: Evidence and policy implications. *Journal of Retirement*, 5(1), 107–114.

Mankiw, N. G., & Reis, R. (2002). Sticky information versus sticky prices: A proposal to replace the New Keynesian Phillips curve. *Quarterly Journal of Economics*, 117(4), 1295–1328.

Meier, D., & Schulz, R. (2020). *Credit behavior in times of low interest rates* [Kreditverhalten in Zeiten niedriger Zinsen]. Dr. Kovac Publishing.

Modigliani, F., & Brumberg, R. (1954). Utility analysis and the consumption function: An interpretation of cross-section data. In K. K. Kurihara (Ed.), *Post-Keynesian economics* (pp. 388–436). Rutgers University Press.

Müller, A., & Schmidt, B. (2016). *Youth debt in Germany* [Jugendliche Verschuldung in Deutschland]. VS Verlag.

Shafir, E., Diamond, P., & Tversky, A. (1997). Money illusion. Quarterly *Journal of Economics*, 112(2), 341–374.

Statistisches Bundesamt (Destatis). (n.d.). *Income and expenditure survey (EVS): Income and living conditions in Germany* [Einkommens- und Verbrauchsstichprobe (EVS): Einkommens- und Lebensbedingungen in Deutschland].

Statistisches Bundesamt (Destatis). (2021). *Consumption and income of young people in Germany* [Konsum und Einkommen junger Menschen in Deutschland].

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, 14(3), 207–222.

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly*, 26(2), xiii–xxiii.

Weber, C. (2017). *Financial education and debt prevention* [Finanzielle Bildung und Schuldenprävention]. Leipzig University Publishing.

Deutsche Bundesbank. (2023a). *Economic development forecast*. https://www.bundesbank.de/resource/blob/911528/c495d81f40e211f1db051f90d6638791/mL/2023-06-prognose-data.pdf

Deutsche Bundesbank. (2023b). *Wealth survey 2023*. https://www.bundesbank.de/resource/blob/908924/3ef9d9a4eaeae8a8779ccec3ac464970/mL/2023-04-vermoegensbefragung-data.pdf

European Central Bank. (2022). *Inflation and young adults*. https://www.ecb.europa.eu/press/research-publications/resbull/2024/html/ecb.rb240220~a77abebe0e.en.html

Contact Address

Jannik Schumann, MA
University of Finance and Administration
Estonská 500
101 00 Praha 10
Czechia
(Jannik.schumann@basec.de)

Interval and Global Progressivity. The Case of the Visegrad Group

JIŘÍ SLEZÁK

Abstract

Background: The countries of the Visegrad Group (Czech Republic, Slovakia, Poland and Hungary) apply different personal income tax systems that reflect their different economic and social policies. Taking into account the fact that often every year changes are made in the tax legislation, there are changes in tax systems.

Aim: The article is focused on measuring the progressivity of the tax on dependent activity in the Czech Republic, Slovakia, Poland and Hungary.

Methods: Interval and global progression methods were used. Specifically, these are the progressivity of the average rate, the progressivity of the tax liability, the Lorenz curve, the Gini coefficient and the Musgrave and Thin index.

Results: The resulting values are calculated according to model examples based on the tax laws of individual countries. Based on the results of interval progressivity, similar but also different features can be observed in individual countries. In the case of the Czech Republic, Slovakia and Poland, it can be observed that the tax on income from dependent activity is progressive. In the case of taxpayers with low incomes and in the case where a child lives with the taxpayer, the tax in some cases even has a regressive effect. On the other hand, in Hungary, a proportional tax applies throughout. Based on indicators of global progressivity, they show that the tax on income from dependent activities is the most progressive in Poland.

Keywords

Gini coefficient, global progressivity, interval progressivity, Lorenz curve, tax progressivity, Visegrad group.

JEL Codes

D71, D73, H83

DOI

http://dx.doi.org/10.37355/acta-2024/1-02

Introduction

Taxation of the income of natural persons represents a fundamental role in the fiscal policy of every state, as it represents the main source of public revenue and is also an important tool for influencing the economic behavior of individuals and companies. In the context

of the Visegrad Four countries, that is, the Czech Republic, Slovakia, Poland and Hungary, the analysis of tax systems and their progressivity represents an important aspect for understanding wider economic and social impacts.

Progressive taxation, which involves increasing the tax rate as income rises, is often seen as a way to reduce income inequality and ensure a more equitable distribution of wealth. On the other hand, flat or less progressive tax systems can be seen as a means of promoting economic efficiency and growth, as they can motivate higher work effort and investment. This article focuses on analyzing these differences and their implications within the Visegrad Four countries. Using quantitative data on incomes, tax rates and other economic indicators, the article provides a comprehensive overview of how different forms of personal income taxation affect economic equality and stability in the Central European region. The conclusions of this analysis will offer a deeper understanding of the role of tax policies in the development and management of modern market economies in the Central European context.

The article is structured in the usual way, where the introduction is followed by the theoretical background and a description of the data and methods used in the methodology section. Furthermore, progressivity results are analyzed in the results section, which are then discussed in the discussion section. All main ideas are further summarized in the conclusion.

1 Literature review

Daniels & VanHoose (2009) analyzed the progressivity of the tax system and inflation and found that an increase in the progressivity of the tax system induces a smaller response of real output to a change in the price level. The increased progressivity of the income tax therefore reduces the equilibrium rate of inflation. Nadirov & Dehning (2020) dealt with the analysis of tax progressivity and entrepreneurship. According to their conclusions, it can be concluded that increased downward progressivity has a positive effect on the rate of transition from start-up business to established business ownership. Tahová & Banociová (2020) claim that the tax progressivity of corporate income tax can be considered progressive in the EU-28 in the period under review.

Lee (2023) examined the progressivity of public pension benefits and labor income taxes and argues that the optimal ratio of progressivity of public pension benefits to labor income tax progressivity is not a constant rate of time discounting. The optimal public pension benefit is more progressive than the optimal tax on labor income. The results of Eydam & Qualo (2023) confirm a statistically significant negative association between the progressivity of the personal income tax and income inequality. Overall, we find that average and marginal tax rates in particular have the potential to reduce income inequality.

Slintáková & Klazar (2010) investigated the progressivity of the value added tax in the Czech Republic and their results show that the value added tax is regressive when analyzing annual income, while the analysis of lifetime income showed it to be progressive. Genčev, Musilová & Široký (2018) claim that the global progressivity of the tax relief system in the Czech Republic was slightly progressive during the analyzed period 2006-2016. The significant change in the structure of personal income tax in 2008 did not essentially reflect global tax progressivity. Krajňák (2020) examined the analysis of the tax progressivity of the income tax of natural persons from dependent activities in the Czech Republic in the period 1993-2018. The results of the analysis show that, despite the linear tax rate, personal income tax in the Czech Republic is not linear. In most cases, income tax has a progressive character due to the non-taxable part or tax reliefs. Based on a questionnaire survey in the Czech Republic, Cabelková & Smutka (2021) claim that taxpayer income was related to the perception that taxes for the rich are inadequately high, but not related to the perception of tax adequacy for the average and poor groups of respondents. According to Krajňák (2021), it was found that in 2021, compared to 2020, the tax burden in the Czech Republic according to the effective tax rate decreased in all model cases.

Horvath et al (2019) found that a hypothetical transition to a highly progressive tax structure in Slovakia generates some increase in employment but is associated with a decrease in total income and tax revenue. Based on their earlier analysis, Brzezinski, Myck & Najsztub (2022) conclude that Poland has become one of the most unequal European countries among the countries for which there are the highest corrected estimates of inequality. Krajewski & Pilát (2017) found that tax progressivity is not the main reason for the effectiveness of a progressive personal income tax in Poland as an automatic stabilizer. The study shows that changes in progressive rates have little effect on the effectiveness of passive fiscal policy. Based on ideological preferences, Adam & Simonovits (2019) argue that the pension system in post-2010 Hungary could be expected to be more financially sustainable, but less redistributive, compared to the previous period. Yet we find that while redistribution through the pension system to the poor has indeed been reduced, fiscal sustainability has not improved due to erratic policies.

Based on the analysis of progressivity in Croatia, Ledic, Rubil & Urban (2023) claim that in the case of a progressive (regressive) tax, approaching a relative view reduces (increases) the importance of progressivity (regressivity) for the tax's impact on well-being. Thus, the perception of the importance of progressivity and regressivity is influenced by the accepted view of inequality. According to Rubolino (2023), stricter tax enforcement tilts the balance in favor of higher marginal tax rates for middle and top incomes, while the lower marginal tax rate is weak in Italy. Serrano-Puente (2020) finds that increasing progressivity in Spain would be optimal, even if it would mean a loss of efficiency. Optimal tax schedule reform would reduce wealth and income inequality at the cost of negative impacts on capital, labor, and output.

Outside the European Union, tax progressivity was dealt with for example by Akkot, Gemicioglu & Kizilirmak (2023), who investigated the progressivity of indirect taxes in Turkey. The findings show that the value added tax is progressive according to the expenditure method and regressive according to the income method, and the special

consumption tax is progressive according to both methods. Echevarría (2015) looked at progressivity in the US and selected consequences of increasing income tax progressivity include reduced labor supply, lower GDP growth, lower future consumption growth. A higher appreciation of the well-being of future generations requires a lower level of progressivity. Datt, Ray & Teh (2022) find that in India, despite high levels of progressivity, the redistributive effects of income taxes remain modest among tax assessors and negligible in the adult population. Equalizing the difference between statutory and actual average tax rates will do little to improve redistributive effects. Based on an analysis of Latin American countries, Coelho & deOliviera (2016) claim that when there is no real progressiveness in personal income taxation, it causes low tax morale, low tax compliance and thus greater tax evasion.

2 Research methods

Eurostat wage statistics are used as the data source for the progressivity analysis. The Gini coefficient was calculated using the decile distribution of income, which allows for a more accurate estimate of the level of income inequality in the population. This type of distribution captures the shares of individual tenths of the population in total income, and is therefore a suitable basis for constructing the Lorenz curve and the subsequent calculation of the Gini index. The advantage of these input data is their reliability, the disadvantage is that they do not cover illegal income. The tax is calculated based on model taxpayers and does not abstract from the calculation of social security and health insurance. The OECD methodology was used in the analysis of taxpayers. The amount and procedures for calculating taxes are based on the tax laws of individual countries.

Taxpayer incomes are derived as multiples of the average wage of individual countries. Hypothetical taxpayers are divided according to individual incomes determined from multiples of the average wage into 10 income groups, see Table 1 in 2024.

Table 1: Division of taxpayers into income groups

Income group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Multiple	0,5	0,75	1	1,5	2	2,5	3	3,5	4	5

Source: Own processing

Table 2-5 shows the distribution of employees into groups according to the average salary band measured by Eurostat. For the purposes of this analysis, the household income distribution was chosen according to the decile distribution, i.e. into ten equally large groups, each representing 10% of the population ranked by the amount of equivalent disposable income.

Table 2: Shares of employees % in the Czech Republic

	1. decile	2. decile	3. decile	4. decile	5. decile	6. decile	7. decile	8. decile	9. decile	10. decile
From	0	18 474	22068	24950	27424	30273	33548	37086	42020	50530
To	18 473	22 067	24949	27423	30 272	33547	37085	42019	50529	
%	4,1	6,1	7,1	7,9	8,6	9,6	10,6	11,8	13,8	20,3

Source: Eurostat (2024), own processing

Table 3: Shares of employees % in Slovakia

	1. decile	2. decile	3. decile	4. decile	5. decile	6. decile	7. decile	8. decile	9. decile	10. decile
From	0	437	603	707	778	849	924	1003	1102	1286
To	436	602	706	777	848	923	1002	1101	1285	
%	3,5	6,1	7,5	7,7	9,4	10,2	11,1	12,1	13,7	17,9

Source: Eurostat (2024), own processing

Table 4: Shares of employees in Poland

	1. decile	2. decile	3. decile	4. decile	5. decile	6. decile	7. decile	8. decile	9. decile	10. decile
From	0	2433	3059	3559	4014	4514	4989	5525	6326	7724
To	2 432	3058	3558	4013	4513	4988	5524	6325	7723	
%	3,5	5,6	6,8	8,6	8,7	9,7	10,7	12	14,1	21,2

Source: Eurostat (2024), own processing

Table 5: Shares of employees % in Hungary

	1. decile	2. decile	3. decile	4. decile	5. decile	6. decile	7. decile	8. decile	9. decile	10. decile
From	0	139260	188473	221109	250676	280363	310280	349212	393350	474415
To	139259	188472	221108	250676	280362	310279	349211	393349	474414	
%	3	5,5	6,6	7,7	8,6	9,5	10,7	12	13,9	22,3

Source: Eurostat (2024), own processing

The article uses basic methods of statistical inference such as analysis and comparison and selected methods of interval and global progressivity (see Široký, Friedrich and Maková, 2012). By means of interval progressivity, changes in the tax rate between two selected pension intervals are measured. Global progressivity shows tax progressivity across the entire income range.

One method is used for the analysis of interval progressivity. Average rate progressivity (PAR) represents the change in average rate to change in income (1):

$$PAR = \frac{\frac{T_1}{Y_1} - \frac{T_0}{Y_0}}{Y_1 - Y_0} \tag{1}$$

where Y represents gross income and indices 1 and 2 represent the individual compared income groups of taxpayers. A PAR value greater than 0 represents a progressive tax, and a PAR value less than 0 represents a regressive tax.

Three methods are used to analyze global progressivity. The most frequently used indicator is the Lorenz curve.

The Lorenz curve is a graphic device that shows the inequality in the distribution of income in society. In graphic form, it shows the relationship between absolute equality, absolute inequality and the actual distribution of incomes.

Absolute equality represents the line of absolute equality, which represents a hypothetical situation where all subjects receive the same income. The line of absolute equality is used in determining the deviation of the actual income distribution. Conversely, the line of absolute inequality represents a hypothetical situation where only one household receives income. The further the true Lorenz curve is from the line of absolute equality, the more unequal the distribution of income. If, as a result of taxation, the actual Lorenz curve approaches the line of absolute equality, the imposed tax is progressive, otherwise regressive.

To quantify the data from the Lorenz curve, the Gini coefficient (G) is used, which compares the actual Lorenz curve and the line of absolute equality and expresses the deviation from absolute equality. The modified Gini coefficient formula measures the area under the true Lorenz curve and under the curve of the line of absolute equality see (2).

$$G = \frac{A}{A + B} \tag{2}$$

where: A is the area under the Lorenz curve and B is the area between the line of absolute equality and the true Lorenz curve.

For the change in the Gini coefficient before and after taxation, the Musgrave and Thin coefficient (M) is used, see (4).

$$M = \frac{1 - G_X}{1 - G} \tag{3}$$

where: G is the pre-tax Gini coefficient and Gx is the post-tax Gini coefficient. The pointer values take on values from 0 to ∞. The size of the coefficient less than 1 means a regressive tax, a coefficient greater than 1 a progressive tax, a coefficient equal to 1 means a proportional tax.

The disadvantage of the indicator is that it does not take into account fluctuations within the entire interval. If there is only an intra-group transfer of income with an interval distribution of frequencies, this will not affect the size of the Gini coefficient.

3 Solutions and Results

Figures 1 and 2 show the progressivity values of the tax obligation from dependent activity in the individual countries of the Visegrad Four. Points on the graph that are above 1 represent a progressive tax, values below 1 represent a regressive tax, and values that reach 1 represent a proportional tax.

The Czech tax system shows very significant progressivity in comparison, especially for low-income groups. Taxpayers with an income of 0.5 times the average wage have a PTO of 2.06, i.e., more than twice the burden of the average taxpayer. This effect is caused by the fact that the basic tax credit is a fixed amount, and for low incomes it has an extremely high relative impact on the total burden. With wage growth, the PTO decreases continuously. At 1.5 times the average wage, it is 1.21, and at twice the average wage, it reaches 1.15. This development confirms the decreasing progressivity, i.e., the weakening of the redistributive function of the system as income grows. The change occurs between 3 times and 3.5 times the average wage, when a higher income tax rate comes into effect. The PTO increases slightly again, from 1.10 to 1.34, which confirms the return to a progressive trend for the highest incomes. However, at 5 times the average wage, it drops again to 1.29, which may indicate a saturation of the tax rate or the impact of the insurance premium caps. The Czech tax system is strongly progressive for low-income groups, with some flattening in the middle and higher income bands and a subsequent temporary increase caused by the higher tax rate. However, progressivity is significantly weaker in the higher bands. The tax structure supports social justice, but from an efficiency perspective it may lead to a search for ways to reduce taxation. In the Czech Republic, in the case of a taxpayer with children, strong fiscal support is used for low-income families. The PTO value for a household with an income of 0.5 times the average wage reaches a negative value (−6.18), which may mean that the combination of the child tax credit and the taxpayer discount not only eliminates the tax liability, but the household becomes the recipient of

a tax bonus. This effect is evidence of an expansive tax policy towards low-income families. With increasing income, the PTO value increases rapidly and stabilizes between 1.2 and 1.4 in the range from 1.5 to 4 times the average wage. This indicates a slightly progressive but stable tax structure that does not escalate taxation disproportionately above a certain threshold. The practical consequence is a low disincentive force of the system for the working middle class and at the same time solid social support for families with children.

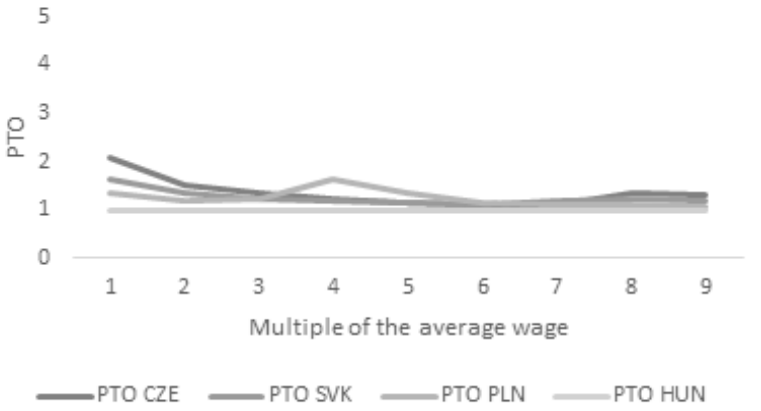
In Slovakia, progressivity follows a similar course as in the Czech Republic, but its overall intensity is milder. At 0.5 times the average wage, the PTO is 1.65, which confirms the higher tax burden on low-income groups relative to the average taxpayer, but lower than in the Czech Republic. As incomes increase, the PTO steadily decreases, to 1.17 at 1.5 times and 1.14 at 2 times. The change is observed at 3 times the wage, where the PTO increases from 1.13 to 1.19 and then to 1.24 at 3.5 times. This phenomenon can be attributed to the gradual reduction of the non-taxable part of the tax base and the onset of a higher tax rate. Subsequently, the PTO decreases again to 1.19 at 5 times the average wage. The Slovak tax system shows a medium level of progressivity, with a smoother and less steep course than the Czech Republic. A more pronounced break occurs only in the upper middle band. Progressivity is moderate here, which leads to greater tax neutrality between individual income groups. Low-income earners are still protected, but less than in the Czech Republic. The Slovak results for taxpayers with children show significant volatility. In the income band around 0.75 times the average wage, the PTO reaches an extremely negative value (−19.65), while at the average wage it rises sharply to 5.31. This sudden increase in the tax burden points to a steep and nonlinear progressivity of the system, which may be caused by the mechanism for calculating the tax benefit for children.

The Polish system shows a very different course. While the PTO at 0.5 times the average wage is relatively low (1.33), in the range between 1 and 1.5 times it increases sharply to 1.64. From this maximum, the PTO decreases significantly again, to 1.14 at 2.5 times and to 1.08 at 5 times the average wage. This development indicates that in Poland the tax burden is concentrated in the middle-income groups, while progressivity weakens at higher incomes. The Polish system is extremely progressive in the middle-income group, but it loses its redistributive power for the highest income groups. It can thus create tax traps for the middle class. In practice, this means that the tax system can demotivate productive employees in the career growth phase, but at the same time be attractive to the highest earners, which can affect the migratory movements of workers. The Polish tax system for taxpayers with children shows the highest stability and uniform progressiveness of all the countries monitored. PTO values range in a narrow range from 1.27 to 1.68 between 0.5 and 3 times the average wage. This reflects a slightly progressive but socially balanced tax regime, where the benefit for children acts evenly across income multiples. A high degree of tax predictability has positive consequences: lower administrative burden, greater taxpayer confidence and less incentive to optimize.

The Hungarian tax system is almost perfectly proportional. The PTO is almost equal to 1 throughout. This is a consequence of the flat tax rate without a basic tax credit for the taxpayer and the almost linear progression of the premium. The effective tax rate thus increases directly proportionally with income, which means that each additional

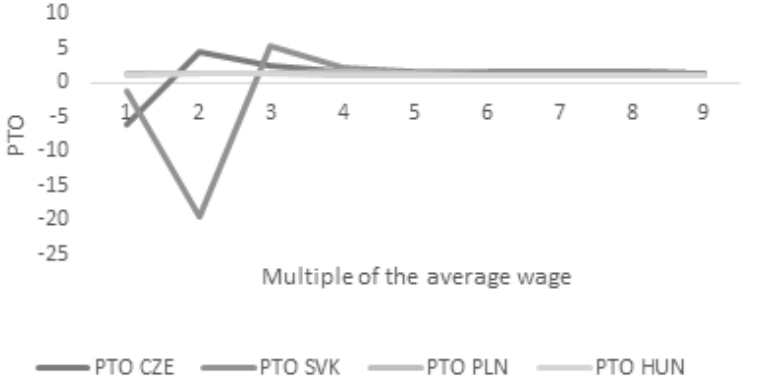
unit of income is taxed in the same way as the previous one. This makes the tax system characterized by zero progressivity, but also the absence of any repressiveness or preferential treatment of low-income groups. Hungary has a completely different approach. This system is very predictable, but it does not offer any natural redistribution. In Hungary, a significantly different trend can be seen in the case of taxpayers with children. The PTO starts at 1.33 at low incomes and decreases slightly below 1 with increasing wages (specifically 0.95 at 3 times the average wage). This indicates the regressive nature of the system, where the effective tax burden decreases at higher incomes. This effect can be explained by the existence of a flat tax without gradual progression and probably. The practical consequence is a tax system that rewards higher incomes with a lower relative burden. From the point of view of family policy, the system is accommodating thanks to a significant tax advantage for children, but the redistributive effect is limited. The system can support economic activity and entrepreneurship, but at the cost of lower tax equality.

Figure 1: Progressivity of tax liability in the case of a basic discount



Source: own processing

Figure 2: Progressivity of tax liability in the case of a child discount



Source: own processing

Figures 3–6 show the Lorenz curves of individual countries. For greater clarity, the curves after taxation are shown only in the case of a discount or deductible item only for thetaxpayer himself and a tax benefit for children. In the case of taxation, the actual Lorenz curve in the Czech Republic, Slovakia and Poland approaches the curve of absolute equality. This confirms the progressive nature of the tax. In Hungary, the situation is different, because in the case of taxation the actual Lorenz curve does not change, which indicates its proportional course.

Figure 3: Lorenz curve of the Czech Republic

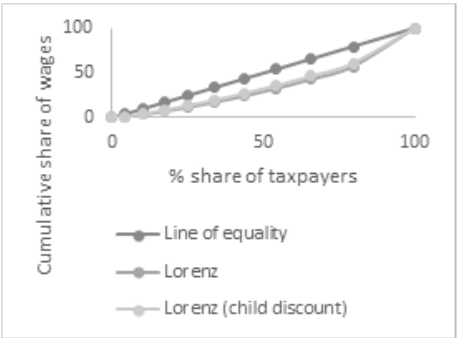
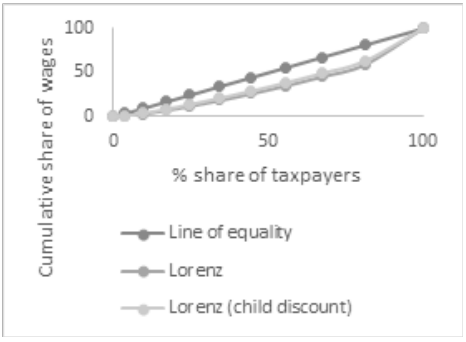


Figure 4: Lorenz curve of Slovakia



Source: own processing

Figure 5: Lorenz curve of Poland

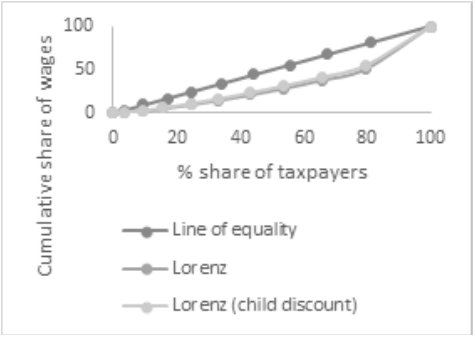
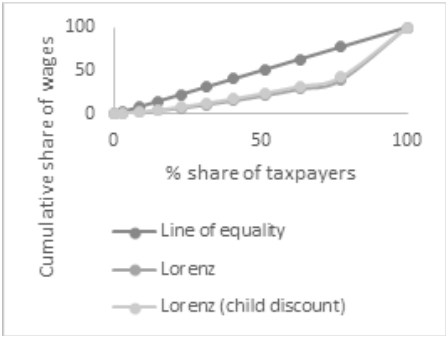


Figure 6: Lorenz curve of Hungary



Source: own processing

Table 6 shows the values of the Gini coefficient before and after taxation by taxation and the Musgrave and Thin coefficient of individual countries.

Table 6: Gini coefficient (G) values before and after taxation and Musgrave and Thin coefficient of individual countries

Coefficient	Czech Republic	Slovakia	Poland	Hungary
G	29,7%	30,7%	34,70%	27,6%
G after tax (discount for two child)	24,9%	25,5%	30,6%	23,61%
Musgrave and Thin coefficient	1,067	1,076	1,063	1,0000

Source: own processing

Tax on income from dependent activity is more progressive than all countries in Poland and least in Hungary according to the difference between the Gini coefficient after taxation (in the Czech Republic 4.8 %, in Slovakia 5,2 %, in Poland 4,1 %. In the case of applying discounts or tax benefits, the Gini coefficient decreases. In the case of applying the basic discount per child, the Gini coefficient is the lowest in the Czech. Republic and Hungary.

4 Discussion

It was found that the income tax from dependent activity within the framework of interval progressivity has a similar character in the Czech Republic and Slovakia. Low-income taxpayers face higher progressivity, and it decreases with increasing income (in the Czech Republic, it increases for high-income taxpayers (from 3.5 times the average wage). In the case of taxpayers with the lowest incomes, the share of tax on total gross income reaches very low values, and with further in the income interval, a large jump in this share can be seen, which then stabilizes (it can be stated that in these countries this tax is progressive throughout, although it decreases from 1.5 times the average wage in both countries. In Poland, a higher progressiveness of the tax can be observed than as in Slovakia, there is a decrease in progressivity towards a proportional tax in Hungary.

Overall, it can be said that the tax on income from dependent activity is progressive (if we take into account the tax rebates in Hungary), but the progressivity is very low. This may be due to the fact that in these states there are no significant tax brackets that increase the tax burden with increasing income. Although in these states one higher rate is usually applied for higher incomes, only one rate still dominates taxpayers. Another reason for similar results may be the similar historical context. The reason may also be competitive pressure to prevent the departure of executives to other countries. The tax on income from dependent activity is the most progressive in Hungary according to the Gini coefficient indicators, as well as the Musgrave and Thin coefficient. The reason for

higher progressiveness in Poland may be tax bands, or rather tax rates, which are higher (mainly the second rate) than in other countries, but also its historical focus on justice and redistribution of wealth.

The resulting differences between the states are caused by deductions from the tax base, respectively the tax, the size of the effective tax rate or the share of income tax on gross income. If the use of the entire spectrum of discounts or non-taxable parts of the tax base, i.e. social and health insurance, were taken into account, the results would certainly be different, which will be the subject of future research.

Conclusion

Values of interval and global progressivity of tax on income from dependent activity were determined in the Czech Republic, Slovakia, Poland and Hungary in 2023. The resulting values were determined on the basis of multiples of the average salary for a model taxpayer who applies only the basic discount (deductible item) per taxpayer or tax benefit (tax discount) for one child). At the same time, it was abstracted from social security contributions.

On the basis of the results, it can be claimed that the progressiveness of low-income taxpayers in the Czech Republic and Slovakia is high, and further decreases with increasing income. The exception is the case of applying the discount for one child, when the tax has a regressive effect. These results are caused precisely by tax rebates and deductible items, which have the effect that the effective tax rate of these taxpayers is less than the nominal tax rate. On the contrary, in Hungary, the tax is proportional throughout, as their tax system does not allow any basic discount to be deducted, but in the case of a child discount, the tax is already slightly progressive throughout.

Based on the Lorenz curve in the case of taxation, in the Czech Republic, Slovakia and Poland, the actual Lorenz curve approaches the curve of absolute equality, which confirms that the tax has a progressive effect. In Hungary, the situation is different, because in the case of taxation, the actual Lorenz curve does not change, which indicates its proportional course. According to indicators of global progressivity, it can be argued that the tax on income from dependent activity is more progressive than all countries in Poland.

References

Akkoç, U., Gemicioğlu, S., & Kızılırmak, B. (2023). Türkiye'de Dolaylı Vergi Yükü ve Dolaylı Vergilerin Artan Oranlılığı. Sosyoekonomi, 31(55), 321-346. https://doi.org/10.17233/sosyoekonomi.2023.01.17

Brzezinski, M., Myck, M., & Najsztub, M. (2022). Sharing the gains of transition: Evaluating changes in income inequality and redistribution in Poland using combined survey and tax

return data. European Journal of Political Economy, 73, 102121. https://doi.org/10.1016/j.ejpoleco.2021.102121

Cabelková I., & Smutka, L. (2021). The Effects of Solidarity, Income, and Reliance on the State on Personal Income Tax Preferences. The Case of the Czech Republic. Sustainability, 13(18). https://doi.org/10.3390/su131810141

Coelho, AFC., & deOliveira, JAWD (2019). How to fight tax evasion: real progressivity. Revista Brasileira De Estudos Politicos, 118, 13-51. https://doi.org/10.9732/P.0034-7191.2019V118P013

Czech statistical office (2024). Household income and living conditions, from https://csu.gov.cz/produkty/prijmy-a-zivotni-podminky-domacnosti-xkhdcg1man

Datt, G., Ray, R. & Teh, C. (2022). Progressivity and redistributive effects of income taxes: evidence from India. Empir Econ 63, 141–178. https://doi.org/10.1007/s00181-021-02144-x

Daniels, JP., & VanHoose, DD. (2009). Openness, income-tax progressivity, and inflation. Journal of Macroeconomics, 31(3), 485-491, https://doi.org/10.1016/j.jmacro.2008.10.003

Echevarría, C.A. (2015). Income tax progressivity, growth, income inequality and welfare. SERIEs 6, 43–72. https://doi.org/10.1007/s13209-014-0119-5

Eurostat (2024). Distribution of income by quantiles. From https://ec.europa.eu/eurostat/databrowser/view/ilc_di01__custom_16776434/default/table?lang=en

Eydam, U., & Qualo, H. (2023). Income inequality and taxes – an empirical assessment. Applied Economics Letters, 1–8. https://doi.org/10.1080/13504851.2023.2208328

Genčev, M., Musilová, D., & Široký, J. (2018). A Mathematical Model of the Gini Coefficient and Evaluation of the Redistribution Function of the Tax System in the Czech Republic. Politická ekonomie, 66(6), 732-750. https://doi.org/10.18267/j.polek.1232

Horváth, M., Senaj, M., Siebertová, Z., Švarda, N., & Valachyová, J. (2019). The end of the flat tax experiment in Slovakia: An evaluation using behavioural microsimulation in a dynamic macroeconomic framework. Economic Modelling, 80,171-184, https://doi.org/10.1016/j.econmod.2018.11.005

Krajewski, P., & Piłat, K. (2017). Czy progresja podatkowa stabilizuje gospodarkę? Porównanie podatku progresywnego i liniowego. Comparative Economic Research. Central and Eastern Europe, 20(1), 21–34. https://doi.org/10.1515/cer-2017-0002

Krajňák, M. (2020). Is Personal Income Tax on Dependent Activity in the Czech Republic Progressive? Politická ekonomie, 68(5), 534-553. https://doi.org/10.18267/j.polek.1295

Krajňák M. (2021). Evaluation the impact of the personal income tax reform in the Czech Republic in 2021 on effective tax rate and tax progressivity. Journal of Tax Reform, 7(2), 134–145. https://doi.org/10.15826/jtr.2021.7.2.094

Kubátová, K. (2016). Interval and global progressivity of the income tax from wages in the Czech and Slovak Republics. Acta Oeconomica Pragensia, 24(1), 54-67. https://doi.org/10.18267/j.aop.498

Ledić, M., Rubil, I. & Urban, I. (2023). Tax progressivity and social welfare with a continuum of inequality views. Int Tax Public Finance 30, 1266–1296. https://doi.org/10.1007/s10797-022-09752-y

Lee, I. (2023). Optimal Progressivity of Public Pension Benefit and Labor Income Tax. Hacienda Pública Española/Review of Public Economics, 246, 3, 3-35. https://dx.doi.org/10.7866/HPE-RPE.23.3.1

Nadiron, O., & Dehning, B. (2020). Tax Progressivity and Entrepreneurial Dynamics. Sustainability, 12(9). https://doi.org/10.3390/su12093584

Rubolino, E. (2023). Does weak enforcement deter tax progressivity? Journal of Public Economics, 219, 104833, https://doi.org/10.1016/j.jpubeco.2023.104833

Serrano-Puente, D. (2020). Optimal progressivity of personal income tax: a general equilibrium evaluation for Spain. SERIEs 11, 407–455. https://doi.org/10.1007/s13209-020-00226-0

Slintáková, B., & Klazar, S. (2010). Impact of Harmonisation on Distribution of VAT in the Czech Republic. Prague Economic Papers, 19(2), 133-149. https://doi.org/10.18267/j.pep.368

Statistical office of the Slovak Republic, 2024. Shares of employees in bands of average gross nominal monthly wage by working time and gender [np2001rs]. Available https://datacube.statistics.sk/#!/view/sk/VBD_SLOVSTAT/np2001rs/v_np2001rs_00_00_00_sk

Statistics Poland, 2023. Salary structure by profession for October 2022. Available https://stat.gov.pl/obszary-tematyczne/rynek-pracy/pracujacy-zatrudnieni-wynagrodzenia-koszty-pracy/struktura-wynagrodzen-wedlug-zawodow-za-pazdziernik-2022-roku,4,11.html

Široký, J., Friedrich, V. & Maková, K. (2012). Testing the Predicative Ability of the Tax Progressiveness Indices. E+M Ekonomika a Management. 15(1), 4–16. ISSN: 2336-5064.

Tahova, S., & Banociova, A. (2020). "Assessment of the Redistribution Function of Corporate Income Tax." Montenegrin Journal of Economics, Economic Laboratory for Transition Research (ELIT), 16(3), pages 57-67. https://doi.org/10.14254/1800-5845/2020.16-3.5

Zoltán, A., & Simonovits, S. (2019). From Democratic to Authoritarian Populism: Comparing Pre - and Post-2010 Hungarian Pension Policies. Acta Oeconomica, 69(3), 333–355. https://doi.org/10.1556/032.2019.69.3.2

Contact Address

Ing. Jiří Slezák, Ph.D.
VSB - Technical University of Ostrava
Faculty of Economics, Department of Accounting and Taxes
Ostrava
Czech Republic
(jiri.slezak@vsb.cz)

Comparison of Classical Arima Forecasting Methods to the Machine Learning LSTM Method: a Case Study on DAX® 50 ESG Index

MANUEL ROSINUS

Abstract

Background: Traditional econometric models like ARIMA, while foundational for time series forecasting, often rely on assumptions of linearity and stationarity. These models can fall short in capturing the complex, nonlinear dynamics frequently present in financial markets. This has led to the adoption of machine learning methods like Long Short-Term Memory (LSTM) networks, which are specifically designed to recognize long-term dependencies in sequential data, offering a potential advantage in modeling volatile financial time series.

Aim: This study compares the predictive performance of a classical econometric model (ARIMA) with a deep learning approach (LSTM) in the context of stock index forecasting using the DAX 50 ESG index from 2020 to 2024.

Methods: An autoregressive integrated moving average (ARIMA) model is compared against a long short-term memory (LSTM) neural network. The models are evaluated using both a static train-test split and a more rigorous expanding window forecast scheme. Predictive accuracy is measured by standard error metrics (MAE, RMSE, MAPE) and the Diebold-Mariano test.

Results: The empirical results show that the LSTM model achieves lower forecast errors than the best-fitting ARIMA model in both evaluation frameworks. In the expanding window scenario (repeated retraining), the LSTM maintains a statistically significant, though modest, forecasting advantage over the ARIMA model.

Originality/Value: The findings suggest that while the LSTM's ability to capture nonlinear patterns offers a forecasting edge, the improvement is incremental in a highly liquid and efficient market. This case study highlights the potential of deep learning methods in finance but also reinforces the notion that strong market efficiency can limit the forecasting benefits of such complex models.

Keywords

Financial markets, Econometrics, Forecast, Machine learning, LSTM, ARIMA

JEL Codes

C53, G17, C45

DOI

http://dx.doi.org/10.37355/acta-2024/1-03

1 Introduction

Forecasting stock prices and market movements is crucial for making informed investment decisions, managing risks, and enhancing market efficiency. Accurate predictions can benefit individual and institutional investors by guiding investment strategies and reducing potential financial losses.

While there is no shared consensus within the scientific community, if stock movement is following a random walk, many researchers suggest this is not the case. For instance, tests on various stock markets, including prominent indices, show deviations from random walk behavior, suggesting inefficiencies (Asaad & Omer, 2024; Danila, 2022; Dsouza & Mallikarjunappa, 2015; Gregory, 2021).

Conventional methodologies for stock market analysis primarily incorporate the fundamental analysis, which aims to determine a stock's intrinsic value by assessing key performance factors of the business itself, or the technical analysis, which analyzes past market performance by looking at the stock's chart activity of price movements, volume, moving averages, and the statistics of various outcomes. In a comprehensive review of 122 studies on stock market forecasting over 11 years, Nti et al. (2020) indicate that 66% of the publications investigated were predicated on technical analysis, while 23% and 11% were based on fundamental and combined investigations.

In contrast, econometrics focuses on utilizing statistical and mathematical techniques to analyze and test economic hypotheses using real-world data. Traditional econometric models have been used extensively to analyze financial time series, predict stock returns, and also estimate volatility (Bhowmik & Wang, 2020). Among the commonly applied methods are the Autoregressive Integrated Moving Average (ARIMA) models, Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models, and factor models. Each of them offers distinct benefits in terms of identifying time-dependent patterns in financial data.

These traditional classical models are valued because of their interpretability and computational efficiency. However, there are serious problems with their reliance on linear correlations and stationarity assumptions. Particularly during times of structural change or market anomalies, these models frequently fall short of capturing the nonlinear and dynamic nature of financial markets (Apte & Haribhakta, 2024). This has encouraged interest in exploring more adaptive and flexible approaches like machine learning and deep learning.

This paper discusses whether machine learning can predict financial time series movement better than the commonly used ARIMA model in the case of the DAX ESG index.

2 Background

2.1 Machine Learning in Financial Time Series Forecasting

Today, the theory and practice of finance have undergone a remarkable evolution due to artificial intelligence (AI) and machine learning (ML). However, the integration of ML/AI in finance can be traced back to the early 1990s, when researchers began experimenting with neural networks and genetic algorithms for trading models (LAKHCHINI et al., 2022). These early studies demonstrated that artificial neural networks (ANNs) could outperform traditional linear models by capturing hidden patterns in financial data. The 2000s saw a growing interest in support vector machines (SVMs) and random forests, which provided more robust feature selection and model interpretability (Teles et al., 2021). By the 2010s, the rise of big data and deep learning led to the development of advanced architectures such as long short-term memory (LSTM) networks and convolutional neural networks (CNNs), which significantly improved the ability to model sequential and high-frequency financial data (Alzubaidi et al., 2021).

2.2 Key Applications in Financial Time Series Forecasting

Machine learning affects virtually all corners of finance. According to market research, the global artificial intelligence in the fintech market grew from $9.15 billion in 2022 to $11.59 billion in 2023, which implies a growth rate of 26.8% per year (*AI in FinTech Market Size, Trends and Global Forecast To 2032*, 2023). These numbers are further supported by the most recent statistics in finance, where 70% of financial services companies use ML to boost their predictive and statistical capabilities. The applications of machine learning in the finance industry are rapidly growing.

One of the most extensively researched applications of ML in finance is stock return prediction. Early ML models such as decision trees and gradient boosting machines demonstrated improved predictive power compared to linear regression, but they required extensive feature engineering and were prone to overfitting (Beatty & Sundkvist, 2024; Mahamat et al., 2024). Deep learning techniques, particularly Long Short-Term Memory (LSTM) networks, have addressed some of these challenges by capturing long-term dependencies in stock price movements, thereby outperforming traditional econometric models in various empirical studies (Alamu & Siam, 2024; Chen, 2023; Latif et al., 2024).

Researchers have also developed ensemble models combining LSTM with other machine learning algorithms such as Support Vector Machine (SVM), Random Forest (RF), and Gated Recurrent Unit (GRU) to improve forecasting accuracy for various ESG indices (Suprihadi & Danila, 2024). These advanced forecasting methods offer valuable insights for investors and policymakers, potentially enhancing investment strategies and economic planning in the context of ESG considerations. Despite these advancements, stock return predictions remain highly complex due to market efficiency, changing macroeconomic conditions, and unpredictable external shocks (Keswani et al., 2024).

3 Case study on ML-forecasting method with LSTM

This case study compares the performance of classical time series forecasting with ARIMA with a machine learning neural network LSTM approach, applied to a concrete example of the German DAX 50 ESG index.

The DAX 50 ESG index aims to provide an ESG index as a benchmark for sustainable German stock portfolios. DAX 50 ESG index is based on the HDAX index, which includes all shares from the DAX, MDAX, or TecDAX indices – covering the performance of the 50 largest and most liquid stocks in the German market that have met standardized ESG criteria concerning Global Standards Screening, including scrutiny of involvement in controversial weapons, tobacco production, thermal coal, nuclear power, and military contracting while demonstrating relatively strong performance based on Environmental, Social, and Governance metrics (*1-DAX 50 ESG (DAXESGK) (DE000A0S3E04)*, 2025).

3.1 Data and methodology

3.2 Data Description

Open-high-low-close (OHLC) data on the DAX 50 ESG Index (ISIN: DE000A0Z3NB0) is provided by Börse Frankfurt.[1] No adjustment for splits, dividend payments, or related to subscription rights is performed. Closing prices for the period from the last four whole years (01.01.2020 to 31.12.2024) are considered.

Missing data handling is not required, as the data set was previously checked for missing closing prices. However, as ARIMA models require evenly spaced time series, forward fill is applied to missing values (e.g., on bank holidays). Further model-specific data preprocessing is described in the sub-chapter of each method.

3.3 Data Split and Validation

The data source is split into 80 % training and 20% test data sets. The training set is used to estimate the parameters (ARIMA) and train the neural network (LSTM), whereas the test set is used to evaluate the method's prediction accuracy.

In addition, an expanding window provides a more resilient and realistic foundation for model assessment than conventional static train-test divisions. In contrast to fixed splits, an expanding window forecast constantly refreshes the training set by regularly integrating the latest data, which is crucial to identifying emerging patterns and structural breaks seen in several real-world datasets, especially in financial markets.

The models are trained and fitted on the initial 70% of data, and the 1-step-ahead forecast is calculated for each day *t* in the test set. Afterwards, the *t+1* actual value is added to the model.

1 https://www.boerse-frankfurt.de/indices/dax-50-esg-performance/price-history/historical-prices--and-volumes

This method is more effective in identifying potential long-term trends, cycles, or dependencies that may be present in the financial time series, as it retains all past observations, which a rolling window could omit. The expanding window approach also eliminates the need to specify a fixed rolling window size, which can substantially impact the results in a rolling window scenario.

In order to prioritize the utilization of all available historical information for model learning and parameter estimation throughout the validation process, the expanding window was selected even though a rolling window may be more rapid in adapting to recent structural breaks.

3.4 Evaluation Methods

The forecast errors are measured against three commonly used scale-dependent methods, "Mean absolute error" (MAE), "Root mean squared error" (RMSE), and "Mean absolute percentage error" (MAPE). While MAE is defined as the arithmetic mean of the absolute differences between predicted values $\hat{y}_i$ and observed (actual) values y_i RMSE is defined as the square root of the average of the squared differences between predicted and observed values. MAPE gives an error as a percentage of actual values, which is scale-independent and allows comparing the benchmark on different scales, for example, individual stocks in EUR or USD and indexes using point scales.

Formulas:

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i| \quad (1) \qquad RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2} \quad (2)$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y}_i}{y_i}\right| * 100 \quad (3) \qquad MDA = \frac{1}{n}\sum_{t} 1_{sgn(y_i - y_{i-1} = sgn(\hat{y}_i - y_{i-1}))} \quad (4)$$

Where:

- n is the number of observations,
- y_i is the actual value, and
- $\hat{y}_i$ is the predicted value.

MAE is robust to outliers due to its linear penalty structure, while RMSE is more sensitive to large deviations because of the quadratic penalty. As MAE might be preferable in the presence of outliers or heavy-tailed error distributions, RMSE is beneficial when large errors are undesirable. Therefore, both methods and the percentage value MAPE are used. Mean directional accuracy (MDA) compares the forecast direction (upward or downward) to the actual realized direction.

By providing more reliable price forecasts, a lower MAE can lead to more confident asset allocation and better-timed market entry or exit points, which in turn translate into more dependable risk assessments (e.g., for models such as Value at Risk). This allows portfolio managers to refine their hedging strategies and protect against downside risk more effectively.

A Diebold-Mariano test was used to compare the predictive accuracy of the best-performing ARIMA specification with that of the final LSTM model.

3.5 Classical Method ARIMA

Introduced by Box and Jenkins in 1976, the ARIMA model is still one of the most fundamental approaches to time series forecasting (Stellwagen & Tashman, 2013). This model considers three components, including an autoregressive (AR) term that models the dependence between previous observations, a moving average (MA) term that accounts for past forecast errors, and a differencing (I) process that stabilizes non-stationary time series (Siami-Namini et al., 2018). These models have been widely applied in financial forecasting because of their ability to model linear dependencies within financial time series (Schaffer et al., 2021). However, it still has its limitations. For example, ARIMA usually does not capture the volatility clustering and nonlinear dynamics that are frequently present in financial time series (Petrică et al., 2016). In order to produce a reliable forecast using an ARIMA model, the underlying time series data needs to fulfill two primary assumptions: 1. Stationarity, as the most critical one, and 2. linearity. The latter assumes that the relationship between the time series values can be described as a linear equation. If these prerequisites are not fulfilled, the model appears to fit the historical data well but produces nonsensical or highly inaccurate forecasts.

ARIMA is represented by three parameters: ***p***, ***d***, and ***q***:

- *p*: The number of past values (lags) considered in the AR term.
- *d*: The degree of differencing applied to the data.
- *q*: The number of past forecast errors included in the MA term.

The following sub-chapters describe the selection of the parameters:

- Data stationarity checks and, if required, differencing to achieve stationarity. Confirmation with ADF.
- The autocorrelation analysis (ACF/PACF) for initial p/q identification and the brute-force search for the best AIC are further described in the next section. Confirmation with Ljung-Box Test.

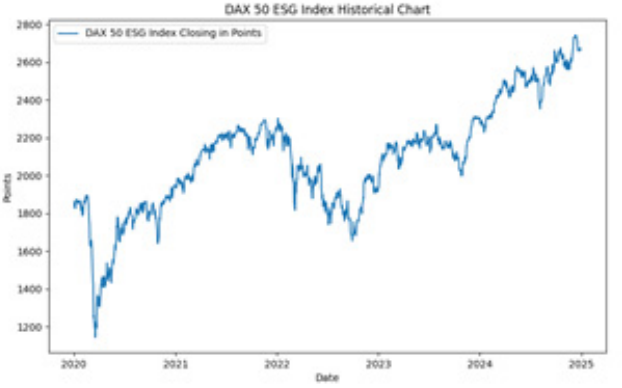
3.5.1 ARIMA Parameter selection (p, d, q) AIC/BIC

3.5.2 Stationary Checks (parameter d)

Using the ARIMA model requires the underlying time series to be stationary, the mean and variance to remain constant over time, and the autocovariance to be solely determined by the lag between observations rather than the actual time they occur.

Figure 1 shows the DAX 50 ESG Index over the observed period, showing a clear upward trend.

Figure 1: DAX 50 ESG Index Chart



Source: DAX

A standard statistical test, Augmented Dickey-Fuller (ADF), can be applied to validate the assumption of non-stationarity in this time series. ADF evaluates whether a time series satisfies the stationarity requirement by setting the null hypothesis that a unit root is present in the series, which would suggest non-stationarity. ARIMA modeling is validated by a significant test result, which indicates that the series is stationary, thereby rejecting the null hypothesis.

Table 1: Augmented Dickey-Fuller (ADF) Test on non-transformed data

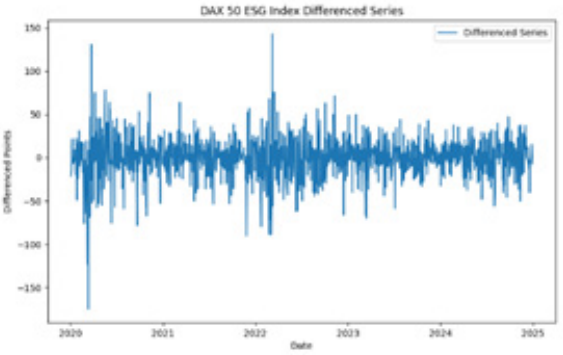
Parameter	Value
ADF Test Statistic:	-0.9954
p-value:	0.75494
Critical value (1%):	-3.4340
Critical value (5%):	-2.8631
Critical value (10%):	-2.5676

Source: Author

As shown in Table 1, Augmented Dickey-Fuller (ADF) Test on non-transformed data, the null hypothesis can not be rejected. Therefore, the time series is considered **non-stationary**.

The series requires transformations such as logarithmic scaling or differencing to stabilize its mean and variance before model fitting.

Figure 2: DAX 50 ESG Index after differencing



Source: DAX

After differencing the time series (see Figure 2) once, Table 2 shows the ADF test results, which allow the rejection of the null hypothesis and confirm the **stationarity** of the time series.

Table 2: Augmented Dickey-Fuller (ADF) Test on transformed data

Parameter	**Value**
ADF Test Statistic:	-14.9966
p-value:	0.00000
Critical value (1%):	-3.4340
Critical value (5%):	-2.8631
Critical value (10%):	-2.5676

Source: Author

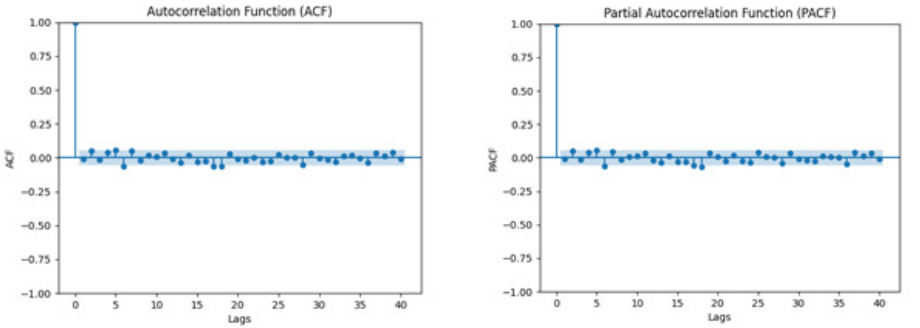
3.5.3 Autocorrelation (Parameter p and d)

Auto-correlation function (ACF) (see Figure 3) and partial autocorrelation function (PACF) (see Figure 4) plots can be a helpful tool to visually confirm the stationarity and select ARIMA model parameters, especially the autoregressive (AR) order.

ACF (Autocorrelation Function): Helps determine *q*, the number of past forecast errors to include. Significant spikes in the ACF plot determine *q* value of ARIMA.

PACF (Partial Autocorrelation Function): Helps determine *p*, the number of lagged observations to consider. Significant spikes in the PACF plot can identify *p* value of ARIMA.

Figure 3: ACF Plot on stationary time series **Figure 4:** PACF Plot on stationary time series



Source: Author

The results of ACF/PACF do not show any significant lags visually. Therefore, further statistical test is required to confirm the white noise property.

Models using higher ARIMA parameters are generally more likely to be overfitted.

By iterating through all combinations of *p*, *q*, and *d* for values <= 100, the ARIMA(10,1,1) model achieved the lowest Akaike Information Criterion (AIC) value of the evaluated ARIMA models. AIC is a metric that can be used in model selection to assess the trade-off between model complexity and its model fit. It achieves this by penalizing models with a higher number of parameters. A lower AIC indicates that the model obtains a more balanced representation of the data, providing a more concise yet practical representation. As a result, the ARIMA(5,1,1) model was chosen as the most suitable option for forecasting in this investigation.

In addition, the following common ARIMA parameter combinations are used as well: ARIMA(0,1,0) (Random walk), ARIMA(1,1,0), ARIMA(0,1,1), ARIMA(1,1,1) and ARIMA(5,1,1).

Table 3: Ljung-Box Test Results

Lag	Ljung–Box Statistic	p-value
10	16.249	0.0927
20	28.476	0.0986

Source: Author

As expected, differentiated stock data (or, in this case, combined stock data within an index) looks like white noise, which indicates an efficient market.

The Ljung–Box Test (LJUNG & BOX, 1978) is a portmanteau test, that checks whether the time series has statistically significant autocorrelation. The null hypothesis states that the data is not correlated (i.e., the population from which the sample is taken is 0, so any observed data correlations result from the sampling process's randomness). The results are shown in Table 3 Ljung-Box Test Results confirm the assumption that there is no significant autocorrelation within the observed data ($p>0.05$), which is suitable for the selected ARIMA configuration. The other ARIMA configurations in scope resulted in significant autocorrelation ($p<0.05$), suggesting the potential for model misspecification.

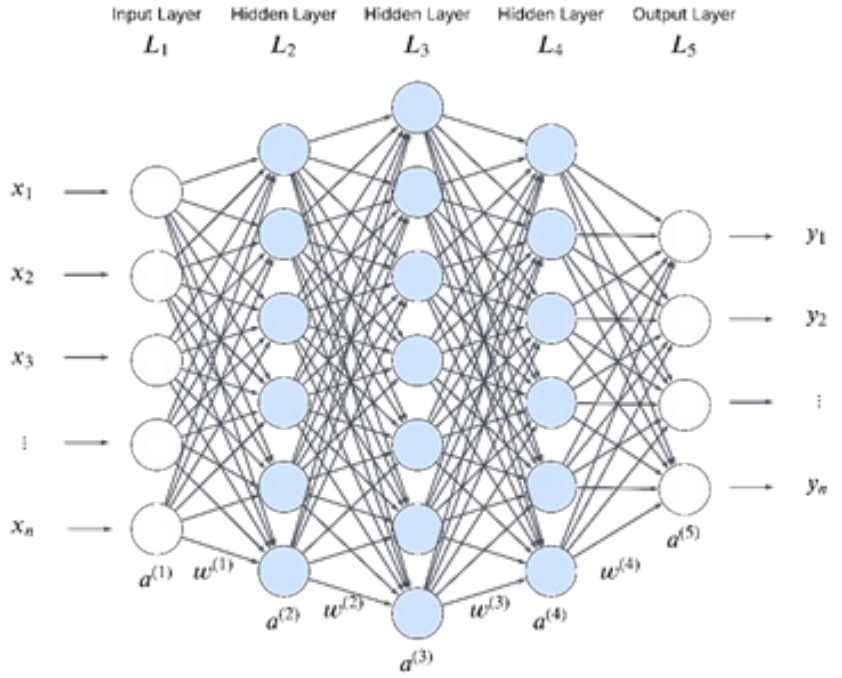
Given the limitations of classical models, researchers have turned to machine learning.

3.6 Machine Learning: LSTM Model

Machine learning (ML) is a subfield of artificial intelligence (AI) that enables computers and machines to mimic human learning, perform tasks autonomously, and enhance their performance and accuracy through experience and exposure to more data.

Artificial neural networks (ANNs) are algorithms whose architecture is inspired by the functioning of the human brain in the broadest sense. They consist of interconnected nodes that, depending on the flow of information, either fire a signal or not. In ANNs, these nodes—also called neurons—are arranged in layers. There are input, output, and hidden layers.

Figure 5: Deep Feedforward Neural Network



Source: Own illustration based on Alzubaidi, L. et al., 2021

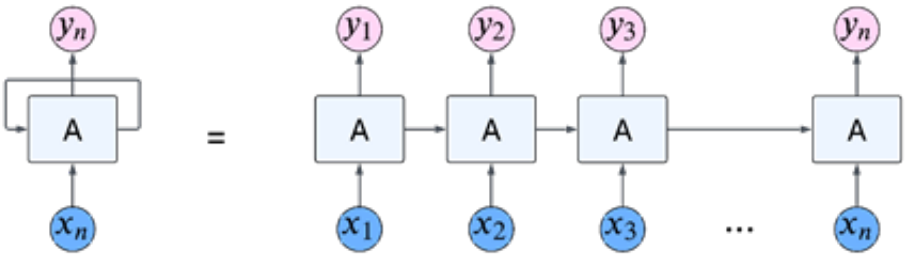
Each layer L_n can have several nodes *a*, also called neurons, connected to the previous and subsequent layers' nodes. Each connection has an associated weight w and threshold. If the output of any individual node is above the specified threshold value, that node is activated, sending data to the next layer of the network. Otherwise, that node passes no data to the next network layer. Combining multiple hidden layers and giving the neural network some depth is generally called a "deep" neural network.

The adjustment of the weights is referred to as "training." When data is processed through the network (forward propagation), the output error - the difference between the network output and the actual output - is computed in a loss function. The error is distributed backward (backpropagation) through the network and provides each neuron in the network with a measure of its contribution to the total error. The aim of training a network is to reduce the error. As a result, ANNs can approximate complex nonlinear mappings and have been successfully applied to tasks such as pattern recognition, predictive modeling, and control systems. ANNs are generally trained with supervised learning using the backpropagation algorithm, which calculates the gradient of a loss function for each weight and updates the weights iteratively to reduce the error. Supervised machine learning uses labeled datasets to train algorithms to classify data accurately or predict outcomes accurately. As input data is fed into the model, the model adjusts its weights until it has been fitted appropriately.

Supervised learning solves real-world problems, such as classifying spam or detecting handwritten text. Some methods used in supervised learning include neural networks, Naïve Bayes, linear regression, logistic regression, random forest, and support vector machine (SVM).

Recurrent neural networks (RNNs) are a class of ANNs designed to process sequential data, such as text, speech, or time series. Unlike common ANNs, which process inputs independently, RNNs have recurrent connections, where the output of a neuron at one-time step is fed back as input to the network at the next step. This architecture enables RNNs to capture temporal dependencies and patterns within the network, maintaining a "hidden state," which acts as memory. RNNs are often displayed compactly, corresponding to an unrolled representation (see Figure 6, left the compact way, right the unfolded/unrolled forward pass).

Figure 6: Recurrent Neural Network (RNN) unrolled

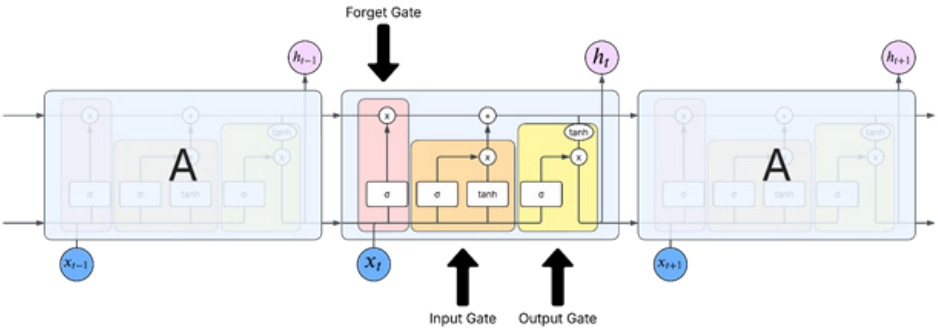


Source: Own illustration based on concepts of Hochreiter and Schmidhuber, 1997

However, traditional RNNs suffer from vanishing and exploding gradient problems, which limits their ability to learn long-range dependencies.

In 1997, the long short-term memory (LSTM) architecture was developed to address this issue, making it the standard RNN variant for handling long-term dependencies (Hochreiter & Schmidhuber, 1997).

Figure 7: LSTM Gates



Source: Own illustration based on concepts of Hochreiter and Schmidhuber, 1997

LSTM blocks consist of three different gates (see Figure 7):

1. Input gate – Determines which value from the input should be considered in the memory (using a sigmoid activation function σ).

2. Forget gate – Defines what information should be discarded from the memory (using a sigmoid activation function σ).

3. Output gate – Combines the input and the memory of the LSTM block. The sigmoid function σ decides which value is used as output, and the *tanh* function is the weighted level of importance of that output.

Each LSTM block is then again connected to the next LSTM block.

3.6.1 LSTM Data Preprocessing

For LSTM Networks, the data needs to be preprocessed with a MinMaxScaler to fit the full bandwidth of the closing prices within the range of 0 and 1. If using multiple variables, scaling ensures that features with larger values do not dominate the learning process.

In this case study, only the closing price is used in the network input; however, it is also required for the network activation functions and to enhance the overall training performance. First, the dataset was partitioned into a training set and a test set. A MinMaxScaler object was then fitted exclusively to the training data. This step calculates

the minimum and maximum values necessary for scaling based solely on the training data. The already-fitted scaler was then used to transform the training data. Crucially, the same scaler was also used to transform the test data, ensuring that the scaling of the test set was based entirely on information from the training set, thereby preventing data leakage. This is required for a valid and unbiased evaluation.

3.6.2 Hyperparameter Tuning

Hyperparameters are model-specific parameters that need to be set before training the model's weights and can significantly influence the model's learning process and performance.

In this case study, the hyperparameters for the LSTM model were tuned using the Python Keras Tuner library, specifically employing the Random Search strategy (see chapter Reproducibility for tuning parameters and software versions used).

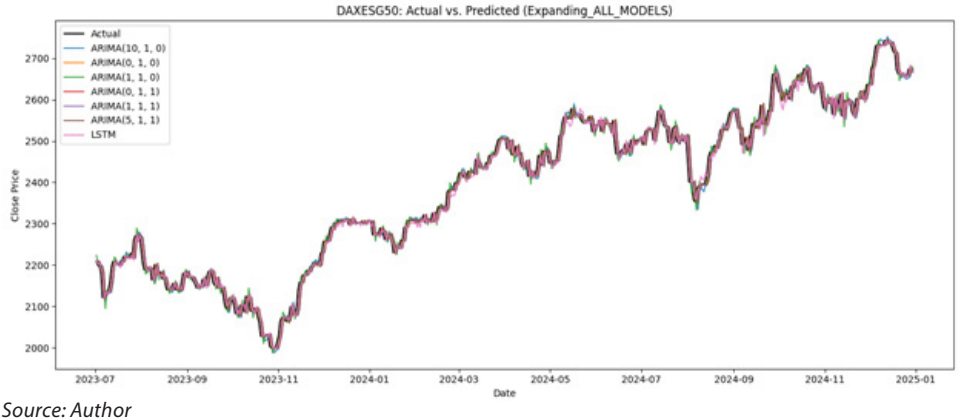
The Random Search was configured to run for 100 trials (LSTM_TUNER_TRIALS = 100), with each trial training for a maximum of 200 epochs (LSTM_TUNER_MAX_EPOCHS = 200). An early stopping mechanism with a patience of 5 epochs (LSTM_TUNER_PATIENCE = 5) was implemented to halt training for any given trial if the validation loss did not improve, preventing wasted computation on unpromising configurations. The search aimed to find the best combination of the number of LSTM units, the learning rate for the Adam optimizer, and the dropout rate. Interestingly, the automated tuning process did not identify a parameter set that significantly outperformed a standard default configuration on the validation set. Therefore, the final model was constructed using the parameters that yielded the most stable and effective performance.

4 Results

The "Best ARIMA" order (p, q) via the Python library auto_arima, based on minimizing the AIC, resulted in ARIMA(0,1,1).

The final LSTM model, consisting of an LSTM layer with 50 units followed by a dense output layer, is trained using a batch size of 32 and early stopping to prevent overfitting. Training continues for up to 200 epochs, monitored via a validation split of 15%, with patience set at four epochs to halt training when improvement stalls.

Figure 8: Forecast Comparison of Expanding Window of all Models



Source: Author

The analysis was performed on the daily closing prices of the DAXESG50 index, including 1825 observations. Initial time series analysis confirmed non-stationarity via the Augmented Dickey-Fuller (ADF) test (p=0.755), necessitating first-order differencing (d=1) to achieve stationarity (ADF p<0.001). Several ARIMA(p, 1, q) models were evaluated against a Long Short-Term Memory (LSTM) network using both a standard Train-Test Split (80%/20%) and an Expanding Window (70% initial train, 30% test with retraining) validation approach.

Among the evaluated ARIMA specifications, the ARIMA(0, 1, 1) model yielded the lowest Mean Absolute Error (MAE) on the out-of-sample test set in the Split validation (MAE = 145.91) and was selected as the benchmark ARIMA model ('Best_ARIMA'). Ljung-Box tests on the residuals of most ARIMA models fitted to the training data indicated remaining autocorrelation (p<0.05), suggesting potential for model misspecification. However, ARIMA(5,1,1) did show statistically insignificant autocorrelation (p>0.05). For the LSTM, automated hyperparameter tuning did not identify parameters superior to the defaults; thus, a final model with 50 LSTM units, no dropout, and a learning rate of 1×10^{-3} was trained (min. validation MSE= 1.5×10^{-4}).

In the Train-Test Split evaluation, the LSTM achieved substantially lower forecast errors (MAE: 12.32 vs. 145.91; RMSE: 16.93 vs. 166.22; MAPE: 0.49% vs. 5.70%) compared to the ARIMA(0, 1, 1). Directional Accuracy (DA) was similar (LSTM: 36.81%, ARIMA: 36.54%).

Under the more rigorous Expanding Window validation, which involved retraining both model types periodically (ARIMA at every step, LSTM every step for five epochs), the LSTM maintained its advantage, though with a smaller margin for ARIMA errors compared to the split results (LSTM MAE: 12.66 vs. ARIMA MAE: 15.46; LSTM RMSE: 17.12 vs. ARIMA RMSE: 22.02; LSTM MAPE: 0.53% vs. ARIMA MAPE: 0.65%). LSTM again showed slightly better Directional Accuracy (34.19% vs. 33.27%).

The Diebold-Mariano test results confirmed that the superior predictive accuracy of the LSTM model compared to the Best_ARIMA was statistically significant ($p < 0.001$)

under both the Split (DM statistic = 32.30) and Expanding Window (DM statistic = 4.89) frameworks.

Table 4: Empirical Results of compared forecast methods and validation methods

Model	**Validation Method**	**MAE** [Index Points]	**RMSE** [Index Points]	**MAPE** [%]	**Directional Accuracy** [%]
ARIMA(0, 1, 0)	Expanding Window	9,8141	15,1440	0,4110	43,6929
ARIMA(0, 1, 1)		15,4632	22,0198	0,6490	33,2724
ARIMA(1, 1, 0)		14,2671	18,9889	0,5986	35,8318
ARIMA(1, 1, 1)		15,6808	22,3392	0,6582	36,3803
ARIMA(10, 1, 0)		16,1193	21,9944	0,6760	36,3803
ARIMA(5, 1, 1)		15,8936	22,3449	0,6670	35,8318
Best_ARIMA		15,4632	22,0198	0,6490	33,2724
LSTM		12,6630	17,1242	0,5291	34,1865
ARIMA(0, 1, 0)	Split Dataset	201,2446	228,9584	7,8566	30,2198
ARIMA(0, 1, 1)		145,9097	166,2172	5,7002	36,5385
ARIMA(1, 1, 0)		201,2446	228,9584	7,8566	30,2198
ARIMA(1, 1, 1)		146,1120	166,4455	5,7080	36,5385
ARIMA(10, 1, 0)		155,9145	177,5403	6,0895	36,8132
ARIMA(5, 1, 1)		146,9816	167,4292	5,7419	36,8132
Best_ARIMA		145,9097	166,2172	5,7002	36,5385
LSTM		12,3228	16,9290	0,4900	36,8132

Source: Author

4.1 Discussion

The results indicate that the LSTM network effectively captured the underlying temporal dependencies of the DAXESG50 index data over the examined period (2020-2024), resulting in significantly more accurate point forecasts than the traditional ARIMA approach. The LSTM's potential to leverage nonlinear patterns that ARIMA models, which rely on linear relationships and autocorrelation structures, may fail to capture properly is shown by the substantial error reduction observed, particularly in the static Train-Test split. This interpretation is further supported by ARIMA models encountering residual autocorrelation difficulties.

The LSTM maintained a statistically significant advantage, even though the performance gap narrowed under the more realistic adaptive Expanding Window scenario. ARIMA benefited from frequent retraining, significantly reducing its error compared to its Split performance. This implies that the LSTM's inherent architecture is a superior fit for this financial time series, even when both models adjust to new data. The low Directional Accuracy figures (approximately 33-37%) for both models suggest that accurately predicting the direction of the next day's price movement remains a highly challenging task, even when point forecast errors (such as MAE/RMSE) are reduced.

Several studies have claimed to successfully attempt linear time series forecasts with ARIMA on stocks while using different underlying stock prices, indices, and periods (e.g. (A. Adebiyi et al., 2014; A. A. Adebiyi et al., 2014; Mondal et al., 2014; tri wahyudi, 2017)).

In this case study, it was shown in the example of the DAX ESG index as a representative of a highly liquid market that any (linear) predictable patterns in historical data, such as those considered by an ARIMA model, can not be used to forecast the market. Otherwise, market participants would rapidly exploit this, leaving little to no systematic opportunity for forecasting.

LSTM's ability to capture nonlinear patterns gave it a modest improvement. However, the improvement is limited, which also aligns with the idea that most patterns are arbitraged away in liquid markets.

The findings suggest that basic time series forecasting techniques are unlikely to produce consistent profits in highly liquid, efficient markets. The risk of overfitting, the random walk behavior of prices, and the rapid incorporation of information render it challenging to forecast future price fluctuations solely based on historical data.

In summary, the LSTM model provided better forecasts than ARIMA for the DAX 50 ESG index, but the improvement was incremental rather than transformative, reinforcing the notion that these advanced models, while helpful, do not completely overcome market efficiency.

Integrating complex machine learning models may marginally enhance forecast accuracy; however, investors in indices such as the DAX 50 ESG should not expect substantial

arbitrage profits solely from historical-data-based models. Instead, the focus could be on alternative data or fundamental ESG developments.

Although high-frequency trading (HFT) and advanced techniques may exploit extremely short-term market imperfections (milliseconds or microseconds), these are not within the scope of conventional time series analysis and do not provide evidence against the general principle of market efficiency. Consequently, investors in efficient markets are more likely to succeed by emphasizing portfolio diversification, risk management, and fundamental analysis.

4.2 Future Directions

Neural Networks in hybrid models combined with ARIMA often outperform standalone ARIMA models, especially in handling nonlinear data (Babu & Reddy, 2014; Jin et al., 2023; Zhang, 2003). However, combining multiple ANNs with so-called "Ensemble Models" also showed promising results.

Studies showed combining LSTM with attention mechanism – specific neural network architectures that enable the model to focus on specific parts of its input data—often a sequence—when predicting an output (Bahdanau et al., 2016; Wen & Li, 2023).

Since its invention in 1997, several minor modifications have been made to the original LSTM. In 2014, Cho et al. (2014) proposed another type of recurrent network, called gated recurrent units (GRUs), which works slightly differently from LSTM but has similar capabilities. While GRUs are generally faster and easier to run but less expressive, according to Chung et al. (2014). These effects cancel out in practice, and GRUs can outperform LSTMs when extra expressiveness is not required.

In recent years, Transformers, which rely on self-attention mechanisms instead of recurrence, have become the dominant architecture for many sequence-processing tasks, particularly in natural language processing. Nevertheless, RNNs remain relevant for applications where computational efficiency, real-time processing, or the inherent sequential nature of data is crucial.

While LSTM has its limitations in handling complex, multi-modal data and long-range dependencies, researchers created an entirely new scientific area of research opportunities in the area of foundation models.

With the launch of ChatGPT by OpenAI in November 2022, the incredible success of "artificial intelligence" started. This success was driven by breakthroughs in foundation models – large-scale neural networks pre-trained on massive, diverse datasets – enabled by the vast amount of available data, fast computing hardware, reduction in data storage, and new methods.

Its success stems from a confluence of technological innovation, strategic design choices, and societal readiness for human-AI interaction, enabled by making ChatGPT free to

public access allowing non-experts to interact with cutting-edge AI. Its ability to assist with tasks like essay writing, coding, or brainstorming made it a "Swiss Army knife" tool. Earlier chatbots (e.g., ELIZA, Siri) were brittle and scripted. ChatGPT's contextual awareness – remembering prior dialogue turns and adapting tone – created an illusion of "understanding," enhancing user engagement.

Other companies also created their Large Language Models (LLMs), like BERT by Google (Devlin et al., 2019) , Claude by Anthropic (*The Claude 3 Model Family*, n.d.) or LLaMA by META (*The Claude 3 Model Family*, n.d.).

These LLMs are trained on broad data at scale (text, images, etc.) that can be adapted ("fine-tuned") to downstream tasks. They derive power from transfer learning: pre-training captures universal patterns (e.g., grammar, causality), which are then specialized for specific uses.

While these LLMs have advanced capabilities to surpass traditional sentiment analysis methods, such as the Loughran-McDonald dictionary model, in predicting and explaining stock returns (Kirtac & Germano, 2024), they are not suited for time series forecasting, as shown by several studies (Cao & Wang, 2024; Tan et al., 2024; Zhou & Yu, 2024).

It needs to be determined if newer architectures (such as attention-based models or Transformers) to determine if they can further improve forecast accuracy for ESG indices.

Funding

The result was created through solving the student project "Wireless networks security focusion on IoT" using objective oriented support for specific university research from the University of Finance and Administration, Prague, Czech Republic.

References

1-DAX 50 ESG (DAXESGK) (DE000A0S3E04). (2025, February 10). STOXX. https://stoxx.com/index/daxesgk/

Adebiyi, A. A., Adewumi, A. O., & Ayo, C. K. (2014). Comparison of ARIMA and Artificial Neural Networks Models for Stock Price Prediction. *Journal of Applied Mathematics*, 2014(1), 614342. https://doi.org/10.1155/2014/614342

Adebiyi, A., Adewumi, A., & Ayo, C. (2014, March 26). *Stock price prediction using the ARIMA model*. Proceedings - UKSim-AMSS 16th International Conference on Computer Modelling and Simulation, UKSim 2014. https://doi.org/10.1109/UKSim.2014.67

AI in FinTech Market Size, Trends and Global Forecast To 2032. (2023, March 17). https://www.thebusinessresearchcompany.com/press-release/ai-in-fintech-market-2023

Alamu, O. S., & Siam, M. K. (2024). Stock Price Prediction and Traditional Models: An Approach to Achieve Short-, Medium- and Long-Term Goals. *Journal of Intelligent Learning Systems and Applications*, 16(04), 363–383. https://doi.org/10.4236/jilsa.2024.164018

Alzubaidi, L., Zhang, J., Humaidi, A. J., Al-Dujaili, A., Duan, Y., Al-Shamma, O., Santamaría, J., Fadhel, M. A., Al-Amidie, M., & Farhan, L. (2021). Review of deep learning: Concepts, CNN architectures, challenges, applications, future directions. *Journal of Big Data*, 8(1), 53. https://doi.org/10.1186/s40537-021-00444-8

Apte, M., & Haribhakta, Y. (2024). *Advancing Financial Forecasting: A Comparative Analysis of Neural Forecasting Models N-HiTS and N-BEATS* (No. arXiv:2409.00480). arXiv. https://doi.org/10.48550/arXiv.2409.00480

Asaad, Z. A., & Omer, B. M. R. (2024). Random walk tests for the MENA stock returns. *Journal of Enterprise and Development*, 6(2), 324–334. https://doi.org/10.20414/jed.v6i2.9819

Babu, C. N., & Reddy, B. E. (2014). A moving-average filter based hybrid ARIMA–ANN model for forecasting time series data. *Applied Soft Computing*, 23, 27–38. https://doi.org/10.1016/j.asoc.2014.05.028

Bahdanau, D., Cho, K., & Bengio, Y. (2016). *Neural Machine Translation by Jointly Learning to Align and Translate* (2728171). INSPIRE. https://doi.org/10.48550/arXiv.1409.0473

Beatty, J., & Sundkvist, S. (2024). *Comparative Analysis of Tree-Based Methods for Predictive Modeling*. https://urn.kb.se/resolve?urn=urn:nbn:se:umu:diva-226745

Bhowmik, R., & Wang, S. (2020). Stock Market Volatility and Return Analysis: A Systematic Literature Review. *Entropy, 22*(5), Article 5. https://doi.org/10.3390/e22050522

Cao, R., & Wang, Q. (2024). *An Evaluation of Standard Statistical Models and LLMs on Time Series Forecasting*. https://doi.org/10.48550/ARXIV.2408.04867

Chen, Z. (2023). *Predicting S&P 500 ESG Index Trends with LSTM and ARIMA Models*. https://www.semanticscholar.org/paper/Predicting-S%26P-500-ESG-Index-Trends-with-LSTM-and-Chen/5d4b6d2b45d498ca4229fa6bb257dfbb6f7d2d8c

Chung, J., Gülçehre, Ç., Cho, K., & Bengio, Y. (2014). Empirical evaluation of gated recurrent neural networks on sequence modeling. *ArXiv, abs/1412.3555, null*.

Danila, N. (2022). Random Walk of Socially Responsible Investment in Emerging Market. *Sustainability*, 14(19), Article 19. https://doi.org/10.3390/su141911846

Devlin, J., Chang, M.-W., Lee, K., & Toutanova, K. (2019). *BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding* (2727118). INSPIRE. https://doi.org/10.48550/arXiv.1810.04805

Dsouza, J. J., & Mallikarjunappa, T. (2015). Do the Stock Market Indices Follow Random Walk? *Asia-Pacific Journal of Management Research and Innovation, 11*(4), 251–273. https://doi.org/10.1177/2319510X15602969

Gregory, R. P. (2021). Market Efficiency in ESG Indexes: Trading Opportunities. *The Journal of Impact and ESG Investing, 1*(4), 72–82. https://doi.org/10.3905/jesg.2021.1.016

Hochreiter, S., & Schmidhuber, J. (1997). Long Short-Term Memory. *Neural Comput*., 9(8), 1735–1780. INSPIRE. https://doi.org/10.1162/neco.1997.9.8.1735

Jin, Y.-C., Cao, Q., Wang, K.-N., Zhou, Y., Cao, Y.-P., & Wang, X.-Y. (2023). Prediction of COVID-19 Data Using Improved ARIMA-LSTM Hybrid Forecast Models. *IEEE Access, 11*, 67956–67967. https://doi.org/10.1109/ACCESS.2023.3291999

Kirtac, K., & Germano, G. (2024). Enhanced Financial Sentiment Analysis and Trading Strategy Development Using Large Language Models. *Proceedings of the 14th Workshop on*

Computational Approaches to Subjectivity, Sentiment, & Social Media Analysis, 1–10. https://doi.org/10.18653/v1/2024.wassa-1.1

Lakhchini, W., Wahabi, R., & Kabbouri, M. E. (2022). Artificial Intelligence & Machine Learning in Finance: A literature review. *International Journal of Accounting, Finance, Auditing, Management and Economics, 3*(6–1), 437–455. https://doi.org/10.5281/zenodo.7454232

Latif, S., Javaid, N., Aslam, F., Aldegheishem, A., Alrajeh, N., & Bouk, S. H. (2024). Enhanced prediction of stock markets using a novel deep learning model PLSTM-TAL in urbanized smart cities. *Heliyon, 10*(6). https://doi.org/10.1016/j.heliyon.2024.e27747

Ljung, G. M., & Box, G. E. P. (1978). On a measure of lack of fit in time series models. *Biometrika, 65*(2), 297–303. https://doi.org/10.1093/biomet/65.2.297

Mahamat, A. A., Boukar, M. M., Leklou, N., Celino, A., Obianyo, I. I., Bih, N. L., Stanislas, T. T., & Savastanos, H. (2024). Decision Tree Regression vs. Gradient Boosting Regressor Models for the Prediction of Hygroscopic Properties of Borassus Fruit Fiber. *Applied Sciences, 14*(17), Article 17. https://doi.org/10.3390/app14177540

Mondal, P., Shit, L., & Goswami, S. (2014). Study of Effectiveness of Time Series Modeling (Arima) in Forecasting Stock Prices. *International Journal of Computer Science, Engineering and Applications, 4*, 13–29. https://doi.org/10.5121/ijcsea.2014.4202

Nti, I. K., Adekoya, A. F., & Weyori, B. A. (2020). A systematic review of fundamental and technical analysis of stock market predictions. *Artificial Intelligence Review, 53*(4), 3007–3057. https://doi.org/10.1007/s10462-019-09754-z

Petrică, A.-C., Stancu, S., & Tindeche, A. (2016). Limitation of ARIMA models in financial and monetary economics. *Theoretical and Applied Economics*, XXIII(4(609), Winter), 19–42.

Schaffer, A. L., Dobbins, T. A., & Pearson, S.-A. (2021). Interrupted time series analysis using autoregressive integrated moving average (ARIMA) models: A guide for evaluating large-scale health interventions. *BMC Medical Research Methodology*, 21(1), 58. https://doi.org/10.1186/s12874-021-01235-8

Siami-Namini, S., Tavakoli, N., & Namin, A. (2018). A comparison of ARIMA and LSTM in forecasting time series. 2018 *17th IEEE International Conference on Machine Learning and Applications (ICMLA), null*, 1394–1401. https://doi.org/10.1109/ICMLA.2018.00227

Stellwagen, E., & Tashman, L. (2013). ARIMA: The Models of Box and Jenkins. *Foresight: Int. J. Appl. Forecast.*, 28–33.

Suprihadi, E., & Danila, N. (2024). Forecasting ESG Stock Indices Using a Machine Learning Approach. *Global Business Review*, 09721509241234033. https://doi.org/10.1177/09721509241234033

Tan, M., Merrill, M. A., Gupta, V., Althoff, T., & Hartvigsen, T. (2024). *Are Language Models Actually Useful for Time Series Forecasting?* https://doi.org/10.48550/ARXIV.2406.16964

Teles, G., Rodrigues, J. J. P. C., Rabêlo, R. A. L., & Kozlov, S. A. (2021). Comparative study of support vector machines and random forests machine learning algorithms on credit operation. *Software: Practice and Experience, 51*(12), 2492–2500. https://doi.org/10.1002/spe.2842

The Claude 3 Model Family: Opus, Sonnet, Haiku. (n.d.). Retrieved January 23, 2025, from https://www.semanticscholar.org/paper/The-Claude-3-Model-Family%3A-Opus%2C-Sonnet%2C-Haiku/de8ba9b01c9ab7cbabf5c33b80b7bbc618857627

tri wahyudi, S. (2017). The ARIMA model for the Indonesia stock price. *International Journal of Economics and Management, 11*, 223–236.

Wen, X., & Li, W. (2023). Time series prediction based on LSTM-attention-LSTM model. *IEEE Access : Practical Innovations, Open Solutions, 11*, 48322–48331. https://doi.org/10.1109/ACCESS.2023.3276628

Zhang, G. P. (2003). Time series forecasting using a hybrid ARIMA and neural network model. *Neurocomputing, 50*, 159–175. https://doi.org/10.1016/S0925-2312(01)00702-0

Zhou, Z., & Yu, R. (2024). *Can LLMs Understand Time Series Anomalies?* https://doi.org/10.48550/ARXIV.2410.05440

Contact Address

Manuel Rosinus, M.Sc.
University of Finance and Administration
Estonská 500/3
101 00, Prague 10
Czech Republic
(manuel.rosinus@gmail.com)

Reproducibility

The empirical part of this case study was done using Python and the following libraries.

Software versions used:

Python	: 3.12.7
pandas	: 2.2.3
numpy	: 1.26.4
matplotlib	: 3.9.2
seaborn	: 0.13.2
statsmodels	: 0.14.4
pmdarima	: 2.0.4
scikit-learn	: 1.5.2
tensorflow	: 2.18.0
keras	: 3.9.1
keras-tuner	: 1.4.7

Parameters / Assumptions used for LSTM Training:

PYTHONHASHSEED = 42 *# for initialization of weights*
LSTM_RETRAIN_EPOCHS = 10 *# Number of epochs for retraining in expanding window*
LSTM_TUNER_MAX_EPOCHS = 200 *# Max epochs per trial during tuning*
LSTM_TUNER_TRIALS = 100 *# Number of hyperparameter combinations to try*
LSTM_TUNER_PATIENCE = 5 *# Early stopping patience during tuning*
LSTM_FINAL_PATIENCE = 5 *# Early stopping patience during final model training*

Design and Methodology of a Real Estate Fund Index for the Czech Market

ADAM ČERNOHORSKÝ

Abstract

Background: The Czech real estate market has experienced rapid growth in recent years, driven by macroeconomic trends and limited housing supply. Retail investors face increasing barriers to direct property ownership, prompting a shift toward real estate investment funds (REIFs). However, the lack of a standardized performance benchmark hinders market transparency and comparability.

Objective: This study aims to design a dual-index framework to benchmark the performance of Czech real estate investment funds. It investigates how fund structure, size, and investor segmentation affect index behaviour and evaluates the implications of different methodological approaches.

Methods: Two types of indices, arithmetic and NAV-weighted, were constructed separately for retail and qualified investor funds. Data were collected quarterly from 39 real estate funds, with inclusion based on data availability and reporting consistency. Indices were computed using Python-based time-series processing, with quarterly rebalancing and weight capping to reduce concentration risk.

Results: Qualified investor funds achieved higher average returns and exhibited lower performance dispersion. In contrast, retail funds displayed greater heterogeneity, and the weighted index was strongly influenced by a single large, underperforming fund. The arithmetic index proved sensitive to outliers, while the weighted index highlighted capital concentration effects.

Recommendation: Investors and analysts should use both index types for a comprehensive performance view. Policymakers should encourage broader data disclosure and consider the systemic impact of dominant funds on retail benchmarks.

Practical relevance: The indices provide a transparent benchmarking tool for market participants, enabling better performance evaluation and investment decision-making. The framework also supports regulatory efforts to enhance market maturity.

Originality/value: This study is the first to introduce a dual real estate fund index for the Czech market. It provides an analytically sound and practically applicable model for benchmarking performance across investor segments, with methodological insights relevant to other emerging real estate markets.

Keywords

Real Estate, Investment Funds, Market Benchmarking, Czech Capital Market, Index Construction

JEL Codes
R30, C43, G11

DOI
http://dx.doi.org/10.37355/acta-2025/1-04

Introduction

In recent years, the Czech real estate market has undergone a period of robust growth, marked by sustained increases in residential and commercial property prices. Rising demand, limited housing supply, and macroeconomic conditions have contributed to a sharp appreciation in real estate values, rendering direct property acquisition increasingly unattainable for a large segment of the population (Hromada & Krulický, 2021; Crnadak et al., 2025). Retail investors, in particular, face considerable entry barriers due to the high capital requirements associated with property ownership, limited liquidity, and significant transaction costs (Adamuscin, 2010). As a result, alternative vehicles for real estate exposure have gained prominence, with real estate investment funds emerging as a viable and increasingly popular option (Malhotra, 2024).

Real estate investment funds (REIFs) are collective investment vehicles that pool capital from multiple investors to acquire, manage, and operate income-generating properties. These funds offer diversified exposure to real estate markets while mitigating some of the constraints of direct investment. In the Czech Republic, REIFs are primarily structured either for retail investors or for qualified investors, the latter typically subject to fewer regulatory restrictions and capable of employing more sophisticated investment strategies. The key distinction lies in their investor eligibility, reporting obligations, liquidity profiles, and overall risk tolerance. Retail real estate funds are publicly accessible and more conservative by design, while funds for qualified investors may pursue more complex or concentrated positions with higher return potential and associated risks (Kurzrock et al., 2009; Morri & Lee, 2009).

The specific nature of real estate as an asset class further differentiates REIFs from traditional investment funds. Real estate assets are inherently illiquid, long-term in nature, and characterized by valuation opacity and management intensity. These features impact the risk-return profile of REIFs, their reporting dynamics, and the manner in which fund performance should be assessed. Compared to equity or bond funds, where price discovery is near-instantaneous and fully market-based, real estate funds require alternative methods of valuation and benchmarking, particularly in less mature or transparent markets.

Given the wide spectrum of fund structures, investment styles, and risk exposures, evaluating the performance and credibility of individual funds is a non-trivial task for both investors and analysts (MacGregor et al., 2021). One important mechanism that enhances transparency and comparability in financial markets is the use of performance indices (Bolla et al., 2016); Anadu et al., 2020). Market indices serve as neutral, objective benchmarks that help contextualize fund performance, indicate market trends, and support investment decision-making. In this context, a well-constructed index functions not only as a measurement tool but also as a signal of institutional credibility and product quality (Cremers et al., 2016).

Index construction in financial markets follows a range of methodological frameworks. From simple arithmetic averages to more complex capitalization-weighted schemes, the choice of index design significantly influences its representativeness and analytical value. Prominent examples such as the S&P 500, MSCI indices, or FTSE benchmarks demonstrate how different weighting, inclusion criteria, and rebalancing strategies yield distinct index behaviors. In real estate, index design must additionally contend with data limitations, valuation lags, and the heterogeneity of fund structures (Jiang et al., 2015). These factors underscore the necessity of a thoughtful, transparent, and replicable methodology for index construction, especially in the context of emerging markets such as the Czech Republic.

Approaches, such as the use of unweighted arithmetic averages, can lead to distortions, particularly in the presence of outliers or asymmetric return distributions (Rogers et al., 2018). On the other hand, weighted indices, typically based on assets under management (AUM) or net asset value (NAV), can overemphasize the performance of large funds, diminishing the visibility of trends among smaller constituents. Striking a balance between simplicity, fairness, and informational value remains a core challenge in index design, with methodological choices carrying important implications for both market interpretation and investor behavior.

Building on these considerations, this study introduces the Czech Real Estate Fund Index and develops a comprehensive framework for its design, implementation, and interpretation. Specifically, the paper investigates the implications of different index construction techniques and evaluates the performance characteristics of funds segmented by investor type. In this context, the following research hypotheses are formulated:

- **H1**: Real estate investment funds intended for qualified investors exhibit higher average annual returns than those designed for retail investors.

- **H2**: Indexes constructed using arithmetic averages are sensitive to extreme values and may be distorted by outlier performance.

- **H3**: Weighted indices are susceptible to concentration effects, whereby a small number of large funds disproportionately influence overall index performance.

The objective of this paper is to design and analytically validate a transparent methodology for constructing a real estate fund performance index tailored to the Czech investment environment. By establishing a robust benchmarking framework, the study aims to enhance transparency in the Czech REIF market and support more informed investment decisions among both institutional and retail participants.

1 Literature Review

Recent developments in the Czech real-estate market have been characterized by rapid price appreciation and marked regional disparities. District-level evidence links selling prices, rental yields and broader socio-economic indicators, underscoring the heterogeneity of risk–return profiles within the country (Hromada & Krulický, 2021). The Czech residential market also carries a post-transition legacy that shapes both pricing and liquidity. Following the mass privatization of the 1990s, a large share of the housing

stock moved to private ownership at administratively set prices, creating initial price distortions that still echo in regional differentials and supply inelasticity. Empirical work by Égert & Mihaljek (2008) documents how limited new construction, alongside income convergence, has fueled persistent appreciation pressures across Central-European capitals. These structural frictions, small free-float, slow permitting processes and a thin rental segment, translate into pronounced upward rigidity during booms and only muted corrections during downturns, a pattern highly relevant for REIF valuation cycles. At the Visegrad-region scale, inflation has exerted a statistically significant, but not fully explanatory, effect on residential values, confirming the need for richer multivariate tools when modelling Czech price dynamics (Crnadak et al., 2025). International experience further shows that well-designed price indices based on exhaustive transaction data can outperform classical hedonic or repeat-sales measures in detecting speculative pressures (Jiang et al., 2015). Together, these findings justify the construction of a transparent, market-wide benchmark tailored to local institutional realities.

Designing such a benchmark requires sensitivity to the distinctive features of real-estate investment vehicles. Private-equity real-estate funds often deliver higher raw returns for early, smaller vintages but face diminishing performance as fund size and sequence grow (Tomperi, 2010); they also exhibit pronounced exposure to systematic real-estate risk once serial correlation is addressed (Farrelly & Stevenson, 2019). In mixed-asset portfolios, direct real estate dominates at longer horizons, whereas open-end core funds provide liquidity-driven substitutes in the short run (Delfim & Hoesli, 2019). Pension funds worldwide have steadily maintained sizeable real-estate allocations, predominantly private vehicles, yet rising intermediation costs erode net performance (Alexander et al., 2021). Within continental Europe, open-ended German funds show that allocation choices rather than management skill drive the gap between institutional and retail returns (Kurzrock et al., 2009), while Italian evidence highlights the benefits of property-type diversification and active asset management, even over short sample windows (Morri & Lee, 2009). Collectively, these studies warn that any Czech index must separate size effects and structural biases if it is to serve both qualified and retail investors.

The mutual-fund literature paints a similarly complex picture of manager value-added. Early work finds little abnormal performance once sector factors are priced (Lin & Yung, 2004), with later studies documenting style drift towards large-cap growth (Lin & Yung, 2007) and a persistent tendency of investors to chase past winners to their own detriment (Chou & Hardin, 2014). International diversification delivered benefits prior to the global financial crisis but lost its edge thereafter (Shen et al., 2012). More recently, managerial activeness has declined and no longer predicts outcomes (Viktoriya & Nelling, 2020), while robust error-adjusted tests show that many apparent alphas vanish under wild-bootstrap inference (Rogers et al., 2018). Crisis-adjusted analyses reveal that outperformance disappears when 2007–2008 turmoil is included (Kaushik & Pennathur, 2012). Yet selectivity within global real-estate funds still appears to generate economically meaningful gross alpha, although timing skill remains elusive (Kaushik, 2024). Large-sample evidence across U.S. sector funds corroborates the rarity of persistent skill, only a fraction of managers outperform after fees (MacGregor et al., 2021), and even when value is created, it is largely absorbed by expenses (Elyasiani et al., 2022). These insights emphasize the importance of a benchmark that can disentangle genuine skill from artefacts of model specification and error estimation.

Benchmarking frameworks themselves are evolving. ESG considerations now feature prominently in asset-owner mandates, yet industry stakeholders argue that current real-estate benchmarks insufficiently capture measurable sustainability outcomes; improved data granularity and climate-risk metrics are urgently required (Newell et al., 2023). Within REIT-dominated vehicles, dividend yields materially influence mutual-fund allocations (Price, 2011), while real-estate ETFs exhibit period-specific alpha that turns negative under market stress, reflecting high beta to equity factors and limited timing ability (Malhotra, 2024). These patterns highlight the need for Czech indices that can flexibly accommodate alternative weighting schemes, arithmetic for pure performance dispersion and NAV-weighted for capital momentum, without masking structural ESG or liquidity asymmetries.

At a broader market level, the rise of passive investing shapes both fund behavior and systemic risk. Growing commonality in price and liquidity movements has been linked to index-linked strategies across regions (Bolla et al., 2016), and the migration to passive vehicles carries ambiguous implications for financial stability, reducing some redemption risks yet amplifying volatility and concentration (Anadu et al., 2020). Changes in index membership can induce abnormal returns and volumes, the so-called index effect, whose persistence and drivers remain debated (Afego, 2017). Nevertheless, vigorous competition from low-cost index funds pushes active managers toward higher activeness and lower fees where explicit indexing is prevalent (Cremers et al., 2016). These dynamics underscore that any Czech fund index must consider its own potential to influence market structure and investor flows.

Finally, the European regulatory context cannot be ignored. Despite investor appetite, the absence of harmonized REIT legislation constrains cross-border scalability and complicates comparability of fund structures (Adamuscin, 2010). An index that transparently discloses weighting caps, eligibility thresholds and rebalancing rules can mitigate part of this opacity, offering both domestic and foreign investors a credible signal of market maturity.

In sum, prior studies demonstrates substantial variability in real-estate fund performance across segments, geographies and cycles; methodological pitfalls in measuring manager skill; and systemic repercussions of index design itself. Building on these insights, the present study develops a dual-index framework for the Czech market, arithmetic and NAV-weighted, each for retail and qualified funds, to provide a nuanced, policy-relevant benchmark that addresses concentration, outlier sensitivity and transparency requirements identified in the international literature.

2 Data

The data used in this study were obtained directly from individual Czech real estate investment funds. In total, 39 funds were approached, consisting of 21 funds for qualified investors (FQI) and 18 retail real estate funds (FRI). The tables (Table 1; Table 2) presented in this section list all funds that were contacted as part of the data collection process, regardless of whether they are ultimately included in the constructed indices. Each fund was requested to provide quarterly data on two key indicators:

- the number of outstanding shares (units), and
- the price per unit at the end of each quarter.

These two values allow for the calculation of each fund's market capitalization and quarterly performance, which are critical inputs for index construction. The data are collected on a quarterly basis and form the foundation for both the arithmetic and weighted index models presented later in the methodology section.

Not all funds were willing or able to provide complete historical data. Some declined participation, while others had incomplete or inconsistent reporting. Therefore, while Tables 1 and 2 reflect all funds approached during the research, only a subset of these funds meets the eligibility criteria for inclusion in the final index calculation.

In addition to the time-series data used for index calculations, funds were also asked to report their average annual return since inception, calculated in CZK and presented as a per annum (p.a.) figure. This indicator, shown in the tables below, serves as a point of reference for comparing long-term performance between individual funds and the developed benchmark indices.

Table 1: Average Annual Returns of Real Estate Funds for Qualified Investors (in CZK, p.a.)

Fund Name	Average Annual Return Since Inception
Salutem Fund SICAV a.s.	21,80%
Aequitas Capital Investment SICAV a.s.	18,62%
CB Property Investors	15,74%
Expandia Industrial Parks	12,86%
Accolade Fund SICAV plc	11,78%
WOOD & Co. Retail podfond	11,75%
Jet Industrial Lease SICAV, a.s.	11,43%
ESG SeniorCARE SICAV	10,50%
WOOD & Co. Office podfond	10,26%
REALIA Fund Retail Parks	10,00%
Silverline Real Estate	10,00%
Property Fund for Living	9,50%
ZDR Investments SICAV a.s.	8,51%
Max Realitní	8,50%
Fond Českého Bydlení	8,09%
Czech Development Fund SICAV a.s.	7,90%
ČSNF SICAV, a. s.	7,14%
Natland nemovitostní podfond	5,87%
AMBEAT INVEST – II. Realitní podfond	5,79%
EVROPA Investiční Fond, podfond realitní	5,46%
NOVA Real Estate	5,34%

Source: E15, 2025

Table 2: Average Annual Returns of Real Estate Funds for Retail Investors (in CZK, p.a.)

Fund Name	Average Annual Return Since Inception
CREDITAS Nemovitostní I	9,59%
MINT I. rezidenční fond	8,64%
Schönfeld & Co Prémiové nemovitosti	8,50%
ZDR Investments Industrial SICAV a.s.	7,43%
ZDR Investments Public SICAV a.s.	7,41%
WOOD & Company Realitní – OPF	6,41%
Trigea nemovitostní fond	6,37%
INVESTIKA realitní fond	5,89%
Raiffeisen realitní fond	5,40%
IAD Korunový realitní fond	5,06%
ZFP realitní fond	5,05%
Czech Real Estate Investment Fund (CREIF)	4,89%
Fond Realita	4,70%
Fio realitní podfond I.	4,46%
Generali Fond Realit	3,87%
Conseq realitní	3,83%
REICO LONG LEASE	3,79%
REICO NEMOVITOSTNÍ	2,15%

Source: E15, 2025

3 Methodology

The methodology used in this study defines a systematic approach for constructing two complementary indices that track the quarterly performance of Czech real estate investment funds. The first is an arithmetic index, based on equal weighting, and the

second is a weighted index that reflects relative market capitalization. Both indices are calculated using consistent data points provided by individual funds. For computational implementation, the entire index logic is built in Python, using libraries such as NumPy and Pandas, which support the processing of time series data and ensure reproducibility.

To ensure analytical clarity and reflect structural differences in investor eligibility and regulatory oversight, two independent index sets are constructed: one for real estate funds intended for qualified investors (FQI), and one for those designed for retail investors (FRI). Each set consists of two parallel indices, an arithmetic index and a weighted index, calculated using the same methodology but applied separately within each investor category. The base value of each index is set to 100, but the starting period may differ between FQI and FRI indices due to differences in data availability and reporting consistency. However, within each group, both the arithmetic and weighted indices are calculated from the same starting quarter to ensure direct comparability.

A fund is included in the index only if it meets the following conditions:

- It has reported data for at least six consecutive quarters.
- It becomes eligible for inclusion starting from the seventh quarter.
- It continues to report all required data without interruption.

A fund is removed from the index if:

- It fails to report data for a given quarter.
- It becomes closed to new investors.

Additionally:

- Index rebalancing is conducted quarterly (Q1, Q2, Q3, Q4).
- A minimum of five eligible funds is required for index calculation in each quarter.
- In the weighted index, a maximum weight cap of 30% per fund is applied.

The arithmetic index is based on the simple average return of all eligible funds in each quarter, without accounting for fund size. This method is transparent and easy to interpret but may distort market-wide trends when smaller funds experience high volatility. The quarterly return of each fund is calculated using the formula:

$$return_{i,t} = \frac{price_{i,t} - price_{i,t-1}}{price_{i,t-1}}$$

Where:

- $price_{i,t}$ the unit price of fund i at the end of quarter *t*,
- $price_{i,t-1}$ the unit price of fund i at the end of the previous quarter.

The average return for the index in quarter t is then calculated as:

$$average\ return_t = \frac{1}{N_t}\sum_{i=1}^{N_t} return_{i,t}$$

Where:

- N_t the number of funds included in the index during quarter *t*,
- $return_{i,t}$ the quarterly return of fund i as defined above.

The index value is then updated cumulatively over time using the following recursive formula:

$$index_t = index_{t-1} \times (1 + average\ return_t)$$

Where:

- $index_{t-1}$ the index value at the end of the previous quarter,
- $average\ return_t$ the average return for the current quarter.

In contrast to the arithmetic index, the weighted index incorporates market capitalization to reflect the proportional size of each fund. This approach allows larger funds to have a greater influence on the index value and better represents the actual distribution of capital in the market. The initial weight of each fund is calculated based on its NAV as follows:

$$original\ weight_{i,t} = \frac{NAV_{i,t}}{\sum_{j=1}^{N_t} NAV_{j,t}}$$

Where:

- $NAV_{i,t}$ the market capitalization of fund *i* in quarter *t*,
- N_t the number of eligible funds in quarter *t*,
- $\sum_{j=1}^{Nt} NAV_{j,t}$ the total NAV of all eligible funds in that quarter.

If any fund exceeds the maximum allowed weight of 30%, the excess is proportionally redistributed among all funds below the cap according to their original weights. This process produces the final adjusted weights used in the weighted return calculation. The weighted return of the index in quarter *t* is then calculated as:

$$weighted\ return_t = \sum_{i=1}^{N_t} final\ weight_{i,t} \times return_{i,t}$$

Where:

- $final\ weight_{i,t}$ the adjusted weight of fund *i* after applying the weight cap,
- $return_{i,t}$ the quarterly return of fund *i*.

The cumulative index value is then updated with:

$$index_t = index_{t-1} \times (1 + weighted\ return_t)$$

Where:

- $index_{t-1}$ the previous value of the weighted index,
- $weighted\ return_t$ the weighted average return of all included funds.

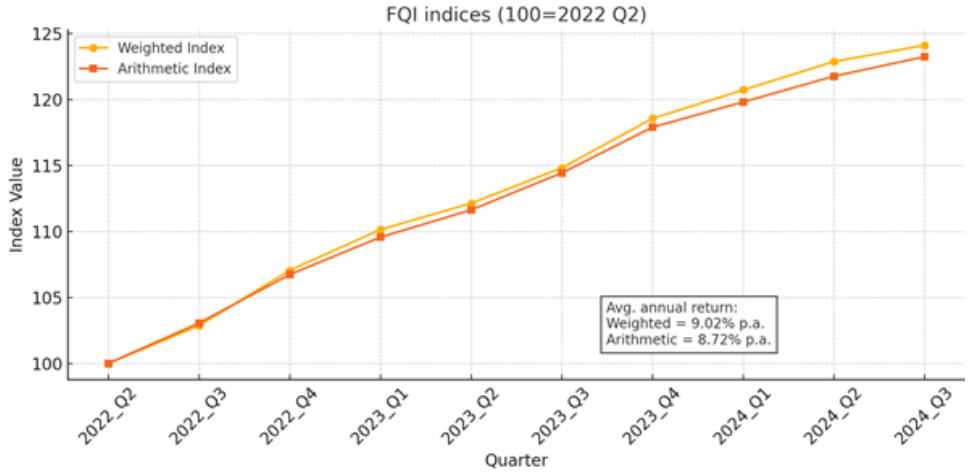
This dual-index approach allows for a balanced view of fund performance: the arithmetic index provides an equal-weighted snapshot of fund returns, while the weighted index reflects the performance of the market based on capital allocation. In the following section, we compare both indices and interpret their implications for market behaviour and investment analysis.

4 Results

This chapter presents the core empirical findings of the study. Based on the methodology and input data described in previous sections, a set of benchmark indices was constructed to reflect the performance of Czech real estate investment funds, segmented into two distinct investor categories: funds for qualified investors (FQI) and funds for retail investors (FRI). For each category, both an arithmetic and a weighted index were calculated. The results are presented in three stages: first, the performance of the indices themselves is analysed; second, the development and distribution of weights among the index constituents in the weighted models is explored; and finally, the performance of individual funds is evaluated relative to their respective benchmark indices.

The first two figures below illustrate the performance of the constructed indices for each investor segment. They track the quarterly evolution of both the arithmetic and weighted indices, thereby offering insight into average market dynamics as well as the influence of fund size. These visualizations serve as a foundational point of reference for the comparative analysis presented in subsequent sections.

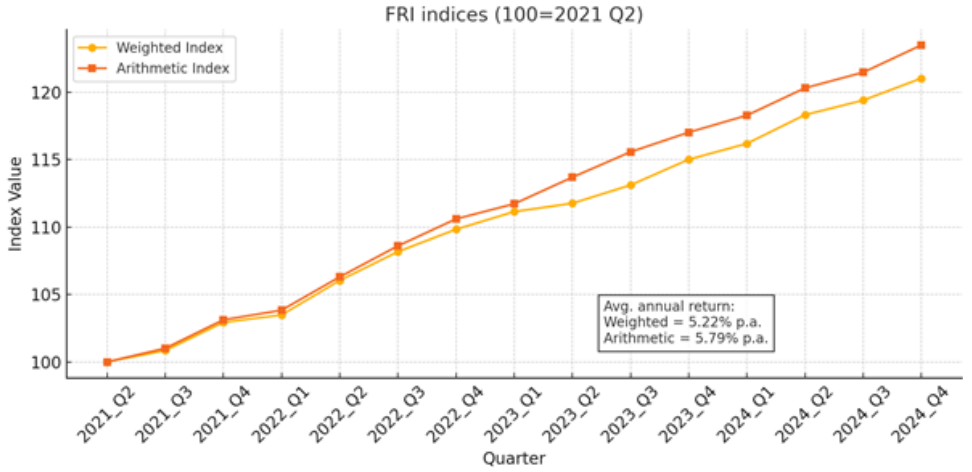
Figure 1: Performance of FQI Indices – Arithmetic and Weighted Index (100 = 2022 Q2)



Sources: Authors own work

Figure 1 presents the time evolution of both the arithmetic and weighted indices for funds serving qualified investors (FQI), starting in 2022 Q2. The trajectories of both indices are nearly identical, indicating that the performance dispersion among constituent funds is relatively limited and that no single fund exerts disproportionate influence. The average annual return of the weighted index is 9.02%, closely followed by the arithmetic index at 8.72%, underscoring the consistency and stability of returns within this fund segment.

Figure 2: Performance of FRI Indices – Arithmetic and Weighted Index (100 = 2021 Q2)



Sources: Authors own work

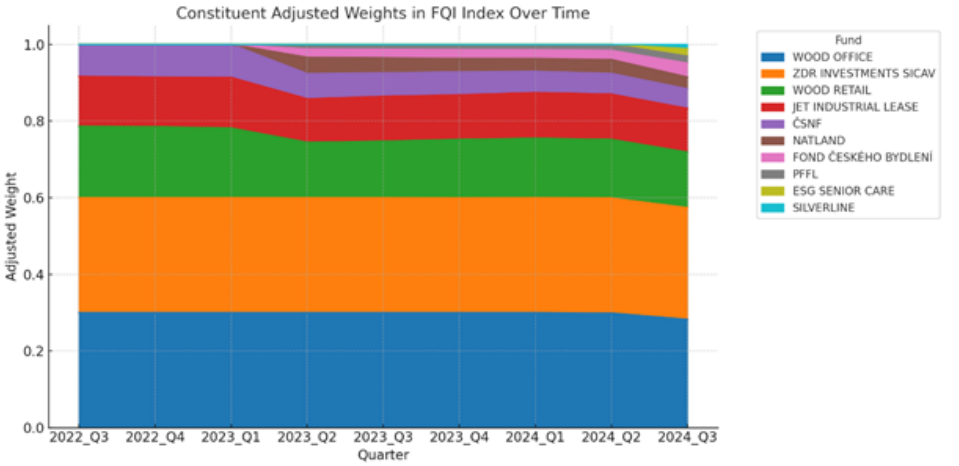
Figure 2 shows the same comparison for funds oriented toward retail investors (FRI), starting in 2021 Q2. In contrast to the FQI segment, the difference between the arithmetic

and weighted indices is more pronounced. While both indices exhibit steady growth over time, the arithmetic index consistently outperforms the weighted version. This divergence suggests a performance imbalance, where smaller funds in the sample have delivered above-average returns but contribute less to the overall market capitalization, thereby having a muted impact on the weighted index. While the divergence is constant through the sample, it widened temporarily in 2020 Q2–2021 Q1, reflecting the pandemic-driven freeze of large retail funds that rely on physical appraisals. The arithmetic index, less exposed to those vehicles, rebounded faster, illustrating how valuation lags amplify size effects under stress.

When comparing the two investor categories, FQI funds exhibit significantly higher performance on average than FRI funds, with average annual returns of approximately 9% compared to less than 6% for retail-oriented vehicles. Moreover, the alignment between arithmetic and weighted indices is tighter in the FQI segment, reflecting a more homogeneous risk-return profile. In contrast, the discrepancy observed in the FRI segment suggests greater heterogeneity and a larger role for fund size in determining index behaviour.

The next two figures present the composition and development of the weighted indices over time. Each figure shows the adjusted weight of each fund that was included in the index at a given quarter. These graphics are essential for understanding the internal structure of the indices and for interpreting the influence of fund size on overall index performance.

Figure 3: FQI Weighted Index Constituents and their Adjusted Weight

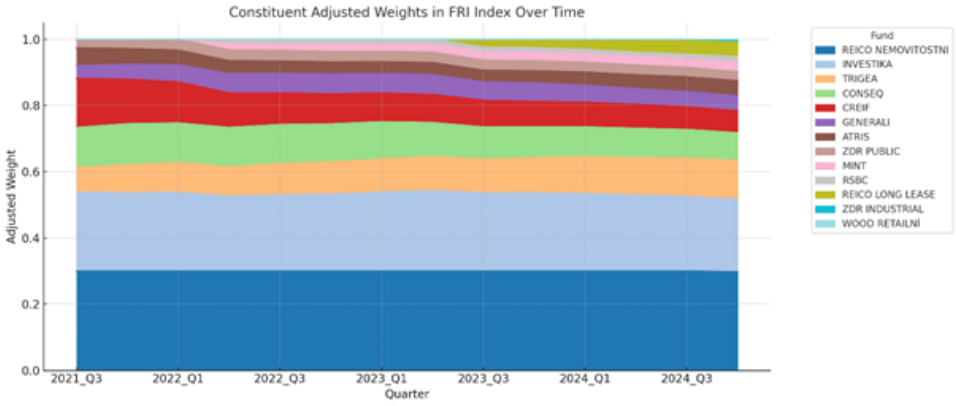


Sources: Authors own work

The construction of the weighted index requires not only fund performance but also relative market size, measured by net asset value (NAV). Figure 3 displays the evolution of individual constituent weights in the weighted index for FQI funds. These charts provide insights into concentration dynamics within the segment. It is evident that two funds (WOOD & Co. Office podfond and ZDR Investments SICAV) together comprise up to 60%

of the total index weight until Q2 2024. Both funds exceeded the 30% maximum cap and were therefore adjusted downward, with the excess weight redistributed among smaller constituents. Despite the capping mechanism, the dominance of capital-heavy funds remains substantial, which has implications for concentration risk and index interpretation.

Figure 4: FRI Weighted Index Constituents and their Adjusted Weight



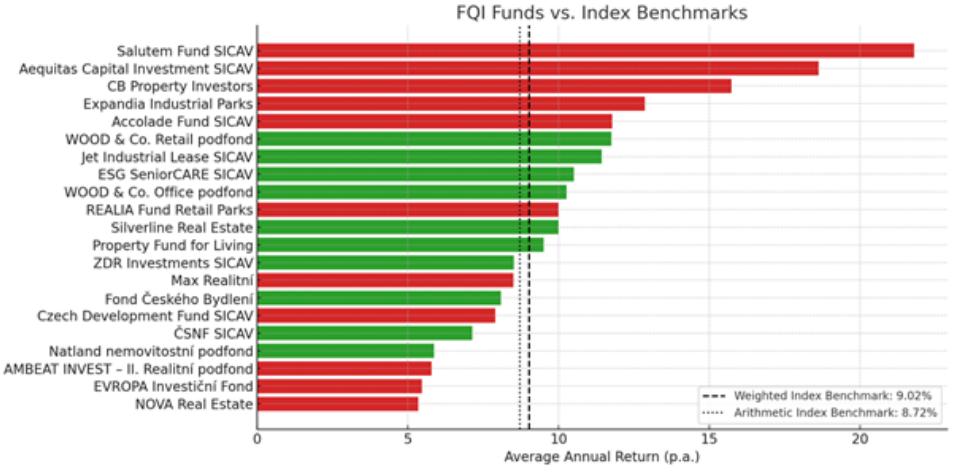
Sources: Authors own work

Figure 4 reveals a more balanced structure among retail funds. While there are fluctuations in individual fund weights, the FRI index appears less concentrated than its FQI counterpart. Nevertheless, REICO NEMOVITOSTNÍ emerges as a dominant fund in this segment, repeatedly surpassing the 30% weight limit and requiring capping. This fund consistently shows the lowest average return among all FRI funds, which strongly pulls down the overall weighted index performance. While more funds are included in the index and the weight distribution is broader, the outsized influence of a single underperforming fund distorts the aggregate signal, especially in comparison with the arithmetic index.

The comparison of weighted index constituents highlights a clear structural divergence. FQI funds tend to be capital-dense and concentrated, where a few major players significantly affect index behaviour. On the other hand, the FRI segment is more fragmented, yet still susceptible to performance distortion when large but underperforming funds dominate index composition. These structural characteristics must be accounted for when interpreting fund performance and benchmarking validity.

The final two figures compare the long-term annualized performance of all funds, whether included in the index or not, against the relevant arithmetic and weighted indices. Funds that have been part of the benchmark at any point are marked in green; all others are shown in red.

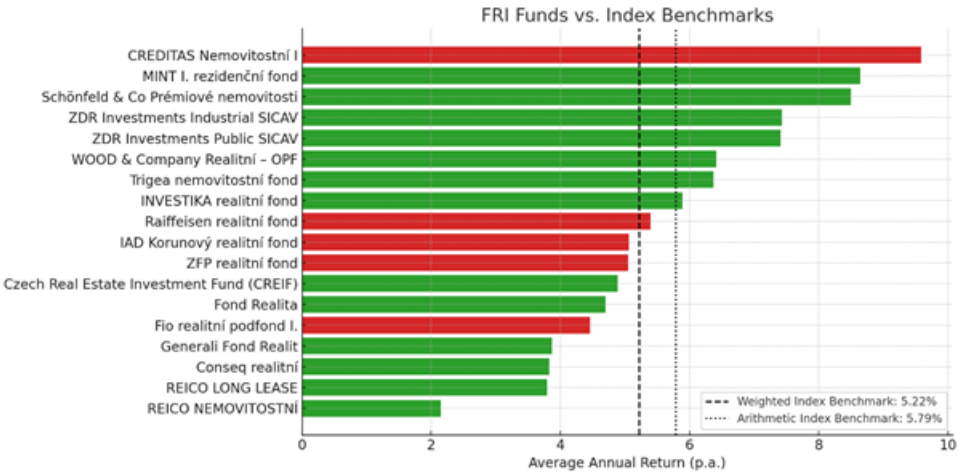
Figure 5: Comparison of Individual FQI Funds with Index Benchmarks



Sources: Authors own work

Figure 5 displays the performance of individual FQI funds relative to the constructed indices. Out of 21 qualified investor funds, 10 were included in the index as of Q3 2024. Most of these indexed funds perform close to or above the benchmark levels. Notably, two outliers (Salutem Fund SICAV and Aequitas Capital Investment SICAV) substantially outperform both indices, confirming the potential for high returns in the FQI segment. However, their exclusion from the benchmark (due to eligibility criteria) highlights the variability and sometimes extreme dispersion of returns within this group, which must be carefully considered when evaluating market performance through an index.

Figure 6: Comparison of Individual FRI Funds with Index Benchmarks



Sources: Authors own work

In the retail segment, 13 out of 18 FRI funds were included in the benchmark by Q4 2024. Figure 6 illustrates that the average return levels are notably lower than those in the FQI segment. Most of the indexed funds cluster tightly around the benchmarks, but the overall dispersion is more pronounced than among FQI funds. A few non-included funds fall well below the index values, reinforcing the rationale behind the inclusion rules. Nevertheless, the overall lower return environment among FRI funds confirms the more conservative and risk-averse profile of this category.

Taken together, the comparison between qualified and retail investor funds reveals a more consistent and concentrated return structure in the FQI segment, contrasted with a more fragmented and lower-return environment in the FRI space. These findings underscore the importance of tailoring index methodology and performance expectations to the structural realities of each investor class.

The empirical results presented above allow for a direct evaluation of the hypotheses defined in the theoretical framework. Each hypothesis was formulated to reflect a specific aspect of real estate fund performance and index construction methodology. By comparing the behaviour of arithmetic and weighted indices across investor segments, and by examining the internal structure of the weighted models and their constituent dynamics, we can critically assess the validity of each hypothesis considering the observed data.

H1 (*Real estate investment funds intended for qualified investors exhibit higher average annual returns than those designed for retail investors*) is strongly supported. The average annualized return of the FQI indices exceeds 9% across both the arithmetic and weighted constructions, whereas the FRI indices report average annual returns below 6%. This performance gap is not only visible at the aggregate index level but is also reflected in individual fund outcomes. As shown in Figure 5, several FQI funds outperform the benchmark, while most FRI funds (Figure 6) cluster closer to or below the retail indices. This consistent divergence confirms the assumption that funds serving qualified investors, benefiting from greater investment flexibility, lower liquidity constraints, and reduced regulatory oversight, can generate higher long-term returns.

H2 (*Indexes constructed using arithmetic averages are sensitive to extreme values and may be distorted by outlier performance*) is validated by the substantial spread between the arithmetic and weighted indices in the FRI segment. While both indices grow steadily over time, the arithmetic index clearly outpaces the weighted one, highlighting the effect of smaller, high-performing funds on the unweighted average. For instance, funds such as MINT I. rezidenční fond and Schönfeld & Co Prémiové nemovitosti, with reported returns above 8.5% p.a., contribute disproportionately to the arithmetic index due to their relatively low NAVs. Their influence is muted in the weighted version, which gives more prominence to large but lower-performing funds such as REICO NEMOVITOSTNÍ. In the FQI segment, the difference between the two indices is minimal, indicating more balanced performance across fund sizes and less distortion in the arithmetic calculation.

H3 (*Weighted indices are susceptible to concentration effects, whereby a small number of large funds disproportionately influence overall index performance*) is also confirmed. The

structure of the FQI weighted index, illustrated in Figure 3, reveals significant concentration in a few capital-dominant funds. Notably, WOOD & Co. Office podfond and ZDR Investments SICAV a.s. together comprised over 60% of the index's total weight for most of the observation period. Although the 30% capping mechanism was applied to limit their influence, the dominance of these two constituents remains substantial. A similar pattern is evident in the FRI segment (Figure 4), where REICO NEMOVITOSTNÍ, despite recording the lowest average return among all retail funds (2.15% p.a.), repeatedly reached the weight cap and therefore strongly dragged down the weighted index. These findings demonstrate that even well-designed capping rules cannot fully eliminate concentration risk in size-weighted benchmarks, especially in markets where capital is unevenly distributed.

In conclusion, the empirical results validate the dual-index benchmarking approach and confirm key distinctions between retail and qualified investor funds. These distinctions have important implications for fund evaluation, market regulation, and investor decision-making. The index framework proposed in this study offers a credible and adaptable foundation for benchmarking performance in the Czech real estate fund sector and can serve as a basis for future refinements and comparative studies.

5 Discussion

The results of this study offer several noteworthy insights into the structure, behaviour, and performance dynamics of real estate investment funds in the Czech Republic. The empirical evidence confirms the importance of segmenting the market by investor type, as substantial differences in returns, volatility, and concentration patterns emerge between funds for qualified and retail investors. The superior performance of FQI funds reflects both their regulatory flexibility and access to more aggressive investment strategies, yet this performance is not uniformly distributed, with notable outliers skewing averages. The strong alignment between the arithmetic and weighted indices within the FQI segment further suggests a relatively homogeneous group in terms of size and return distribution, which enhances the robustness of benchmarking outcomes in this space.

Conversely, the FRI segment exhibits greater dispersion in both fund size and performance, which introduces specific methodological challenges in index construction. The arithmetic index in this group is clearly affected by the high returns of smaller funds, while the weighted index is disproportionately influenced by the underperformance of dominant, capital-heavy funds such as REICO NEMOVITOSTNÍ. This divergence reinforces the theoretical concern that weighting schemes can obscure underlying performance signals, especially when concentration thresholds are repeatedly breached despite capping mechanisms. The results therefore underscore the need for hybrid benchmarking tools that balance simplicity, fairness, and market representativeness.

Beyond methodological validation, the findings have broader implications for investor behaviour and regulatory design. For retail investors, reliance on market-cap-weighted benchmarks may lead to misleading conclusions about sector health, particularly if underperforming giants dominate the narrative. Meanwhile, institutional investors and

policymakers should take note of the high concentration in the FQI space, which may amplify systemic risks in the event of adverse market shocks. Overall, the dual-index framework proposed here demonstrates both its analytical utility and practical relevance in disentangling complex fund performance in a rapidly evolving market environment.

Conclusion

This study set out to design and validate a robust benchmarking framework for real estate investment funds operating in the Czech Republic. In response to increasing investor demand for transparency and comparability, a dual-index model was developed, comprising arithmetic and NAV-weighted indices, separately for retail and qualified investor funds. By systematically collecting and analysing fund-level data, the research provides a nuanced view of market behaviour and confirms the structural differences between investor segments.

The empirical results demonstrate that funds targeting qualified investors consistently deliver higher average returns, supported by greater strategic flexibility and less restrictive regulation. However, they also exhibit concentration risks, as a few large funds dominate capital allocation and index influence. Retail funds, while more diverse in composition, are susceptible to performance distortion when low-yielding, high-AUM funds are overrepresented in weighted benchmarks. The dual-index approach successfully highlights these contrasts and offers a balanced perspective on fund performance, avoiding the biases associated with single-method benchmarks.

Overall, the proposed Czech Real Estate Fund Index contributes to both academic understanding and practical application. It supports investors in making informed decisions, enables analysts to conduct fairer performance comparisons, and provides regulators with a clearer picture of market dynamics. Future research may expand the index framework to include ESG indicators, risk-adjusted performance metrics, or extend coverage to neighbouring markets, thereby enriching the regional benchmarking infrastructure.

Funding

The result was created in solving the student project "Controlling 4.0 - business future" using objective oriented support for specific university research of the University of Finance and Administration. The text allowed setting the parameters for the following research on the project.

References

Adamuscin, A. (2010). Investing in European market real property through REITs. Slovak Journal of Civil Engineering, 18(1), 31. https://doi.org/10.2478/v10189-010-0001-9

Afego, P. N. (2017). Effects of changes in stock index compositions: A literature survey. International Review of Financial Analysis, 52, 228–239. https://doi.org/10.1016/j.irfa.2017.06.004

Alexander, C., Eichholtz, P., & Kok, N. (2021). Three decades of global institutional investment in commercial real estate. Journal of Portfolio Management, 47(10, Special Real Estate Issue), 25–40. https://doi.org/10.3905/jpm.2021.1.275

Anadu, K., Kruttli, M., McCabe, P., & Osambela, E. (2020). The shift from active to passive investing: Risks to financial stability? Financial Analysts Journal, 76(4), 23–39. https://doi.org/10.1080/0015198X.2020.1779498

Bolla, L., Kohler, A., & Wittig, H. (2016). Index-linked investing—A curse for the stability of financial markets around the globe? The Journal of Portfolio Management, 42(3), 26–43. https://doi.org/10.3905/jpm.2016.42.3.026

Chou, W., & Hardin, W. G. (2014). Performance chasing, fund flows and fund size in real estate mutual funds. Journal of Real Estate Finance and Economics, 49(3), 379–412. https://doi.org/10.1007/s11146-013-9444-x

Cremers, M., Ferreira, M. A., Matos, P., & Starks, L. (2016). Indexing and active fund management: International evidence. Journal of Financial Economics, 120(3), 539–560. https://doi.org/10.1016/j.jfineco.2016.02.008

Crnadak, O., Černohorský, A., & Petrů, N. (2025). Impact of inflation on residential property prices in the V4 countries. Journal of European Real Estate Research, ahead-of-print. https://doi.org/10.1108/JERER-04-2024-0023

Delfim, J.-C., & Hoesli, M. (2019). Real estate in mixed-asset portfolios for various investment horizons. Journal of Portfolio Management, 45(7, Special Real Estate Issue), 141–158. https://doi.org/10.3905/jpm.2019.45.7.141

E15. (2025). Overview of real estate funds. Czech News Center a.s. https://www.e15.cz/system/obsah-pro-specialy/e15-prehled-nemovitostnich-fondu-1411914

Elyasiani, E., Rytchkov, O., & Stetsyuk, I. (2022). Do real estate mutual fund managers create value? The Quarterly Review of Economics and Finance, 86, 396–406. https://doi.org/10.1016/j.qref.2022.08.007

Égert, B., & Mihaljek, D. (2007). Determinants of house prices in Central and Eastern Europe. Comparative Economic Studies, 49(3), 367–388. https://doi.org/10.1057/palgrave.ces.8100221

Farrelly, K., & Stevenson, S. (2019). The risk and return of private equity real estate funds. Global Finance Journal, 42, 100471. https://doi.org/10.1016/j.gfj.2019.04.005

Hromada, E., & Krulický, T. (2021). Investing in real estate in the Czech Republic and analyzing the dependence of profitability and technical and socio-economic factors. Sustainability, 13(18), 10273. https://doi.org/10.3390/su131810273

Jiang, L., Phillips, P. C. B., & Yu, J. (2015). New methodology for constructing real estate price indices applied to the Singapore residential market. Journal of Banking & Finance, 61(Supplement 2), S121–S131. https://doi.org/10.1016/j.jbankfin.2015.08.026

Kaushik, A. (2024). Do fund managers of global real estate funds exhibit superior skill? Journal of Accounting and Finance, 24(3), 120–133. Retrieved from https://www.proquest.com/scholarly-journals/do-fund-managers-global-real-estate-funds-exhibit/docview/3092052054/se-2

Kaushik, A., & Pennathur, A. K. (2012). An empirical examination of the performance of real estate mutual funds 1990–2008. Financial Services Review, 21(4), 343–358. https://www.proquest.com/scholarly-journals/empirical-examination-performance-real-estate/docview/1243039086/se-2

Kurzrock, B.-M., Gläsner, S., & Wilke, E. (2009). Performance of open-ended real estate funds in Germany: Are institutional investors better off than retail investors? Journal of European Real Estate Research, 2(2), 110–131. https://doi.org/10.1108/17539260910978445

Lin, C. Y., & Yung, K. (2004). Real estate mutual funds: Performance and persistence. The Journal of Real Estate Research, 26(1), 69–93. https://doi.org/10.1080/10835547.2004.12091132

Lin, C. Y., & Yung, K. (2007). Real estate mutual funds: A style analysis. Financial Services Review, 16(4), 261–273. https://www.proquest.com/scholarly-journals/real-estate-mutual-funds-style-analysis/docview/212047723/se-2

MacGregor, B. D., Schulz, R., & Zhao, Y. (2021). Performance and market maturity in mutual funds: Is real estate different? Journal of Real Estate Finance and Economics, 63(3), 437–492. https://doi.org/10.1007/s11146-020-09787-0

Malhotra, D. K. (2024). Evaluating the performance of real estate exchange-traded funds. Journal of Risk and Financial Management, 17(1), 7. https://doi.org/10.3390/jrfm17010007

Morri, G., & Lee, S. L. (2009). The performance of Italian real estate mutual funds. Journal of European Real Estate Research, 2(2), 170–185. https://doi.org/10.1108/17539260910978472

Newell, G., Nanda, A., & Moss, A. (2023). Improving the benchmarking of ESG in real estate investment. Journal of Property Investment & Finance, 41(4), 380–405. https://doi.org/10.1108/JPIF-10-2021-0084

Price, R. M. (2011). REIT performance from real estate mutual fund holdings. Journal of Business & Economics Research (Online), 9(12), 19. https://doi.org/10.19030/jber.v9i12.6603

Rogers, N., Tieslau, M., & Karafiath, I. (2018). Significant alphas in real estate funds: An empirical comparison of alternative estimators. Journal of Real Estate Portfolio Management, 24(2), 167–179. https://doi.org/10.1080/10835547.2018.12090016

Salzman, D., & Zwinkels, R. C. J. (2017). Behavioral real estate. Journal of Real Estate Literature, 25(1), 77–106. https://doi.org/10.1080/10835547.2017.12090455

Shen, Y., Lu, C., & Lin, Z. (2012). International real estate mutual fund performance: Diversification or costly information? Journal of Real Estate Finance and Economics, 44(3), 394–413. https://doi.org/10.1007/s11146-010-9257-0

Tomperi, I. (2010). Performance of private equity real estate funds. Journal of European Real Estate Research, 3(2), 96–116. https://doi.org/10.1108/17539261011062592

Viktoriya, L., & Nelling, E. (2020). Active management in real estate mutual funds. Journal of Real Estate Finance and Economics, 61(2), 247–274. https://doi.org/10.1007/s11146-019-09722-y

Contact Address

Adam Černohorský
University of Finance and Administration
Faculty of Economic Studies
Estonská 500/3
101 00, Prague 10
Czech Republic
(adam.cernohorsky@mail.vsfs.cz)

Czech Participation in Ukraine's Reconstruction: Risks, Scenarios and Opportunities in the Housing Sector

MIROSLAV PAVLÁK, ROMAN MENTLÍK, MIROSLAV HALOUZKA, SVETLANA YURCHENKO

Abstract

Background: The post-conflict reconstruction of Ukraine, especially in the housing and construction sector, has become a strategic priority for the European Union and its member states. Despite declared support, the real participation of Central European businesses, including those from the Czech Republic, remains limited due to multiple legal, security and financial barriers.

Aim: The paper aims to identify the conditions, instruments and risks influencing the potential engagement of Czech enterprises in the reconstruction of Ukraine's housing and construction sector after 2022, with emphasis on investment frameworks, scenario modelling, and institutional capacities.

Methods: The study combines a qualitative case study (cooperation between the University of Finance and Administration and V. N. Karazin University in Kharkiv), stakeholder analysis based on coded interviews with Czech entrepreneurs, and quantitative investment scenario modelling (2024–2033). Data triangulation was applied to ensure internal validity.

Results: Findings confirm that while institutional and financial instruments (e.g., Ukraine Facility) are in place, their uptake is limited by high perceived risk and a lack of implementation facilitators. Investment scenarios range from 65 to 95 billion USD depending on security and absorption conditions. Czech SMEs face specific constraints such as insufficient legal safeguards and capacity limits yet remain strategically positioned to benefit from targeted support schemes.

Recommendations: Policy actors should prioritise the development of national coordination platforms, risk insurance schemes (e.g., via EGAP), and pilot cooperation models with Ukrainian institutions. Stronger links between academia, public sector and private firms are essential to de-risk market entry and build long-term resilience.

Practical relevance/social implications: The research provides applicable insights for government agencies, export organisations and business associations aiming to support Czech firms in entering high-risk post-conflict markets. Moreover, it demonstrates the role of academic institutions as platforms for international capacity building and post-war recovery.

Originality/value: This is the first study focusing on the Czech context of post-war investment in Ukraine, combining scenario modelling with a grounded case study. The

integration of qualitative and quantitative methods provides a comprehensive framework for further research and policy development.

Keywords
Post-conflict reconstruction, Czech enterprises, Ukraine Facility, housing sector, risk assessment, investment scenarios, international cooperation, public-private partnership

JEL Codes
R31, O18, F35, H56

DOI
http://dx.doi.org/10.37355/acta-2024/1-05

Introduction

The Russian military aggression against Ukraine, which began in February 2022, has fundamentally transformed the geopolitical and economic reality of Eastern Europe and redefined Ukraine's relations with the European Union. As an EU candidate country since June 2022, Ukraine faces the extraordinary challenge of rebuilding its economy in the context of the ongoing armed conflict, as well as the opportunity for accelerated European integration (Herbert, 2024; Economic priorities in post-war Ukraine, 2023).

One of the key areas of this recovery is the construction and housing sector, a sector that suffered considerable damage because of the war operations and is considered a priority under Ukraine's National Recovery Plan (OECD, 2024). It is estimated that more than 10% of the housing stock has been damaged or destroyed, with more than two million households affected. Total damage in this sector is estimated at around USD 55.9 billion, and recovery needs are estimated at USD 80.3 billion over the period 2024–2033 (Investment Guide, 2024).

In parallel with the physical reconstruction of the country, a deeper structural transformation of the Ukrainian economy is underway, including the approximation of legislative and technical standards to those of the European Union, integration into the EU internal market, and opening to foreign direct investment (EU-Ukraine Deep and Comprehensive Free Trade Area, 2023). This process is supported by instruments such as Ukraine Facility, which will provide Ukraine with up to EUR 50 billion in grants and loans, including a special investment framework, in 2024–2027 (European Commission, 2023).

The aim of this article is to analyse the transformation of trade and investment relations between the European Union and Ukraine in the construction and housing sector after 2022. Special attention is paid to the issue of opportunities and risks that this development brings for Czech business entities considering entering the Ukrainian market. The article is based on a review of professional and political documents and a case study of cooperation between the VŠFS and V. N. Karazin University in Kharkiv, which represents a concrete

example of the need for infrastructure reconstruction on the line of direct threat (Ministry of Economy of Ukraine, 2023).

The research question is: How have the conditions for trade and investment cooperation between the EU and Ukraine in the construction and housing sector changed after 2022 and what opportunities does this provide for Czech businesses?

1 Literature review

Post-conflict economic recovery and reconstruction is a complex process that includes not only the physical restoration of destroyed infrastructure, but also the revitalization of institutions, the restoration of investor confidence, and the provision of macroeconomic stability (Barakat, 2003). Modern approaches in this area are based on the concept of "build back better," which emphasizes using the crisis as an opportunity to create more resilient and effective structures (Clarke & Deron, 2016).

From the perspective of economic theory, reconstruction can be understood as a combination of fiscal interventions, foreign aid and private capital mobilization. Public-private partnerships (PPPs) play a special role here, allowing for risk sharing between the state and investors and are particularly important in the construction sector, where projects are often capital-intensive and long-term (Grimsey & Lewis, 2004; Alfen et al., 2009).

The process of European integration in a war or post-conflict context is a relatively unique phenomenon that requires flexibility on the part of both the EU and the candidate country. In this regard, Ukraine moves on the border of two transformation axes: geopolitical orientation towards the West and urgent needs for reconstruction after extensive destruction (Kostanyan, 2023). This dual framework creates a unique environment for analysing the mechanisms of political and economic adaptation in crisis conditions.

Research shows that the housing and construction sector is one of the most affected sectors after armed conflicts, and at the same time the most sensitive to restoring citizens' trust in the state. Reconstruction of this sector therefore has not only economic but also socio-political implications – it contributes to stabilizing society, supporting the return of refugees and restoring the local economy (Fan, 2013; United Nations-Habitat, 2020).

From a public policy perspective, it is important to integrate reconstruction into long-term development strategies, rather than implementing it as an isolated intervention program. A key aspect is the government's ability to allocate resources transparently and strategically, including involving local governments and communities in planning and implementation (Pritchett, Woolcock & Andrews, 2013).

At the level of international support, there is a noticeable shift from purely grant models to using a combination of grants, loans and guarantees. This approach is reflected in the current support to Ukraine through so-called blending finance, financial frameworks that combine public and private resources, often with the support of international financial institutions (Benn et al., 2016).

Finally, it is necessary to perceive risk factors that significantly affect the willingness of foreign investors to enter post-conflict zones. These include not only the ongoing military threat, but also legal and institutional uncertainty, levels of corruption, and low law enforcement (Collier, 2009; Transparency International, 2023).

1.1 Trade and investment relations between the EU and Ukraine in the construction and housing sector

Trade relations between Ukraine and the European Union have fundamentally changed since 2014, and especially since 2022 in connection with the full-fledged Russian invasion. The so-called Deep and Comprehensive Free Trade Area (DCFTA), which is part of the Association Agreement between Ukraine and the EU, has been operating since 2016 and serves as a tool for the gradual convergence of the Ukrainian economy with the EU internal market (European Commission, 2023). In 2022 and onwards, this cooperation was strengthened by the adoption of temporary liberalization measures, which abolished tariffs, quotas and safeguard measures on Ukrainian exports to the EU until June 2025 (Ministry of Economy of Ukraine, 2023).

This liberalization also affected the construction materials and industry sector, where Ukraine has long been an exporter of raw materials and semi-finished products, such as cement, steel and other construction commodities. At the same time, the scope for imports and investments from EU countries has also expanded significantly – both in the field of construction machinery and know-how and technological solutions (Reland, 2022).

The construction and housing sector has become one of the priority areas for the country's reconstruction after 2022, which was also reflected in the government document Ukraine Facility Plan prepared by the Ministry of Economy of Ukraine and presented to the European Commission (European Commission, 2024). This plan envisages the reconstruction of more than 10% of the affected housing stock and investments in the construction of sustainable and resilient houses and infrastructure. Total damage in the housing sector was estimated at USD 55.9 billion by 2024, with investment needs by 2033 amounting to approximately USD 80.3 billion (Investment Guide, 2024).

To implement these investments, a special investment framework (Ukraine Investment Framework) was established within Ukraine Facility, which provides guarantees and grants of EUR 9.3 billion and is expected to mobilise investments of up to EUR 40 billion (European Commission, 2024). This framework is intended to create an attractive environment for foreign investors, including those from the Czech Republic, and to mitigate investment risks through risk sharing with the public sector.

Trade between the EU and Ukraine in the construction materials and technologies sector has been largely affected by the disruption of logistics routes and the need to redirect exports from Black Sea ports to rail and road corridors through EU countries, in particular Poland, Slovakia, Hungary and Romania (EU Solidarity Lanes, 2023). The importance of this factor should also be considered in the investment strategies of companies planning to operate in the Ukrainian market.

Also worth noting are the initiatives to support small and medium-sized enterprises

implemented by the EU through the so-called Flagship Initiative for SMEs. This supports access to finance, mentoring, participation in public procurement and certification according to European standards, which is particularly relevant for Czech construction companies seeking partnerships or subcontracting on the Ukrainian market (European Commission, 2023).

It follows from the above that the construction industry is an area where key economic interests of Ukraine and the EU meet, and where specific investment opportunities can be found. However, these are subject to significant risk factors, including security threats, regulatory uncertainty and limited legal enforceability. From the perspective of Czech companies, it is therefore necessary to conduct thorough risk analyses and use available support mechanisms, including cooperation with public institutions, chambers of commerce and universities.

2 Research Methodology

Given the research objective, which is to analyse the transformation of trade and investment relations between the EU and Ukraine in the construction and housing sectors after 2022 with an emphasis on opportunities for Czech businesses, a combined research design was chosen. This approach allows combining the advantages of qualitative and quantitative analysis and offering a comprehensive view of the issue (Creswell & Plano Clark, 2017).

2.1 Qualitative part, case study

The core of the qualitative part of the research is a case study of cooperation between the University of Finance and Administration (VŠFS) and V. N. Karazin University in Kharkiv. This case was chosen based on the criterion of informativeness, it represents a real situation of cooperation between a Czech entity and a heavily affected Ukrainian institution in the higher education and infrastructure sector. The intention is to illustrate how the war conflict affects investment decisions in building reconstruction in a high-risk environment.

Case studies are considered an effective tool in qualitative research for a deeper understanding of complex phenomena in a real context, especially when a unique or extreme case is examined (Yin, 2018; Stake, 1995). In our case, it serves as a means of illustrating practical barriers, risks and motivational factors for Czech investors.

2.2 Quantitative part, descriptive statistics and prediction model

The second research line is based on the analysis of publicly available data sources – mainly data from the European Commission, OECD, World Bank and Ukrainian government agencies. These data will be used to quantify the development of trade between the EU and Ukraine in the selected sector (construction, raw materials, housing construction), to provide an overview of the amount of funds allocated so far for reconstruction (mainly

through the Ukraine Facility), to estimate investment needs for the period 2024–2033 (including their year-on-year structure).

To calculate the predicted volume of investments in the housing sector, a linear projection model based on trend extrapolation of data published in the Investment Guide 2024 and Ukraine Facility Plan will be used. The calculations will be performed in variants with constant and slightly increasing increment of investment activity and will serve to illustrate the possible distribution of investments over time. This approach is based on commonly used methods in macroeconomic estimation of recovery after crises (Felbermayr & Groschl, 2013). The intention is not to create a prediction with a high degree of accuracy, but rather to analytically estimate the scope of opportunities for potential foreign investors and the state.

2.3 Combination of methods and interpretation

By combining both approaches, qualitative and quantitative, it is possible not only to describe the institutional framework and clarify the logic of actors on the supply and demand sides of investments, but also to illustrate the scope of investment potential and needs based on numerical data. The interpretation of the results will subsequently be supported by contextual information on the specifics of the Ukrainian legal environment, the security situation and the EU's approach to financing reconstruction.

The following research question was asked: "How have the conditions for trade and investment cooperation between the EU and Ukraine in the construction and housing sector changed after 2022 and what opportunities do they provide for Czech companies?" The answers will be sought in various parts of this contribution.

3 Results of the analysis of EU-Ukraine trade and investment relations in construction and housing

3.1 Development of EU-Ukraine trade relations after 2022

The relations between Ukraine and the European Union in the field of trade and investment have changed significantly after 2022. Based on the Association Agreement and the Deep and Comprehensive Free Trade Area (DCFTA), which were already implemented in 2016-2017, the EU has become Ukraine's main trading partner. In 2022, the EU's share of total Ukrainian exports was approximately 63% (European Commission, 2023).

After the outbreak of the Russian invasion, the EU introduced a set of emergency measures, including temporary trade liberalization – in particular, the abolition of tariffs, quotas and anti-dumping measures on exports from Ukraine to the EU. These measures have been extended until June 2025 (Ministry of Economy of Ukraine, 2023). In addition, the so-called Solidarity Lanes, alternative corridors for exports through neighbouring Member States (EU Solidarity Lanes, 2023). For the construction sector, these changes had the following impacts:

- removal of import restrictions on construction materials (steel, cement, timber),
- access of Ukrainian companies to the European public procurement market under contractual cooperation,
- accelerated adoption of European technical standards in the field of construction and building (Reland, 2022).

Table 1: Total exports from Ukraine to the EU (in USD billion)

Year	Exports to EU (billion USD)	Share in total exports (%)
2021	26,6	39
2022	28	63
2023	27,5	64

Sources: Compiled by the authors based on Trade Map, 2024

The increase in the EU's share as a trading partner after 2022 is a result of the loss of exports to Russia and Belarus and the opening of the European market under the duty-free cooperation regime.

Table 2: Export of construction materials from Ukraine to the EU (in million USD, selected categories)

Year	Iron and steel (HS 72)	Cement (HS 2523)	Wood (HS 44)
2021	1346	108	603
2022	1029	126	710
2023	732	103	819

Source: Compiled by the authors according to Trade Map – aggregation of HS codes 72, 2523, 44)

The decline in steel exports is related to the destruction of steelworks (e.g. Mariupol), while wood exports paradoxically increased slightly despite national restrictions. Cement remains a stable export item.

Participation of Ukrainian companies in public procurement can be traced within the framework of contracts registered on the TED portal (2022–2024) and on Prozorro (2022–2024):

- Ukrainian companies appeared for the first time in 2023 as suppliers in several EU-funded infrastructure projects, mainly in Poland, Romania and Slovakia (e.g. subcontracting cement or precast concrete).
- Total: 16 records, of which 9 directly indicate Ukrainian companies as participants, mainly in subcontracting. (TED – CPV 45000000, supplier UA)

- In the period 2022–2023, the portal records more than 3,500 contracts in the field of infrastructure construction and renovation with the support of international donors (USAID, EIB, EU).

- 60% of contracts were awarded to Ukrainian companies. Regional construction companies predominate, several contracts were also won by a consortium with Czech participation (Prozorro analytics, 2024).

These factors created conditions for a deeper connection of the European and Ukrainian construction industries, and thus new opportunities for the involvement of foreign investors.

3.2 The EU Financial support

The EU has provided a robust support package to Ukraine, reflecting the complex challenges that the country faces. This blend of grants, loans, guarantees, budget support and structural initiatives has been essential in maintaining Ukraine's economic stability and supporting its long-term recovery.

"Europe will be at Ukraine's side for every single day of the war, and for every single day thereafter. Europe is true to its word. We will continue to deliver much-needed funding and predictability for our brave partner and aspiring member" told Ursula von der Leyen, President of the European Commission

A major global financial effort will be required to rebuild Ukraine once the war is over. The EU has already contributed substantial financial support to boost the country's resilience and recovery, but more support will be needed in the medium to long-term: to re-establish the foundations of a free and prosperous country, anchored in European values and well-integrated into the European and global economy and to support it on its European path.

While Russia's war of aggression continues, the overall needs for the reconstruction of Ukraine are not yet known. Nevertheless, it is important to design the main building blocks of this international effort already now.

3.2.1 Macro-financial assistance and budget support

In 2023, to continue supporting Ukraine, the EU budget enabled **€19.5 billion** in short-term assistance, including an unprecedented support package of €18 billion in concessional loans. This was on top of the €11.6 billion provided in **loans and grants** in 2022. Thanks to this, Ukraine has been able to

- continue paying wage and pensions,

- restore critical infrastructure damaged by the war,

- maintain essential public services such as hospitals, schools, and housing for relocated people,

- ensure macroeconomic stability.

In October 2024, the EU adopted a new financial assistance package. It consists of an exceptional macro-financial assistance (MFA) loan of **approximately €18 billion** and a loan cooperation mechanism that will support Ukraine in repaying loans provided by the EU and G7 partners for **up to €45 billion**.

This loan cooperation mechanism is to be financed by extraordinary revenues stemming from immobilised Russian sovereign assets. €5 billion of this exceptional MFA has been disbursed to Ukraine so far.

3.2.2 Ukraine Facility

To help Ukraine in its recovery, reconstruction and modernisation efforts, the EU has launched a new support mechanism for the years 2024 to 2027. Ukraine **Facility** is a dedicated instrument which will allow the EU to provide Ukraine with **up to €50 billion** in stable and predictable financial support during this period.

The **Facility** underlines the EU's commitment to supporting Ukraine in the face of Russia's ongoing war of aggression and on its path towards EU membership.

Aims of the Facility are following:

- Support Ukraine's recovery, reconstruction and modernisation.
- Support Ukraine's financing needs to allow the government to deliver uninterrupted public services.
- Mobilise investments in Ukraine's private sector for fast economic recovery and reconstruction.
- Support Ukraine to make the reforms needed on its path to EU accession.
- Support the broader Ukrainian society by helping to address the social consequences of the war.

The Facility is organised around three pillars:

Pillar 1: Direct financial support to Ukraine

The government of Ukraine prepared a plan that sets out its vision for the recovery, reconstruction and modernisation of the country, as well as the reforms it intends to take as part of the EU accession process.

If the conditions set out in this plan are deemed to be fulfilled, the EU will provide financial support of over €38 billion to Ukraine during the period 2024 to 2027 through a combination of loans (up to €33 billion) and grants.

Pillar 2: A specific investment framework for Ukraine

The Facility establishes a specific framework to scale up investment for Ukraine's recovery and reconstruction. To achieve this, the framework will enable investors to take advantage of EU budget guarantees and a blend of grants and loans from public and private institutions which will make investing in Ukraine more attractive.

Ukraine Investment Framework is equipped with €9.3 billion in guarantees and grants. It is expected to mobilise up to €40 billion in public and private investments in Ukraine over the coming years.

Pillar 3: Accession assistance

The Facility introduces new assistance measures to help Ukraine align with EU laws and carry out the reforms necessary on its EU accession path. Technical assistance will be provided to authorities at national, regional, and local level, as well as to civil society organisations.

3.2.3 Measures to support the Ukrainian economy

In February 2023, the European Commission and Ukraine signed an agreement for Ukraine to join the Single Market Programme (SMP). This agreement will support Ukrainian businesses by facilitating

- access to markets,
- a favourable business environment,
- sustainable growth,
- internationalisation.

Additionally, the EU has renewed its suspension of import duties, quotas and trade defence measures on Ukrainian exports until 5 June 2025. The measures have reinforced safeguards and an emergency brake if imports of specific agricultural products reach a certain threshold.

Established in May 2022, the **EU-Ukraine Solidarity Lanes** help ensure that Ukraine can continue to export its goods and import the goods it needs to support its economy.

The EU also provides support through guarantees, issued by financial institutions, such as the EIB and EBRD. This will enable the Ukrainian government to provide credit and allows companies to offer vital services.

3.3 OECD support to Ukraine

The OECD provides inputs to Ukraine's National Recovery and Development Plan and works with international partners to co-ordinate international support for Ukraine, including as part of the Multi-Agency Donor Co-ordination Platform for Ukraine co-chaired by Ukraine, the European Union and the United States.

The OECD has worked with Ukraine since independence three decades ago to support its reform agenda, and the relationship has grown steadily stronger since the 2014 Ukrainian Revolution. Since Russia launched its full-scale invasion in February 2022, and despite the day-to-day challenges of the war, the OECD has steadily deepened its engagement and co-operation with Ukraine. This includes work across a range of policy areas from anti-corruption to tax and public administration reform. The OECD has also helped its member countries address the needs of Ukrainian refugees and supported educational continuity and access to labour-market opportunities for those displaced by the war.

Responding to Ukraine's request for accession, the OECD's governing Council recognised Ukraine as a prospective OECD member in October 2022 and asked the Secretary-General to launch an initial accession dialogue. To structure this dialogue and move the relationship into a new phase, the OECD invited Ukraine to engage in an OECD Country Programme, which was launched in June 2023. The Programme does not grant Ukraine any special status at the OECD, nor does it commit the OECD or Ukraine to an accession process. Nonetheless, a subsidiary objective is to help Ukraine progress toward potential accession by deepening its engagement with OECD bodies and instruments.

3.3.1 Ukraine's National Recovery and Development Plan

The OECD provides inputs to Ukraine's National Recovery and Development Plan and works with international partners to co-ordinate international support for Ukraine, including as part of the Multi-Agency Donor Co-ordination Platform for Ukraine co-chaired by Ukraine, the European Union and the United States.

In addition, the OECD Economics Department has established a Ukraine Desk to incorporate Ukraine into the OECD's forecasting and indicator systems.

3.3.2 The OECD-Ukraine Country Programme

The OECD is working together with Ukraine through a four-year Country Programme to drive the country's agenda for reform, recovery and reconstruction, and help to advance its ambitions to join the OECD and the European Union. The Programme is supporting Ukraine through the war, while ensuring the best use of reconstruction aid to promote economic development and the welfare of citizens.

The OECD-Ukraine Country Programme is structured around six main areas:

- Economic Recovery and Infrastructure Resilience,
- Environmental Sustainability and Energy,
- Taxation and Financial Management,
- Good Governance and Transparency,
- Competitiveness and Regulatory Efficiency,
- Human Capital, Social and Cultural Development.

3.4 Construction and Housing Sector: Damage, Needs and Priorities

The housing and construction sector is among the most affected sectors of the Ukrainian economy because of the full-scale Russian invasion since February 2022. In addition to the direct destruction of residential buildings and technical infrastructure, the massive internal and external displacement of the population played a key role, increasing the demand for alternative and social housing. The estimate of the Kyiv School of Economics, which coordinates the assessment of war damage in cooperation with the Ministry of Economy of Ukraine, is as follows:

Indicator	Value
Number of households destroyed or damaged	2,000,000 households
Share in total housing stock	More than 10%
Estimated damages (2023)	$55.9 billion
Estimated investment needs (2024–2033)	$80.3 billion
Number of registered projects	Hundreds of projects across regions (registered by the Ministry of Economy)
Main areas of renewal	new housing stock, reconstruction, water management, materials production

Source: KSE, 2024; Investment Guide, 2024

It is important to emphasize that the figures presented represent the situation as of 31 December 2023 and reflect only the direct damage documented up to that time. Given that the armed conflict in eastern and southern Ukraine continues, it is reasonable to assume that further increases in damage and investment needs are possible. Based on developments in the first quarter of 2024 and updated KSE estimates, it is assumed that by June 2025, accumulated direct damage in the housing and construction sector could exceed USD 70 billion, while the corresponding investment need for reconstruction could range from USD 95 to 100 billion, depending on the extent of the conflict and the speed of implementation of stabilization projects (KSE, 2024; World Bank, 2024). This dynamic development underlines the necessity of continuous monitoring and flexible reconstruction planning in the sector, which is both infrastructurally and socially the most sensitive.

A crucial component of reconstruction is both the restoration of destroyed residential buildings and the construction of new infrastructure that meets current requirements for energy efficiency, resilience to attacks and accessibility. Key areas include:

- construction and renovation of social and affordable housing for displaced persons,
- reconstruction of damaged houses and urban districts,
- renovation of water and energy infrastructure (water, sewage, heating),
- construction of new production capacities for building materials (cement, concrete, wood, panels).

These priorities are included in Ukraine Facility Plan, which defines the construction sector as a strategic area for the period 2024–2027. At the same time, this area is perceived as key in terms of social stabilization. Affordable and safe housing is a prerequisite for the return of residents, the restoration of community relations and the revival of local economies (OECD, 2024).

Effective project management, transparent allocation of funds, and the ability to combine resources from international institutions and the commercial sector are essential for financing the sector's recovery. Specific data supports this claim:

- The Ministry of Economy of Ukraine publishes registers of hundreds of projects in the housing and construction sector, although the specific amounts allocated in the national central database are not centrally published. However, these serve as a basis for negotiations with international donors (KSE, 2024).

- Ukraine Facility (EU) includes a framework for multi-annual planning and financing (2024–2027) with a total budget of up to EUR 50 billion (Dentons, 2024).

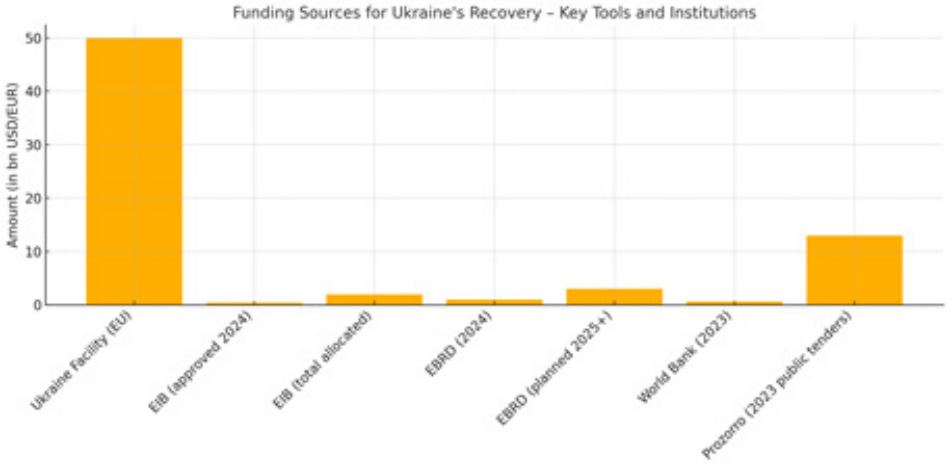
- The European Investment Bank (EIB) supports Ukraine through €2 billion in guarantees for reconstruction and resilience projects. In 2024, €420 million was approved for the public sector, mainly infrastructure, including water, heating and housing.

- Through a memorandum with PM Shmyhal and President Calviño, the disbursement of €560 million in loans and €60 million in grants for 2024 was accelerated and a further €2 billion was allocated under Ukraine Facility (Reuters.com).

- The EBRD (European Bank for Reconstruction and Development) has raised more than €2.6bn in donor funding since 2022, including guaranteed resources, with almost €1bn in 2024 alone. At least €1.5bn in additional funding is planned for 2025, with the bank ready to invest up to €3bn per year in the post-conflict regime.

- The World Bank approved the SURGE programme in 2023 to strengthen economic recovery with initial funding of $283m (IBRD loans) and $300m (SPUR) plus a grant of $10m, building on the wider URTF framework to strengthen public investment management (World Bank, 2024).

Figure 1: Funding Sources for Ukraine's Recovery – Key Tools and Institutions



Source: Compiled by the authors

These figures clearly show that the construction sector is actively supported through EU frameworks (Ukraine Facility, EU guarantee schemes, EIB), up to tens of billions of EUR are ready to be drawn on pilot projects in the field of infrastructure and housing, transparent instruments such as Prozorro enable efficient allocation of funds. Based on these data, the construction sector can be consistently understood as a priority for coordinated post-conflict reconstruction, which contributes to European integration goals and at the same time creates an opportunity for commercial and investment activities of Czech and European entities.

3.5 Investment framework and opportunities for Czech businesses

The reconstruction of Ukraine after 2022 represents not only a political and humanitarian commitment of the European Union, but also an opportunity for European companies to engage in a large-scale process of economic and infrastructural reconstruction. In this context, a special financial architecture has been created – Ukraine Facility, a three-pillar support mechanism, which includes the so-called Pillar 2 – Ukraine Investment Framework.

This investment pillar offers a combination of tools to support public and private investments:

- guarantees of EUR 9.3 billion,
- a combination of grant and loan instruments (so-called blended finance),
- involvement of major financial institutions such as the EIB, EBRD, World Bank,
- expected volume of mobilised investments of up to EUR 40 billion (European Commission, 2024).

Czech companies have been involved in the reconstruction of Ukraine since 2022, through intergovernmental cooperation, subcontracting and direct contracts. The following findings emerge from the data of the Ministry of Industry and Trade, see Table 3.

Table 3: Indicators of involvement of Czech companies

Indicator	Value
Number of Czech companies participating in consultations (2023)	180 companies
Number of companies with completed orders (as of 2022)	about 15 companies
Main areas of involvement	Water treatment plants, modular buildings, electrical engineering, construction technology
Institutions providing support	MIT, Czech Trade, EBRD, EIB

Source: Compiled by the authors according to the Ministry of Industry and Trade, Czech Trade, 2024

To navigate the Ukrainian recovery environment and take advantage of investment opportunities, there are specialized European and Czech support platforms. They help companies prepare bids, enter the Ukrainian market, and identify contracts financed from EU funds. These include:

- Ukraine Facility Helpdesk (EU). Central EU contact point for companies seeking information on the reconstruction of Ukraine.
- Czech Trade Ukraine (Kyiv). On-site assistance service, connections with local partners and businesses.
- Prozorro (UA). Electronic public procurement system – possibility of filtering foreign projects.
- MPO – support programs. Consulting + mediation of contacts with European investment institutions.
- CEBRE / Eurochambres UA Taskforce. European platform for coordination of entrepreneurs and institutions involved in the reconstruction.

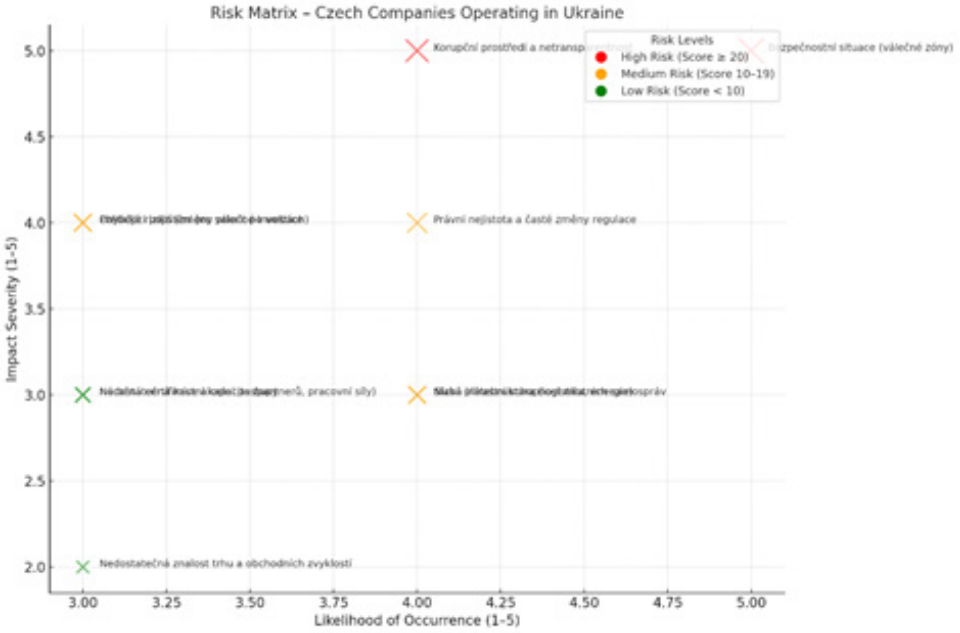
Despite the open investment framework, it is possible to identify significant barriers to entry for companies, see Table 4.

Table 4: Risk score of barriers to entry for companies in Ukraine

Obstacle / Risk	Severity of impact (1-5)	Probability of occurrence (1–5)	Risk score (1–25)
Security situations (war zones)	5	5	25
Legal uncertainty and frequent regulatory changes	4	4	16
Corrupt environment and lack of transparency	5	4	20
Insufficient local capacity (partners, workforce)	3	3	9
Weak infrastructure (logistics, energy)	3	4	12
Missing insurance for war investments	4	3	12
Low solvency of local governments	3	4	12
Demanding certification and customs procedures	3	3	9
Insufficient knowledge of the market and business practices	2	3	6
Political risk (changes in priorities after elections)	4	3	12

Source: Compiled by the authors

Figure 2: Risk Matrix – Czech Companies Operating in Ukraine



Source: Compiled by the authors

It is essential that Czech companies enter these projects, ideally in partnership with larger European actors, under the institutional guarantee of the EIB or EBRD, and using the available EU blending finance instruments. The reconstruction sector of Ukraine offers Czech companies a unique, albeit risky, investment opportunity. Despite the conservative figures on participation so far, it cannot be overlooked that political support, guarantee schemes and dedicated programs create conditions that were not available in any other post-Soviet space after 1989. A strategic and coordinated approach by the state, economic associations and individual entrepreneurs will be key to successful participation in the country's reconstruction within the framework of the European integration process.

3.6 Case Study: Cooperation Between VŠFS and V. N. Karazin Kharkiv National University

This case study was selected as part of the qualitative part of the research to illustrate the possibilities of involving Czech entities in the reconstruction of higher education infrastructure in Ukraine. According to methodological criteria (Stake, 1995; Yin, 2018), it is a so-called information-rich and at the same time extreme case. The selected case connects the academic, business and institutional dimensions of reconstruction in conditions of armed conflict.

The partnership between the University of Finance and Administration (VŠFS) and V. N. Karazin Kharkiv National University was established in 2024 within the framework of the

project "Identification of opportunities and risks for the management of Czech enterprises participating in the reconstruction of Ukraine" (No. 7427/2024/04). The cooperation included the signing of a memorandum, the implementation of an evaluation visits and a basic infrastructure analysis.

3.6.1 Identification of investment needs

Based on the documentation provided by the Ukrainian side, priority projects in the field of renovation of the basic educational and security infrastructure of the Karazin National University in Kharkiv have been identified. Their overview, including location and budgeted costs, is presented in the following table.

Table 5: Identification of investment needs

Project	**Localities**	**Estimated costs (UAH million)**
Renewal of anti-radiation shields in buildings no. 1, 4, 11	Svobody Square, Charkov	139,3
Replacing damaged windows	Svobody Square 6	45
Roof repair (including preparation for solar panels)	Buildings No. 4 and 6	98
General repairs of educational buildings	Various locations in Kharkiv	478
Total required (2025)	—	**855,3**

Source: Compiled by the authors

The total value of the required investments by 2025 exceeds UAH 850 million. These funds are to be mobilized in cooperation with international donors (EU, USAID, UNDP), the Ukrainian state budget and foreign partners. The projects also include preparation for the integration of renewable energy sources (solar panels).

Picture 1: The academic building of the Karazin University Institute of Physics and Technology was significantly destroyed.

Source: https://karazin.ua/en/news/suttievo-zruinovano-navchalnyi-korpus-nni-laquo-fizyko-tekh/

3.6.2 Methodology of the analysis of entrepreneurial attitudes

The case study included an orientation questionnaire and interview survey among Czech entrepreneurs, carried out in cooperation with Business Club Ukraine and the Ukrainian-Czech Chamber of Commerce. The aim was to determine the perception of risks and motivations associated with investments in the field of higher education infrastructure.

N = 42 respondents (SMEs, construction sector, technology, consulting), interviews were conducted online (Microsoft Teams), responses were recorded, transcribed and analysed using the qualitative content analysis method (Mayring, 2014), tokenization and frequency analysis of expressions were performed using the Voyant Tools tool (Sinclair & Rockwell, 2016). Among the most frequently occurring terms were the words: "risk", "uncertainty", "conflict", "guarantee", "yield", "market entry". The recorded responses were further coded according to three key dimensions:

Category	**Typical expressions and attitudes**
Security risk	"The war is still ongoing", "the safety of workers cannot be guaranteed".
Return on investment	"Public infrastructure does not generate cash flow", "risk of loss".
Legal uncertainty	"Laws are changing", "unclear taxes", "law enforcement is non-existent".

The analysis showed a high level of scepticism and caution, consistent with known barriers to foreign investment in post-conflict states (Collier, 2009; Pritchett et al., 2013).

3.6.3 Case study evaluation

The case study shows that even in the context of solidary academic cooperation, practical commercialization and investment participation of Czech companies remains limited. Successful implementation will require:

- involvement of international guarantee funds (e.g. EIB, EBRD),
- use of export insurance (e.g. EGAP),
- inclusion of projects in the framework of Ukraine Facility and NDICI programs.

The study also confirms that the reconstruction of university facilities can serve as a model pilot sector combining education, technology, infrastructure and international development cooperation. Successful implementation in this segment can act as a "test laboratory" for the broader reconstruction of Ukraine in the post-conflict phase.

3.7 Prediction scenarios and models of investment development in the construction and housing sector in Ukraine (2024–2033)

The aim of this part of the research is to quantify possible scenarios of investment activity development in the construction and housing sector in Ukraine in the period 2024–2033. We proceed from official estimates of investment needs according to the Investment Guide (2024), which indicates a volume of 80.3 billion USD for the given period. Since this is an indicative value, three model scenarios were created.

Scenario	Total volume in 10 years	Calculation assumptions
Pessimistic	$65 billion	We assume stagnation/slowdown in recovery, with $6.5 billion invested evenly each year.
Medium	$80.3 billion	Even distribution: $8.03 billion per year.
Optimistic	$95 billion	Slightly increasing investment volume: starting at $7.3 billion in 2024 and increasing by approximately 5% annually.

The calculation of the annual allocation was carried out using the linear interpolation method and a slightly increasing geometric progression (in the optimistic scenario). The results show how investments could be distributed over time. Each row in the table represents one year from 2024 to 2033. There are three columns for each year in the table, i.e. Pessimistic Scenario (USD bn) – investments if the recovery progresses slowly. Baseline Scenario (USD bn) – medium realistic expectations. Optimistic Scenario (USD

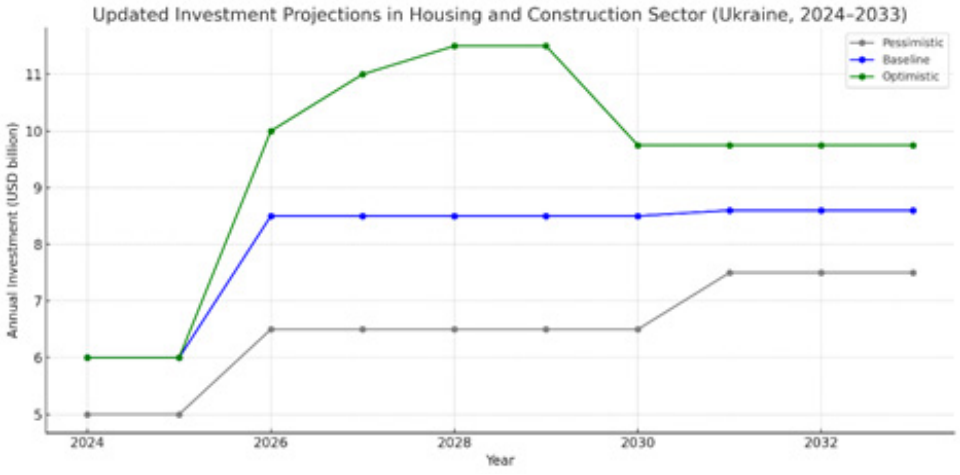
bn) – investments will grow by 5% each year (e.g. due to greater support, a degree of stability, etc.).

Table 6: Projections of investments in the housing sector in Ukraine (2024–2033, in scenarios)

Year	Pessimistic Scenario (USD bn)	Baseline Scenario (USD bn)	Optimistic Scenario (USD bn)
2024	5	6	6
2025	5	6	6
2026	6,5	8,5	10
2027	6,5	8,5	11
2028	6,5	8,5	11,5
2029	6,5	8,5	11,5
2030	6,5	8,5	9,75
2031	7,5	8,6	9,75
2032	7,5	8,6	9,75
2033	7,5	8,6	9,75

Source: Compiled by the authors

Figure 3: Updated Investment Projections in Housing and Construction Sector



Source: Compiled by the authors

In relation to the above table and graph, it can be concluded that the pessimistic scenario assumes limited absorption capacity and a continuing conflict environment. Investments range from 5-7 billion USD per year, without significant growth. Cumulative volume: 65 billion USD. The medium scenario reflects the assumption of stabilization and effective use of funds from Ukraine Facility. A significant increase in allocations in 2026-2030, followed by a slight decline. Cumulative volume: 80.3 billion USD. The optimistic scenario counts for a rapid end to the conflict, active participation of international donors and the entry of private investors. After the initial years (6 billion USD per year), a rapid increase to more than 11 billion USD per year follows. Cumulative volume: 95 billion USD.

This prediction provides a framework for scenario planning, which is necessary for making decisions on financing, capacity planning, supporting the business sector and monitoring the impacts of the recovery. At the same time, it allows for the time targeting of support instruments (guarantees, grants, public procurement) to key periods with high growth (e.g. 2026–2030).

4 Discussion

The discussion part of the research focuses on confronting theoretical knowledge with empirical findings, both qualitative and quantitative. This synthesis allows for a better understanding of the context of Czech companies' investment involvement in the reconstruction of Ukraine, while also pointing out systemic challenges and opportunities.

The theoretical framework was based mainly on the concepts of post-conflict reconstruction (Barakat, 2003; Clarke & Dercon, 2016), public-private partnerships and the concept of "build back better". Our findings largely confirm these approaches by highlighting the importance of infrastructure reconstruction as a key factor for stabilization and economic recovery. The case study of Karazin University shows that university buildings are not only symbols but also the backbone of community renewal (Fan, 2013). Regarding the need to combine public and private resources, Ukraine Facility model confirms that only blended finance (a combination of grants, loans and guarantees) can mobilize the necessary funds. The risks of the post-conflict environment (Collier, 2009; Transparency International, 2023) are reflected in the attitudes of Czech entrepreneurs – a high degree of caution towards legal uncertainty and the security context prevails.

As stated by OECD: Russia's large-scale aggression against Ukraine is inflicting considerable damage on Ukraine's economy, undermining macroeconomic stability and degrading its productive capital. Ukraine's forward-looking recovery and reconstruction aspirations should ensure the right framework conditions are in place and leverage international support, to achieve a sustained recovery that achieves a stronger, greener and more resilient economy. In the short-term, maintaining macroeconomic stability, amidst the ongoing disruption of the war and pressures of defending the country, will buttress Ukraine's defence and ensure solid foundations for the recovery. Seeking to maximise international partners' support in the form of grants or highly concessional loans and developing

mechanisms to provide certainty over the size and timing of support, would support confidence and financing of the budget and the current account. Into the longer-term, agile macroeconomic management will remain essential in managing the reconstruction and supporting the economy's competitiveness. Developing a more effective tax system will support sustainable public finances. The longer-term recovery is an opportunity to "build back better" investment climate, enhancing competition, transparency and integrity across sectors, raising skills, fostering digitalisation and bolstering research, development and innovation. Putting in place the policies and systems enabling all of Ukraine's citizens, especially those displaced by the war or defending the country, to contribute fully to the recovery will provide for a more inclusive economy.

According to Herbert, S. (2024) the rapid evidence review provides insights into global lessons applicable to Ukraine's recovery and reconstruction. It emphasises the need for a holistic approach, considering various concepts like relief, recovery, reconstruction, and the development-humanitarian-peacebuilding nexus. The review suggests that reconstruction can begin during conflict and should involve rebuilding infrastructure and society in an integrated manner. It highlights Ukraine's unique context, including its EU candidate status and the nature of its conflict. Key messages include ensuring local ownership, addressing corruption, fostering inclusion and equity, and leveraging private sector investment for a modernised economy. Governance of reconstruction should be agile, context-specific, and politically aware.

Lemishko, O., Davydenko, N., & Shevchenko, A. (2022) in their article analyse the losses of the economy of Ukraine. According to their opinion it is substantiated that the mobilization of financial resources for the post-war reconstruction of Ukraine should take place according to the principles of system, continuity and balance. It was determined that the coordination of the Ukrainian and European development strategies will contribute to the emergence of second-order effects – synergistic effects. Scientific novelty of the obtained results is as follows: it has been proven that in the field of financing the medium-term recovery strategy of Ukraine, it is necessary to rely on the funds of foreign donors in the form of grants, aid from charitable funds, free financing (the primary direction is financing of the innovative agricultural sector); to ensure the modernization of the country, which is subject to the long-term strategy of post-war recovery, the sources of financing are the attraction of foreign capital, direct foreign investments.

Sinaj, Z., Vela, F., & Shaip, G. (2024) in their study discuss the existing public policy instruments and identified those that would allow for the most effective recovery of Ukraine's post-war economy. The main research methods used were analysis, forecasting, and abstraction. The study examined a large number of policy instruments that could be used in the post-war reconstruction of Ukraine's economy. They covered both financial and social components aimed at facilitating recovery and ensuring long-term stability. Their paper provides a comprehensive overview of the policy instruments and their characteristics, emphasising the importance of their use in the post-war period. Special attention is paid to the issues of economic stability, which was also proposed to be achieved by working on two separate components: economic and political stability, and recommendations for achieving them using certain state instruments were provided.

Economic diversification is highlighted as a separate factor that plays an important role in the long-term development of the country and is a critical part of building the resilience of the Ukrainian economy after the war. The authors bring new knowledge to the analysis of public policy instruments, which will allow to build a more effective strategy for rebuilding the Ukrainian economy in the post-war years.

In this article, we identified several significant differences between expectations and reality. The low level of real participation of Czech companies despite institutional support suggests that political intentions are not enough without an active network of facilitators, mentoring and practical assistance (cf. Benn et al., 2016). The asymmetry between declared opportunities and real implementation, while instruments such as Ukraine Investment Framework are well designed, practice shows that Czech companies are often missing in the final stage of tenders. Theoretical trust in PPPs is not fully fulfilled, local partners, return guarantees and a legal environment suitable for standard investment logic are missing.

Several specific barriers are evident in the Czech environment. Small and medium-sized enterprises (SMEs) represent the backbone of the Czech construction sector, but at the same time they lack the capacity to operate in a conflict environment without a strong institutional framework. Psychological factors, in particular uncertainty and fear of reputational or financial risk, significantly influence the decision-making process. This was also confirmed by the analysis of the interviews (frequency of words such as "risk", "uncertainty", "conflict").

The prediction scenarios confirm that the real development will strongly depend on the political and security situation. The optimistic scenario (95 billion USD by 2033) is possible only under the condition of a quick end to the conflict and strengthening of guaranteed mechanisms. The medium scenario (80.3 billion USD) corresponds to the plans of Ukraine Facility and a realistic pace of reconstruction with EU support. The pessimistic scenario (65 billion USD) would mean a failure in the absorption capacity of Ukraine or the continuation of the state of war. These scenarios also provide recommendations. It is strategic for Czech entities to monitor signals of stabilization in 2025–2026, when the main wave of investments is expected to begin.

Our research has some limitations due to the continuous Russian attacks against the Karazin university, which means that costs are not final and will be going up in the future. Another limitation concerns using different currencies when calculating damages and financial support (USD, Euros and UAH).

Conclusion

The aim of this study was to analyse the investment potential and obstacles to the involvement of Czech entities in the reconstruction of the Ukrainian construction and housing sector after 2022, with a particular emphasis on institutional frameworks, investment scenarios and specific case studies. The research question was: "Under what

conditions and through what tools can Czech entrepreneurs effectively participate in the reconstruction of Ukraine, specifically in the housing and construction sector?" The answer to this question shows that the involvement of Czech companies is realistically possible but requires the presence of several fundamental factors. The key factors are stable legal frameworks, the availability of guarantees and guarantees (especially for small and medium-sized enterprises), the active involvement of intermediary institutions and targeted facilitation of entry into the Ukrainian market. The psychological level of perceived risk is also a significant barrier, which can only be overcome through pilot projects, partnership cooperation and examples of successful implementation.

The study demonstrated the achievement of its objective through several research steps. The investment needs of the housing and construction sector were quantified using a scenario analysis that shows three different investment development trajectories for the period 2024–2033 in the range of 65 to 95 billion USD. Special attention was paid to a case study of cooperation between the University of Finance and Administration and V. N. Karazin University in Kharkiv, which documents the real possibilities of involving the academic sector. The study further elaborated an analytical matrix of investment risks and created prediction models that reflect both security and economic factors. The discussion then showed the consistency and contradictions between the theoretical foundations and empirical findings.

The importance of the topic goes beyond the scope of the research project and has concrete implications for various actors. For the academic sphere, space is opened for further multidisciplinary research in the areas of economics, public administration, security studies and urban planning. Universities can become an environment for pilot projects that connect research, teaching and international cooperation. Based on the results of the study, the public sector should strive to create a national coordination platform to support Czech entities that want to participate in the reconstruction of Ukraine. The availability of tools that minimize risk for investors, such as insurance, consulting or support for participating in European public procurement, is also essential. For private companies, the study provides a realistic framework for making decisions about entering the Ukrainian market, including recommendations regarding the appropriate timing, types of projects and the necessary institutional support.

In the future, the monitoring of actual investment flows and their comparison with predicted scenarios, analysis of the impacts of reconstruction on local economies and the labour market, digital transformation of reconstruction management (for example, through e-procurement platforms), and research on the ethical aspects of reconstruction in a post-conflict environment appear to be key research directions. This study thus not only contributes to the expert debate on post-conflict reconstruction but also provides a practical framework for decision-making by institutions, academic partners, and companies that want to participate in the largest reconstruction effort in Europe since World War II.

Acknowledgements:

The result was created in solving the student project "Identification of opportunities and risks for the management of Czech enterprises participating in the recovery of Ukraine" (No. 7427/2024/04) using objective oriented support for specific university research of the University of Finance and Administration.

References

Alfen, H. W., Kalidindi, S. N., Ogunlana, S., Wang, S., Abednego, M. P., Frank-Jungbecker, A., & Zhao, Y. (2009). *Public-Private Partnership in Infrastructure Development: Case Studies from Asia and Europe*. Weimar: Bauhaus-Universität Weimar.

Antonenko, O. (2024). Ukrajina. Exportní příležitosti pro české firmy. Czech Trade Kyjev https://www.czechtrade.cz/getattachment/ce8990cb-cbce-46b1-b564-f1e1aa2c8f4d/CzechTrade-Ukrajina-Oksana-Antonenko.pdf

Barakat, S. (2003). *Housing reconstruction after conflict and disaster*. Humanitarian Practice Network. Overseas Development Institute.

Benn, J., Sangaré, C., & Hos, T. (2016). *Amounts Mobilised from the Private Sector by Official Development Finance Interventions: Guarantees, Syndicated Loans, Shares in Collective Investment Vehicles, Direct Investment in Companies, Credit Lines*. OECD Publishing.

Clarke, D., & Dercon, S. (2016). *Dull Disasters? How Planning Ahead Will Make a Difference.* Oxford University Press.

Collier, P. (2009). *War, Guns, and Votes: Democracy in Dangerous Places*. Harper.

Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and Conducting Mixed Methods Research* (3rd ed.). SAGE Publications.

Dentons. (2024). *Ukraine Recovery and Reconstruction Tracker: Legal and Investment Framework for 2024–2027*. https://www.dentons.com/

Economic priorities in post-war Ukraine. (2023). Center for Social and Economic Research. https://case-research.eu/publications/economic-priorities-in-post-war-ukraine/

EU Solidarity Lanes. (2023). *EU Solidarity Lanes: Helping Ukraine Export Agricultural Goods. European Commission.* https://transport.ec.europa.eu/

European Commission. (2023). *Ukraine Facility Plan – Investment Framework Summary.* https://ec.europa.eu/

European Commission. (2024). *Ukraine Facility: Annual Work Programme 2024*. https://ec.europa.eu/

EU-Ukraine Deep and Comprehensive Free Trade Area. (2023). *DCFTA Implementation Report*. European Commission.

Fan, L. (2013). *Disaster as Opportunity? Building Back Better in Aceh, Myanmar and Haiti.* Humanitarian Policy Group, Overseas Development Institute.

Felbermayr, G., & Gröschl, J. (2013). *Natural Disasters and the Effect of Trade on Income: A New Panel IV Approach*. European Economic Review, 58, 18–30. https://doi.org/10.1016/j.euroecorev.2012.11.003

Grimsey, D., & Lewis, M. K. (2004). *Public–Private Partnerships: The Worldwide Revolution in Infrastructure Provision and Project Finance.* Edward Elgar Publishing.

Herbert, S. (2024). *Recovery and reconstruction lessons for Ukraine*. https://doi.org/10.19088/k4dd.2024.022

Investment Guide. (2024). *Investment Guide to Reconstruction of Ukraine 2024–2033*. Ministry of Economy of Ukraine / KSE.

Kostanyan, H. (2023). *Ukraine's European Integration amid War: Institutional Challenges and Strategic Opportunities*. CEPS Policy Brief.

KSE. (2024). *Damage and Recovery Assessment Report: Housing Sector*. Kyiv School of Economics. https://kse.ua/

Lemishko, O., Davydenko, N., & Shevchenko, A. (2022). *Strategic directions of the economic recovery of post-war ukraine. Journal of Innovations and Sustainability*, 6(2), 09. https://doi.org/10.51599/is.2022.06.02.09

Mayring, P. (2014). *Qualitative Content Analysis: Theoretical Foundation, Basic Procedures and Software Solution*. Klagenfurt.

Ministry of Economy of Ukraine. (2023). *National Recovery Plan – Housing and Infrastructure*. https://www.me.gov.ua/

OECD. (2024). *OECD Economic Survey: Ukraine 2024*. OECD Publishing. https://www.oecd.org/

Pritchett, L., Woolcock, M., & Andrews, M. (2013). *Looking Like a State: Techniques of Persistent Failure in State Capability for Implementation*. Journal of Development Studies, 49(7), 1–18.

Prozorro analytics. (2024). *Public Procurement Dashboard Ukraine 2022–2024.* https://prozorro.gov.ua/

Sinclair, S., & Rockwell, G. (2016). *Voyant Tools: See through your text*. https://voyant-tools.org/

Sinaj, Z., Vela, F., & Shaip, G. (2024). *National policy instruments for restoring the post-war economy and factors of sustainability of the ukrainian economy*. Development Management, 23(2), 49-55. https://doi.org/10.57111/devt/2.2024.49

Stake, R. E. (1995). *The Art of Case Study Research.* SAGE Publications.

Transparency International. (2023). *Corruption Perceptions Index 2023: Ukraine Country Profile.* https://www.transparency.org/

United Nations-Habitat. (2020). *Rebuilding Homes and Communities in Conflict-Affected Areas*. United Nations Human Settlements Programme.

World Bank. (2024). *Ukraine SURGE Project – Status Report 2024*. https://www.worldbank.org/

Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods* (6th ed.). SAGE Publications.

Contact Address

Ing. Miroslav Pavlák, Ph.D.
University of Finance and Administration
Faculty of Economic Studies
Estonská 500
101 00, Prague 10
Czech Republic
(e-mail: miroslav.pavlak@mail.vsfs.cz)

Ing. Roman Mentlík, Ph.D.
University of Finance and Administration
Faculty of Economic Studies
Estonská 500
101 00, Prague 10
Czech Republic
(e-mail: 26198@mail.vsfs.cz)

Ing. Miroslav Halouzka, CSc.
University of Finance and Administration
Faculty of Economic Studies
Estonská 500
101 00, Prague 10
Czech Republic
(e-mail: 37039@mail.vsfs.cz)

MVDr. Svetlana Yurchenko
V. N. Karazin Kharkiv National University
sq. Svobody, 6,
Kharkiv
Ukraine
(e-mail: gubenok@seznam.cz)

INSTRUCTIONS FOR AUTHORS

Instructions for authors:

The length of manuscripts, using the usual structure of research papers, is 15–20 PC pages (single spacing). Please submit the manuscripts in good English in electronic format together with a printed copy. Attached, submit the executive summary – abstract (150 words max.) and keywords (6–8).

Please number your notes as you go along; attach them using application "Insert footnotes" (in "References"). Add a bibliography in alphabetical order, including page numbers when citing magazines or a journal. Inside the text, please use e.g. Afonso (2001), and when citing include the page number. Use the compatible forms for tables and figures in xls, jpg or tif format. Highlight where pictures, graphs and tables will be placed in the text. Write your contact address: full name and titles, name and address of your work, telephone number and email, including the same for all co-authors.

(Detailed instructions can be found at https://acta.vsfs.eu/guidelines-for-authors)