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# Prioritization of the IT Sector in the CEE Stock Markets: Investment Policies, Trends and Hidden Gems

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## Abstract

Objective: The main purpose of the research is to show that the Central and Eastern European (CEE) market is an essential component of the global stock market. It displays similar patterns to developed countries, and there is a special emphasis on information technology.
Research Design & Methods: The study is supported by various machine learning methods and economic analysis, in addition to using Python and R packages. In order to gain a more comprehensive insight into the developments in CEE-region trends, the paper considers a comparative portfolio that focuses on German business, and there is a simulation of the incorporation of the Ukrainian IT sector. Constructing a business strategy in accordance with the Fama–French approach is boosted by incorporating neural networks.
Findings: An examination of the performance of Czech, Polish, and Hungarian firms on the stock exchanges suggests that the investment policy oriented towards software is a reasonable choice. The results yielded by the IT companies unmistakably reveal the substantial benefits of their stock market ventures, as well as indicating the ongoing trend of investor reliance. The problem of IT business valuation is highlighted as one of the pitfalls of investing.
Implications & Recommendations: The research proposes that maintaining a priority focus on IT, even in challenging circumstances, ensures steady regional advancement.



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Contribution & Value added: This research brings a unique emphasis to the status and outlook of the IT sector, contributing to the existing toolkit, even in the face of repeated crises.

Keywords: Central and Eastern Europe, investment, IT, optimal portfolio, stock market

JEL: E22, G11, G41, O16, O30

## Introduction

It is reasonable to presume that the stock markets of Central and Eastern Europe (CEE) do not hold the same level of proficiency as those of developed countries. In comparison to the clear investment in telecommunication, Internet service, software, automation, robotics, and other markets in developed countries during the pandemic, the commitment of CEE stock markets is far from certain, probably due to their relatively short legacy and the institutional insufficiencies of their evolving systems. Nevertheless, the Polish stock market was recently elevated to the status of developed, and the COVID–19 pandemic greatly increased disparities among different industries. Under such conditions, the dynamics and variability of the markets may be unpredictable. Notably, some of the most renowned IT businesses have shown similarities to the established markets' investment preferences, suggesting both short- and long-term trends in terms of investors' and customers' assurance. In recent times, numerous newly established companies have emerged, each with its unique perspective on how business should be both conducted and experienced. Simultaneously, numerous IT businesses are deliberating the suitability of listing on the stock exchange. Meanwhile, Russian aggression has resulted in a new state of affairs, impeding one branch of business while increasing the prominence of another.

The stock market has been significantly impacted by a decrease in customer mobility (as a result of the pandemic), the virtualization of a substantial part of daily life, increased online purchases, accelerated production and delivery operations, increased demand for education, and remote communication. Research, communication, programs and mechanization are essential for markets in both advanced nations and CEE. Social norms determine priorities and thus shape the stock market. The software market's outcomes are the most anticipated. Our assumption is that the CEE market is an essential component of the global stock market, demonstrating similar patterns as developed countries. We focus on Czech, Polish and Hungarian firms since the data are available in the public domain. Furthermore, should Ukrainian IT companies choose to become publicly traded, they are almost certain to succeed in the CEE market and even Western Europe.

## Methodology background

As a starting point, we constructed a portfolio of German firms listen on the DAX, supplemented with a cluster of prosperous IT entities (in terms of market capitalization) listed on some stock markets. Appraising the portfolio from the standpoints of profitability and risk allows us to compare the Czech, Polish and Hungarian markets. Subsequently, based upon these countries' most prominent stock indices, we chose portfolios for analysis. The number of these firms is often so small that they all take part in the examined portfolio. In addition, we calculate the profitability of these portfolios (based on cumulative return), assess the risk (calculated using standard deviation and daily return variations), predictability (through machine learning and linear regression procedures), and examine the presence or a lack of a long-term strategy (using the 5-factor Fama–French model over a ten-year period, considering factors for both developed and emerging markets). For the analysis of these portfolios, we utilized several Python packages, including EfficientFrontier, pypfopt, numpy, pandas_datareader, matplotlib.pyplot, and yahoo_fin, as well as R packages PortfolioAnalytics, fPortfolio, and timeSeries.

All data are obtained based on company tickers and the corresponding Python and R packages. The methods for gathering such information evolve significantly every few years, particularly in the realm of companies' accounting statistics. Machine learning techniques were selected to analyze business predictability. Ridge regression increases the strength of the coefficients to combat multicollinearity, while the Lasso is advantageous as it favors solutions with fewer non-zero coefficients.

Elastic-net proves useful in scenarios where there is a correlation between multiple features. A Random Forest is a capable estimator that leverages averaging to enhance its predictive precision and mitigate over-fitting. In the case of Gradient Boosting, a regression tree is fitted to the negative gradient of the applicable loss function for each stage. Support Vector Machine Regressor is beneficial due to the possibility to use a radial basis function kernel or rbf. At the same time, we analyze the trend based on the Arima model. We believe that the selection of input factors (p, d, and q) of this model is suitable for reliable short-term predictions. To implement prediction models the following packages were used: statsmodels.tsa.arima_model, sklearn.tree, sklearn.svm, sklearn.linear_model, sklearn.ensemble and others.

In order to recognize any potential pitfalls of investing in IT business, a suitable regression model and a neural network approach are implemented.

## Outline of the problem in recent studies

The UNCTAD Report 'Investment policy responses to the COVID–19 pandemic' contained a serious warning: "The pandemic may trigger increased competition for attracting investment in other industries (not of critical importance for host countries) as economies seek to recover from the downturn and disrupted supply chains need to be rebuilt" (UNCTAD 2020). Meanwhile, according to KPMG's predictions, the world of business will be "forever altered by COVID–19" (McKenzie, Eckhardt, and van Dam 2020; see also Hantrais et al. 2021). Many long-held norms of living, working and doing business have now changed and "are not expected to return to pre-pandemic patterns" (McKenzie, Eckhardt, and van Dam 2020; see also Lazonick 2017). During the pandemic, Ernst & Young (EYGM 2020) recommended "four key areas where European companies should focus: financial scenario and business portfolio assessment; portfolio rebalancing: accelerated divestments; asset transfer: sale and leasebacks; auditable financials" (EYGM 2020).

Nevertheless, did this actually take place? Did the pandemic provoke a permanent change in stock market allegiances that had been established for decades? Shortly before the outbreak of the pandemic the European Investment Bank was responsible for carrying out a particularly interesting study. This study indicated the likelihood of investing in knowledge resources in CEE. In the Czech Republic, such noteworthy potential sectors included education, R&D, transport infrastructure and energy. Meanwhile, Hungary focused on education and physical infrastructure, while Poland requires higher spending on R&D and further improvement to its energy infrastructure (Bubbico et al. 2017). The prevailing trend for startups originating from CEE is to relocate overseas, particularly in the case of Ukraine (60%), followed by Croatia and Serbia, both reaching 40% (Dealroom.co 2021). According to Kitt (2004), investors favor domestic bonds in these markets. He used Markowitz mean-variance optimization to identify optimal portfolios, with one such portfolio proposed for MSCI Eastern Europe Index.

In 2018, PricewaterhouseCoopers predicted that New York, London, and Hong Kong would remain at the forefront of the stock markets for the next decade and that the shift to Indian and Chinese competitors would be quite moderate. Markets would strive for tech companies (see also Pan and Mishra 2018). Meanwhile, according to a Digital Society Index (Dentsu Aegis Network 2019, p. 17) survey of more than 43,000 people around the world, less than half (49%) currently believe their basic digital needs are being met (i.e., access to quality digital infrastructure and the trust that people express in business and government to use their data responsibly in terms of privacy and security; see also Xingfu and Siming 2020). So, what are the obstacles to market advancement? The forecast highlights negative factors such as the lack of liquidity, currency volatility, and an uncertain regulatory framework. "The challenge for the exchanges is how they can adapt to the changing landscape, competing

but also collaborating with one another, and complementing other financing alternatives to support the provision of capital across the world" (PwC 2019, p. 2).

Zaimovic, Arnaut-Berilo and Mustafic (2017) stated that diversification enables investors to manage their risk. "The biggest riddle in the world of investments is to find the optimal portfolio within a set of available assets with limited capital". A Markowitz mean-variance (MV) portfolio optimization was used to identify possibilities for diversification. Their research offered insight into the level of integration of South-East European equity markets. Their findings showed that Principal component analysis simplifies asset selection in portfolio management. Meanwhile, Deng et al. (2013) proposed a portfolio optimization framework that selects the portfolio with the largest worst-case-scenario Sharpe ratios. They stated that "traditional Sharpe ratio estimates based on limited historical return data are subject to estimation errors."

Milhomem and Dantas (2020) discussed aspects of portfolio optimization. They found that techniques such as robust optimization, Bayesian statistics, Neural Networks, and Fuzzy Logic can be employed to reduce estimation error. Obtaining data to analyze the optimization model is possible through platforms including Thomson Reuters, OR-Library, and Fama–French, and languages such as Python, R, C++, and Java offer an array of tools for the analysis. Annaert et al. (2011) calculated the market-weighted return index for the largest stocks listed on the Brussels Stock Exchange. They demonstrated that market analysis should focus on market leaders to identify market trends and predict market dynamics.

Within the scientific community, there has been a great deal of research into the stock market in general, the practicality of employing certain tools, as well as Central, South, and Eastern European stock markets (i.e. Syriopoulos and Roumpis 2009; Benaković and Posedel 2010; Bogdan, Bareša, and Ivanović 2010; Syllignakis and Kouretas 2011; Horvath and Petrovski 2013; Guidi and Ugur 2014; Zaimović and Arnaut Berilo 2015). However, there has been no thorough analysis of the emphasis of the market on particular priorities of society, one of which is information technology.

## Research and key findings

The CEE market data in its entirety suggests comparable priorities to those of developed countries (Table 1). So, is the stock market adequately reacting to the transformations? Does it impair its capacity to prioritize entrepreneurial initiatives? Does the pandemic give the region no way out?

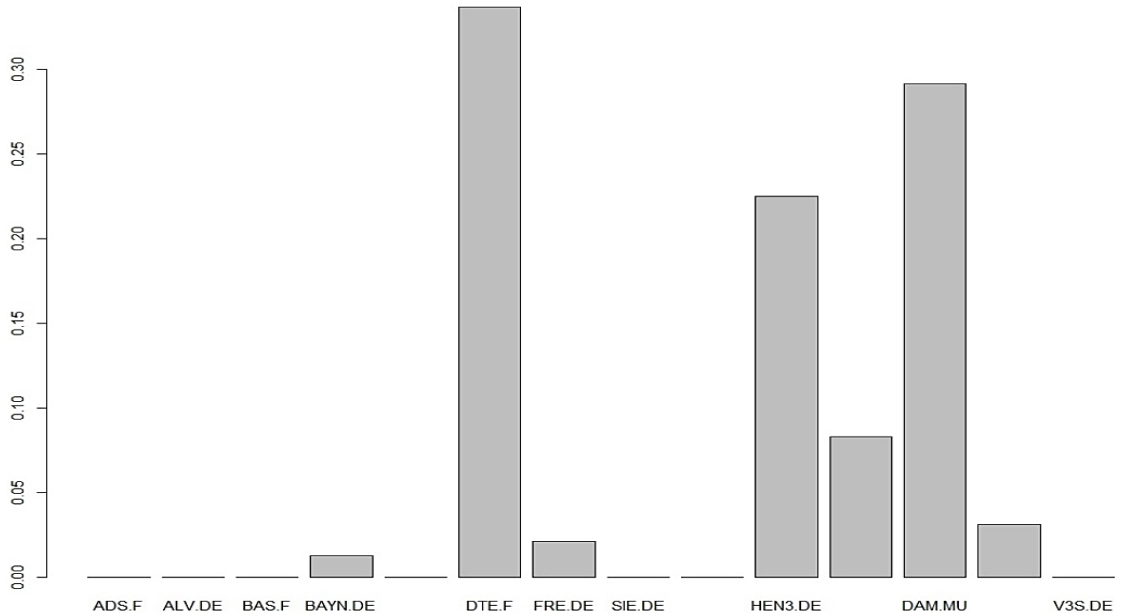
Table 1. CEE investment priorities by sector (€, millions)

| | 2019 | | 2020 | |
|---|---|---|---|---|
| | amount | percent | amount | percent |
| ICT (Communications, computer, electronics) | 1 425 766 | 43.6 | 739 181 | 44.3 |
| Business products and services | 280 349 | 8.6 | 193 824 | 11.6 |
| Consumer goods and services | 545 405 | 16.7 | 173 076 | 10.4 |
| Biotech and healthcare | 142 549 | 4.4 | 240 169 | 14.4 |

Source: data from Invest Europe 2023.

## The German market as a partner and competitor

Selecting the German market for our analysis, we address the questions raised above. Our aim is to construct an optimal portfolio for the German market, using DAX components, while also including a few promising IT companies. We simultaneously apply a portfolio optimization approach based on maximizing the Sharpe ratio and R packages (Figure 1).




Notes: Data Modul AG (DAM.MU), Viscom AG (V6C.DE), Vectron Systems (V3S.DE), Adidas AG (ADS.F), Allianz SE (ALV.DE), BASF SE (BAS.F), Bayer (BAYN.DE), Deutsche Telekom AG (DTE.F), Fresenius SE & Co. KGaA (FRE.DE), Siemens (SIE.DE), Henkel AG & Co. KGaA (HEN3.DE). Other companies are not included in the opti-mal portfolio. It was used fPortfolio of R. Research period: from = "2019–01–01" to = "2023–02–24". Risk Free/Working Days = 0.06647/253.

Figure 1. German portfolio optimization

Source: own elaboration based on historical prices from Yahoo n.d.

Companies with the highest profile include Deutsche Telekom AG (DTE.F), Henkel AG and Co. KGaA (HEN3.DE), Data Modul AG (DAM.MU), i.e., one of the world's leading

integrated telecommunications companies, a chemical corporation, and a worldwide leading supplier of industrial displays and monitors. Our observations show that including the top-performing IT firms in the stock index significantly affects the optimal portfolio. Regarding Figure 2, Deutsche Telecom's superiority is clear, although some IT companies, like Data Modul AG (DAM.MU), Viscom AG (V6C.DE), and Vectron Systems (V3S.DE), also appear to be optimal choices.

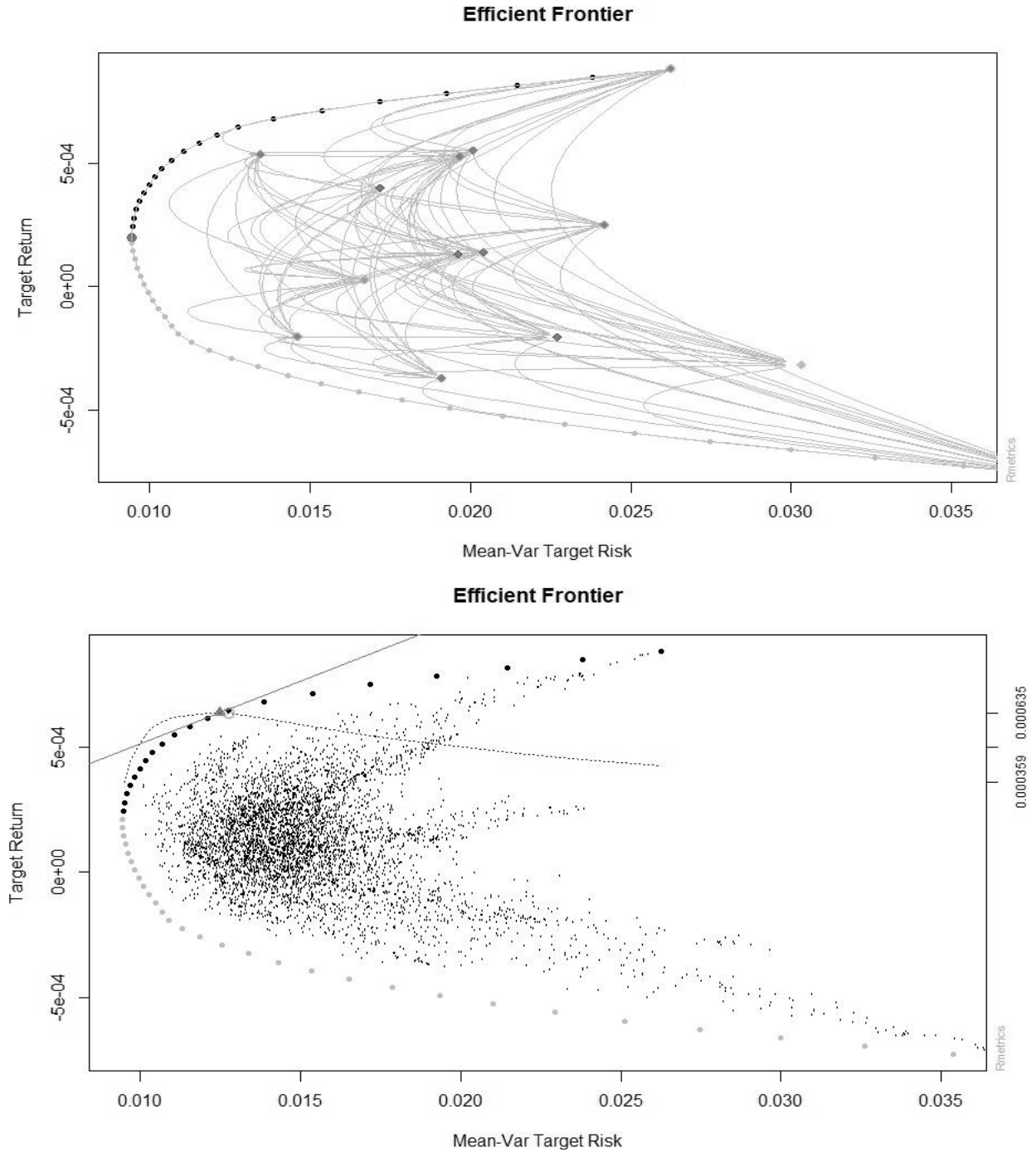



Figure 2. Graphical presentations of Asset Frontiers and the Efficient Frontier for the German portfolio

Source: own elaboration based on Portfolio analytics of R.

## CEE optimal portfolio

For our examination, we decided to select constituents of the PX (Czech Republic), Budapest SE (Hungary) and WIG 20 (Poland) indices and a selection of well-known CEE IT businesses.

Table 2. Portfolio optimization based on the Efficient Frontier method

| Poland | Czech Republic | Hungary |
|---|---|---|
| [('ALE.WA', 0.0), ('ACP.WA', 0.0), ('PEO.WA', 0.0), ('CCC.WA', 0.0), ('CDR.WA', 0.0), ('CPS.WA', 0.0), (**'DNP.WA'**, 0.05142), ('KTY.WA', 0.0), (**'JSW.WA'**, 0.01623), ('KGH.WA', 0.0), (**'KRU.WA'**, 0.14458), ('LPP.WA', 0.0), ('MBK.WA', 0.0), ('OPL.WA', 0.0), (**'PKN.WA'**, 0.04012), ('PPS.WA', 0.0), ('PGE.WA', 0.0), ('PKO.WA', 0.0), ('PZU.WA', 0.0), ('SPL.WA', 0.0), (**'IFI.WA'**, 0.54784), (**'CCE.WA'**, 0.01494), (**'SGN.WA'**, 0.18487), ('LVC.WA', 0.0)] | [(**'CEZ.PR'**, 0.10589), (**'CZG.PR'**, 0.397), ('ERBAG.PR', 0.0),('KOFOL.PR',0.0),('KOMB.PR', 0.0), (**'MONET.PR'**, 0.00246), (**'TABAK.PR'**, 0.27002), ('TMR.PR', 0.0), ('VIG.PR', 0.0), ('TOMA.PR', 0.14665), (**'PEN.PR'**, 0.06273), ('GEN.PR', 0.0), (**'EMAN.PR'**, 0.01524), ('FIXED.PR', 0.0)] | [(**'4IG.BD'**, 0.07993), (**'AKKO.BD'**, 0.04867), (**'ALTEO.BD'**, 0.73881), (**'ANY.BD'**, 0.13246), ('BIF.BD', 0.0), ('DELTA.BD', 0.0), ('ENEFI.BD', 0.0), ('MOL.BD', 0.0), ('NAP.BD', 0.0), ('NUTEX.BD', 0.0), (**'UBM.BD'**, 0.00013), ('AMIXA.BD', 0.0)] |
| Stock Start Date: 2019–01–01 | | |
| Day of study: 2023–03–09 | | |
| Expected annual return: | | |
| 101.8% | 26.5% | 39.4% |
| Annual volatility: | | |
| 29.0% | 13.6% | 26.8% |
| Sharpe Ratio: | | |
| 3.44 | 1.80 | 1.39 |

Notes: Allegro (ALE.WA), Asseco Poland (ACP.WA), Bank Polska Kasa Opieki (PEO.WA), CCC (CCC.WA), CD Project (CDR.WA), Cyfrowy Polsat (CPS.WA), Dino Polska (DNR.WA), Grupa Kety (KTY.WA), Jastrzebska Spólka Weglowa (JSW.WA), KGHM Polska Miedz (KGH.WA), Kruk (KRU.WA), LPP (LPP.WA), mBank (MBK.WA), Orange Polska (OPL.WA), Orlen (PKN.WA), Pepees (PPS.WA), PGE (PGE.WA), PKO Bank Polski (PKO.WA), PZU (PZU.WA), Santander Bank (SPL.WA), Ifirma JSC.(IFI.WA), Clean&Carbon Energy S.A. (CCE.WA), Sygnity S.A. (SGN.WA); CEZ (CEZ.PR), Colt CZ Group (CZG.PR), Erste Group Bank (ERBAG.PR), Kofola (KOFOL.PR), Komercni Banka (KOMB.PR), Moneta Money Bank (MONET.PR), Philip Morris (TABAK.PR), Tatry mountain resorts (TMR.PR), Vienna insurance (VIG.PR), Toma (TOMA.PR), Photon energy (PEN.PR), Gen Digital (GEN.PR), eMan (EMAN.PR), Fixed.zone (FIXED.PR); 4iG Ltd. (4IG.BD), AKKO Invest (AKKO.BD), Alteo (ALTEO.BD), Amixa Holding (AMIXA.BD), ANY Security Printing (ANY.BD), ASTRASUN (ASTRA.BD), Budapesti Ingatlan Hasznosítási és Fejlesztési (BIF.BD), Chameleon Smart Home Zartkoruen Mukodo Reszvenytarsasag (CHOME.BD), CYBERG CORP. (CBRG.BD), Delta Technologies (DELTA.BD), ENEFI Vagyonkezelo (ENEFI.BD), MOL Magyar Olaj- és Gázipari Nyilvánosan Muködo Részvénytársaság (MOL.BD), Nap Zartkoruen Mukodo Reszvenytarsasag (NAP.BD), NUTEX Investments Public Limited Company (NUTEX.BD), UBM Holding (UBM.BD), Amixa Holding Nyilvánosan Muködo Részvénytársaság (AMIXA.BD).
Source: own elaboration based on historic prices from Yahoo n.d.

We have already incorporated companies from the IT sector into separate country portfolios. Polish company Ifirma JSC has developed a website that allows businesses

to manage themselves online. The other Polish firm, Sygnity S.A., has designed, implemented and maintains the technology that supports businesses in digital transformation and forms a foundation for digital government. Czech company eMan a.s. develops applications for smartphones, tablets, websites, cars, and other devices. Hungary's 4IG Ltd. specializes in custom software development, while SAP ERP concentrates on business solutions, specifically, data-focused business solutions for executives.

Next, we explore the results of forming a combined portfolio of these three countries from the CEE region (Table 3). Assets with non-zero weights are highlighted in bold. The portfolio comprises the following assets: (**'DNP.WA'**, 0.12057), ('JSW.WA', 0.0), ('KRU.WA', 0.0), ('OPL.WA', 0.0), ('PKN.WA', 0.0), (**'IFI.WA'**, 0.12713), (**'CCE.WA'**, 0.0059), (**'SGN.WA'**, 0.00199), (**'CEZ.PR', 0.03245**), (**'CZG.PR'**, 0.29215), ('MONET.PR', 0.0), (**'TABAK.PR'**, 0.07851), (**'TOMA.PR'**, 0.04487), (**'PEN.PR'**, 0.02486), (**'EMAN.PR'**, 0.0355), (**'4IG.BD'**, 0.08181), (**'AKKO.BD'**, 0.02866), (**'ALTEO.BD'**, 0.10082), (**'ANY.BD'**, 0.02475), ('UBM.BD', 0.0). Using the Efficient Frontier method, the expected annual return is 40.8%, the annual volatility is 14.1%, and the Sharpe Ratio is 2.75. The Sharpe Ratio of this portfolio decreased compared to the Polish market. At the same time, risk is significantly lower than in both the Polish and Hungarian markets. Regarding utility optimization, risk is given less consideration. The aforementioned IT companies maintained significant positions within the optimal portfolio with regard to utility maximization (Figure 3).

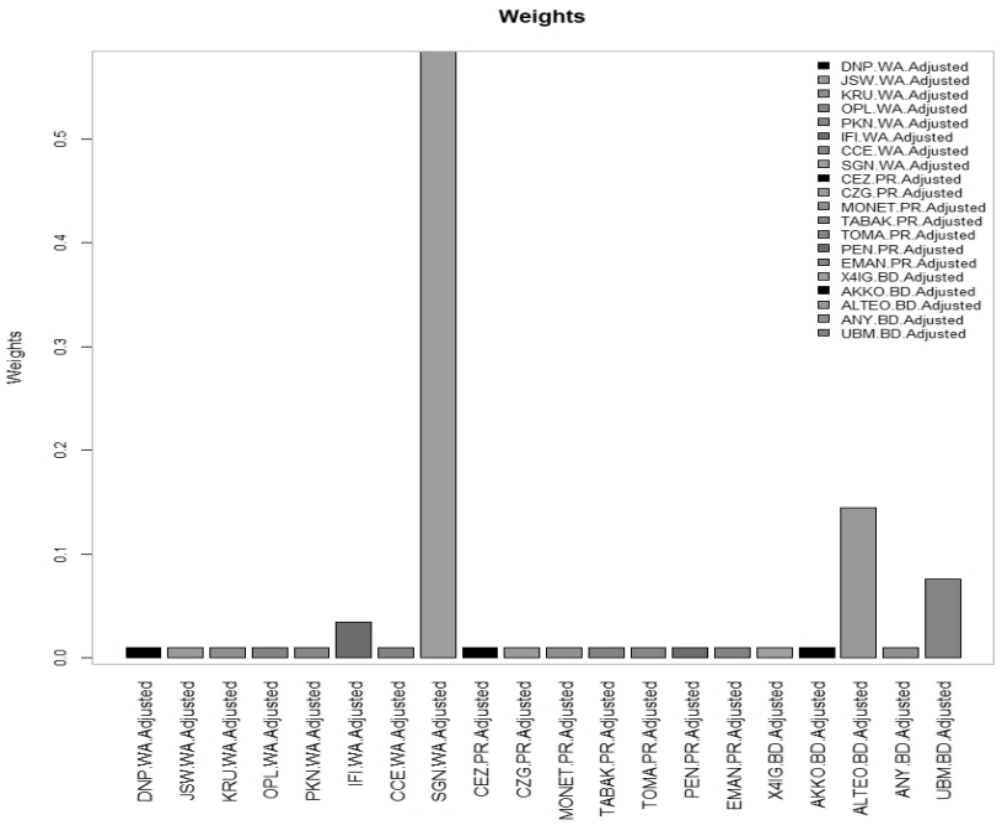



Figure 3. United optimal portfolio (Utility maximization)

Source: own elaboration based on the PortfolioAnalytics of R package.

This approach also guarantees the inclusion of at least two IT firms (i.e., Ifirma JSC. and Sygnity S.A.) in the optimal portfolio. The model we used has limitations with weighting coefficients ranging from 0.01 to 0.9. Figure 4 demonstrates the Efficient Frontier, Global Minimum Variance Portfolio, two-asset frontiers, and the Monte Carlo portfolio. The graphic presentation of the selected portfolio is certainly interesting (Figure 2). The portfolio attains a balance between profitability and risk. The top graph is a good representation of how each company can shape the Efficient Frontier and the maximum Sharpe ratio. We will focus our analysis on the companies included in the optimal portfolios later.

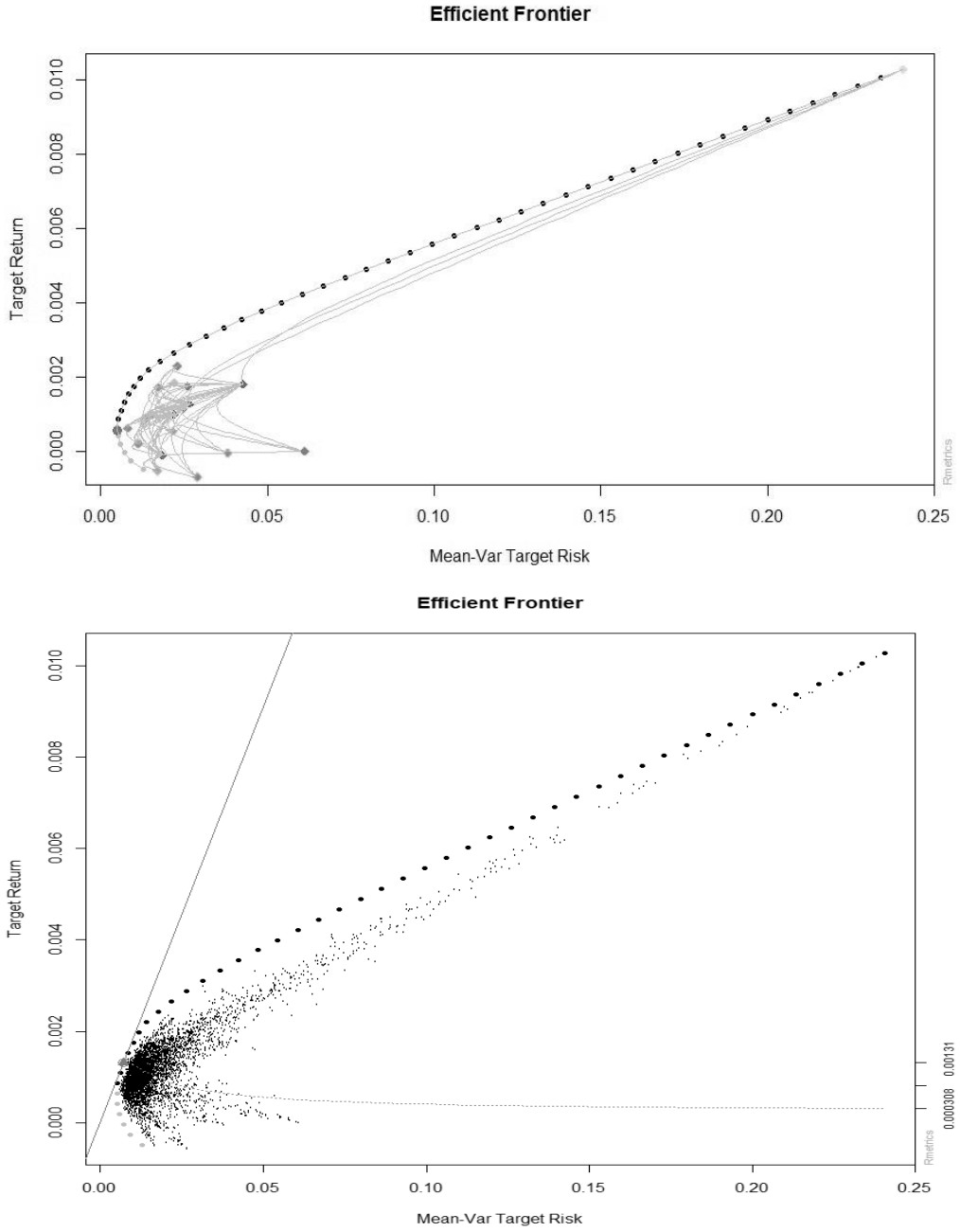
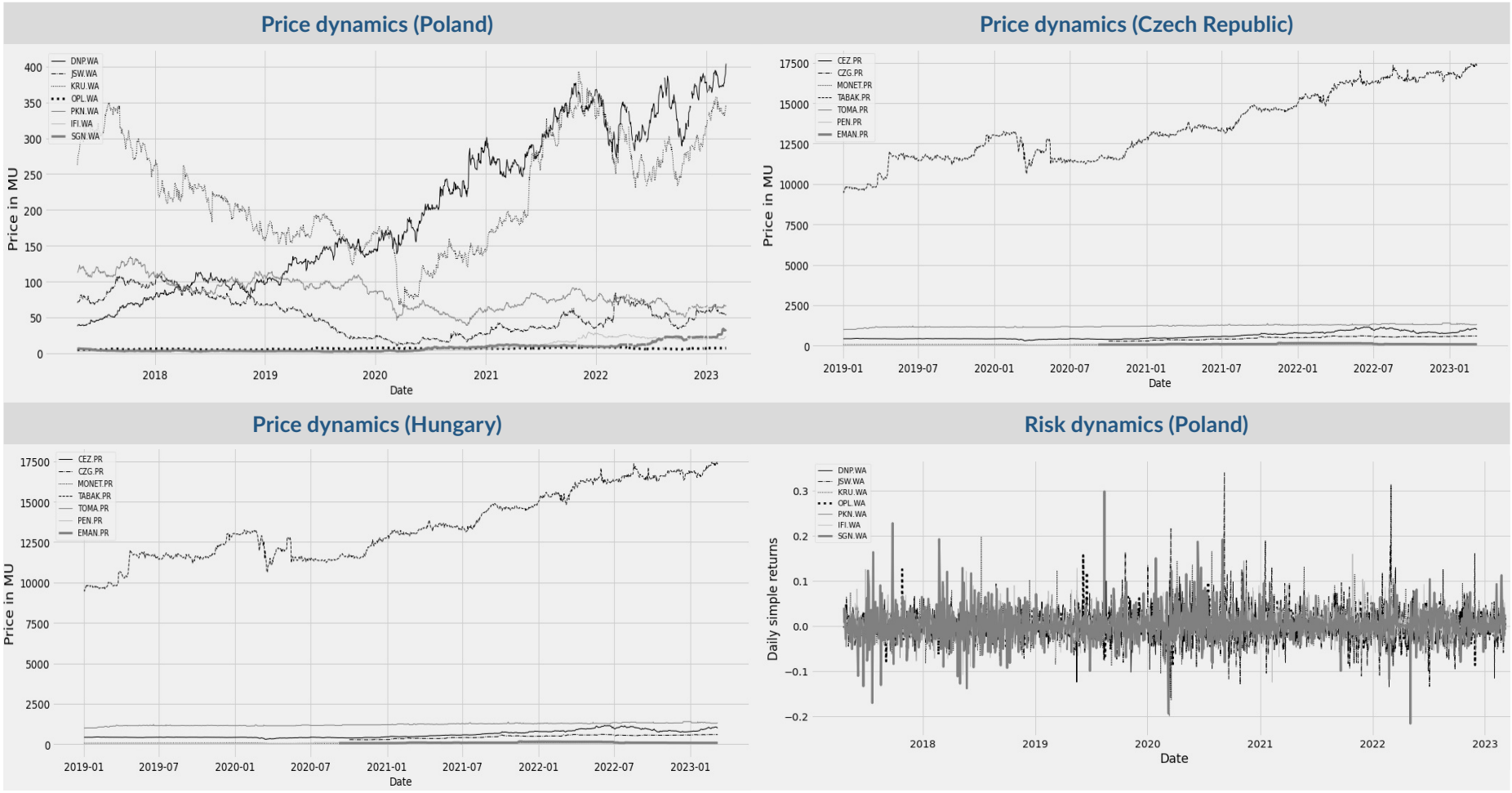



Figure 4. Efficient frontier graphical presentations (CEE united portfolio)

Source: own elaboration based on historical prices from Yahoo n.d.Market analysis


Price dynamics (Poland)
DNP.WA
JSW.WA
KRU.WA
OPL.WA
PKN.WA
IFI.WA
SGN.WA
Price in MU
Date
Price dynamics (Czech Republic)
CEZ.PR
CZG.PR
MONET.PR
TABAK.PR
TOMA.PR
PEN.PR
EMAN.PR
Price in MU
Date
Price dynamics (Hungary)
Price in MU
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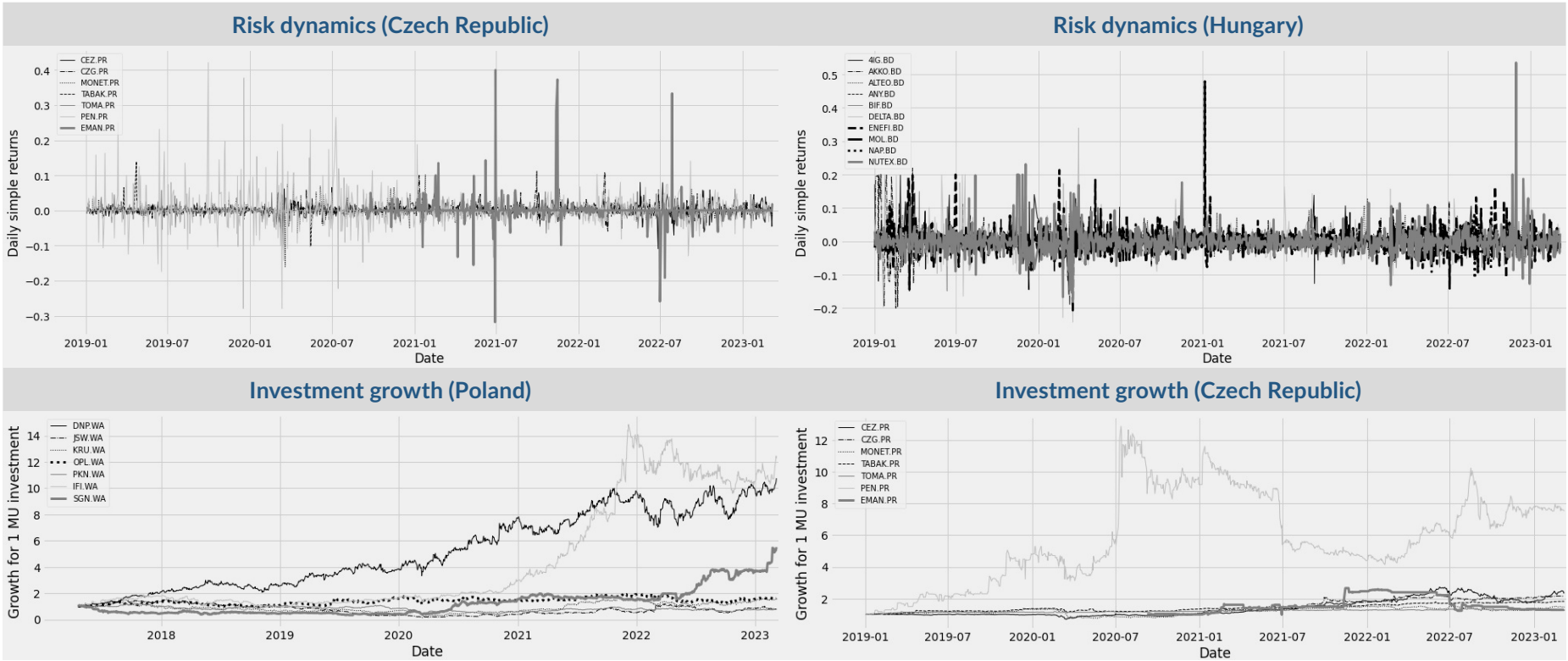
Risk dynamics (Poland)
Daily simple returns
Date


Risk dynamics (Czech Republic)
CEZ.PR
CZG.PR
MONET.PR
TABAK.PR
TOMA.PR
PEN.PR
EMAN.PR
Daily simple returns
Date
Risk dynamics (Hungary)
4IG.BD
AKKO.BD
ALTEO.BD
ANY.BD
BIF.BD
DELTA.BD
ENEFI.BD
MOL.BD
NAP.BD
NUTEX.BD
Daily simple returns
Date
Investment growth (Poland)
DNP.WA
JSW.WA
KRU.WA
OPL.WA
PKN.WA
IFI.WA
SGN.WA
Growth for 1 MU investment
Date
Investment growth (Czech Republic)
CEZ.PR
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MONET.PR
TABAK.PR
TOMA.PR
PEN.PR
EMAN.PR
Growth for 1 MU investment
Date

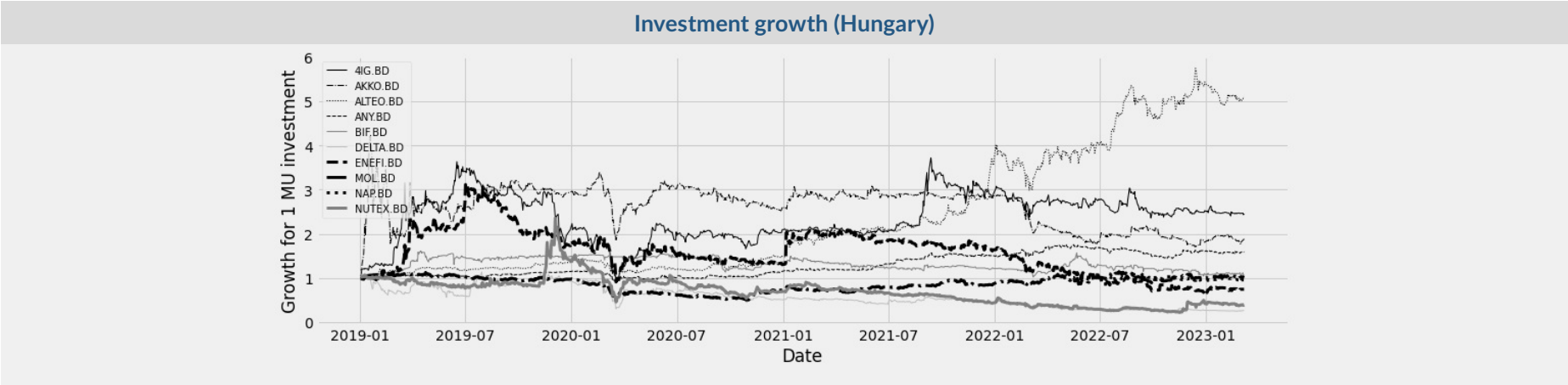



Figure 5. Price dynamics, risk, and economic growth dynamics in Poland, the Czech Republic and Hungary

Source: own elaboration based on historical prices from Yahoo n.d.

The analysis of the price dynamics, risk, and economic growth dynamics of the three CEE countries made it possible to identify growth trends, level of vulnerability, and economic growth for the constructed optimal portfolios, including their inclusion of IT companies (Figure 5). Although the Hungarian market is not performing as well as the other countries, companies from this country were still included in the optimal CEE portfolio, including a company from the IT sector.

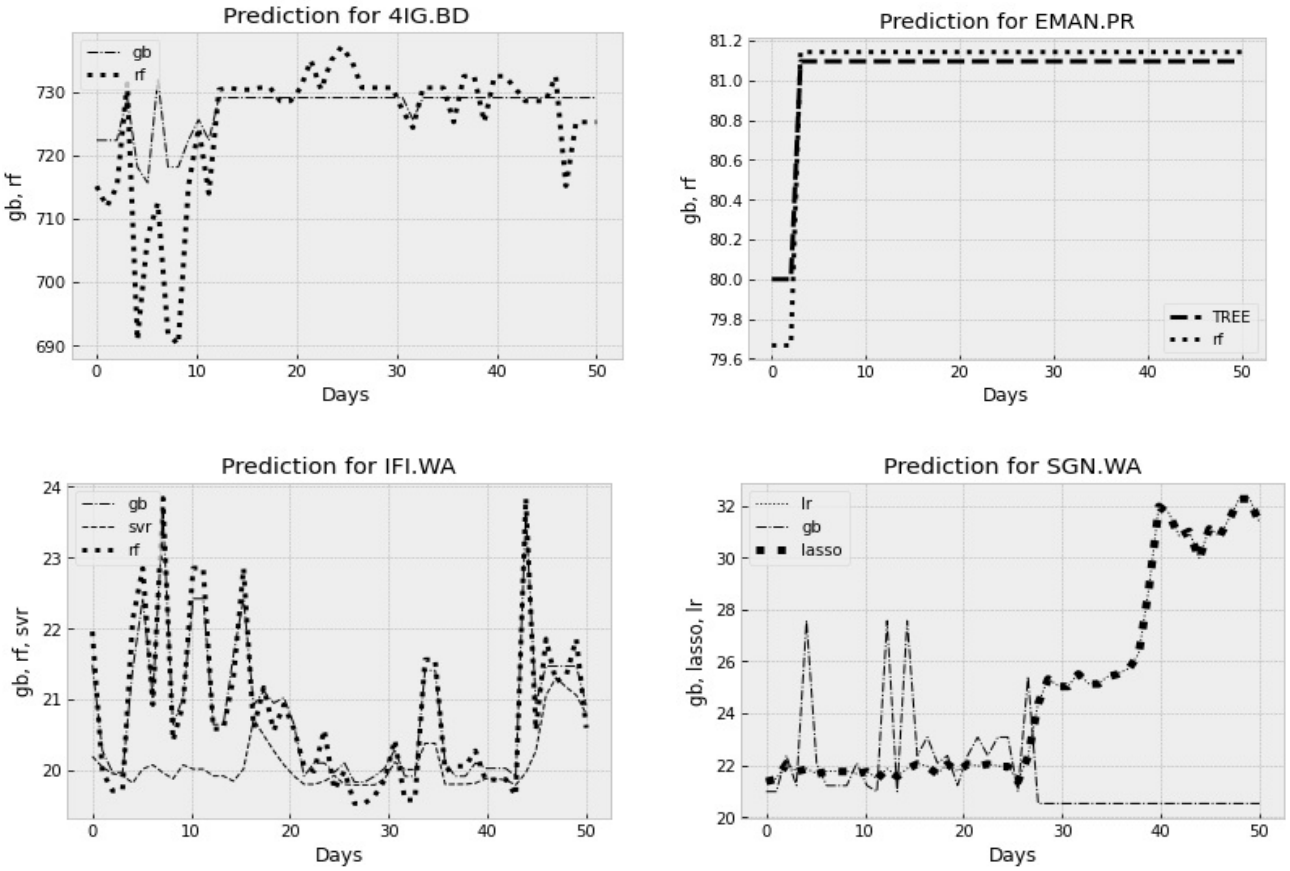
## Predictability analysis

Using Support Vector Machine Learning, traditional Linear Regression and Random Forest, Gradient Boosting and Lasso, our aim is to gain a thorough understanding of the previously illustrated trend. The acceptability of such an approach could be analyzed based on $R^2$, mean absolute error, maximum error, mean squared log of error, mean absolute percentage error, and mean squared error. In our opinion, the coefficient of determination ($R^2$) is the most suitable indicator.

Table 3. Confidence level ($R^2$)

| Method / Company | 4IG.BD | EMAN.PR | IFI.WA | SGN.WA |
|---|---|---|---|---|
| Linear Regression | 0.934 | 0.382 | 0.935 | 0.934 |
| Support Vector Regressor | 0.951 | 0.363 | 0.984 | 0.934 |
| Random Forest | 0.958 | 0.658 | 0.988 | 0.948 |
| Gradient Boosting | 0.957 | 0.662 | 0.987 | 0.946 |
| Lasso | 0.934 | 0.382 | 0.935 | 0.934 |

Source: own calculations based on historical prices from Yahoo n.d.




Notes: abbreviations used: lr (linear regression), svr (support vector regressor), rf (random forest), gb (gradient boosting).

Figure 6. The 50-day prediction for IT portfolio elements

Source: own elaboration.

For IT firms included in the optimal portfolio, we employed a range of techniques to reveal a subtle yet perceptible upward trend (Figure 6). Confidence in the results of these calculations is quite high, typically reaching 93–98% (Table 3). For the single firm, the outcomes of numerous processes revealed inadequate performance (EMAN.PR, 36–38%).

Table 4. Competing ingredients confidence level ($R^2$)

| Method / Company | ALTEO.BD | CEZ.PR | DNP.WA | PEN.PR |
|---|---|---|---|---|
| Linear Regression | 0.970 | 0.908 | 0.936 | 0.675 |
| Support Vector Regressor | 0.985 | 0.951 | 0.956 | 0.723 |
| Random Forest | 0.990 | 0.950 | 0.957 | 0.796 |
| Gradient Boosting | 0.989 | 0.947 | 0.955 | 0.806 |
| Lasso | 0.970 | 0.908 | 0.936 | 0.670 |

Source: own elaboration.

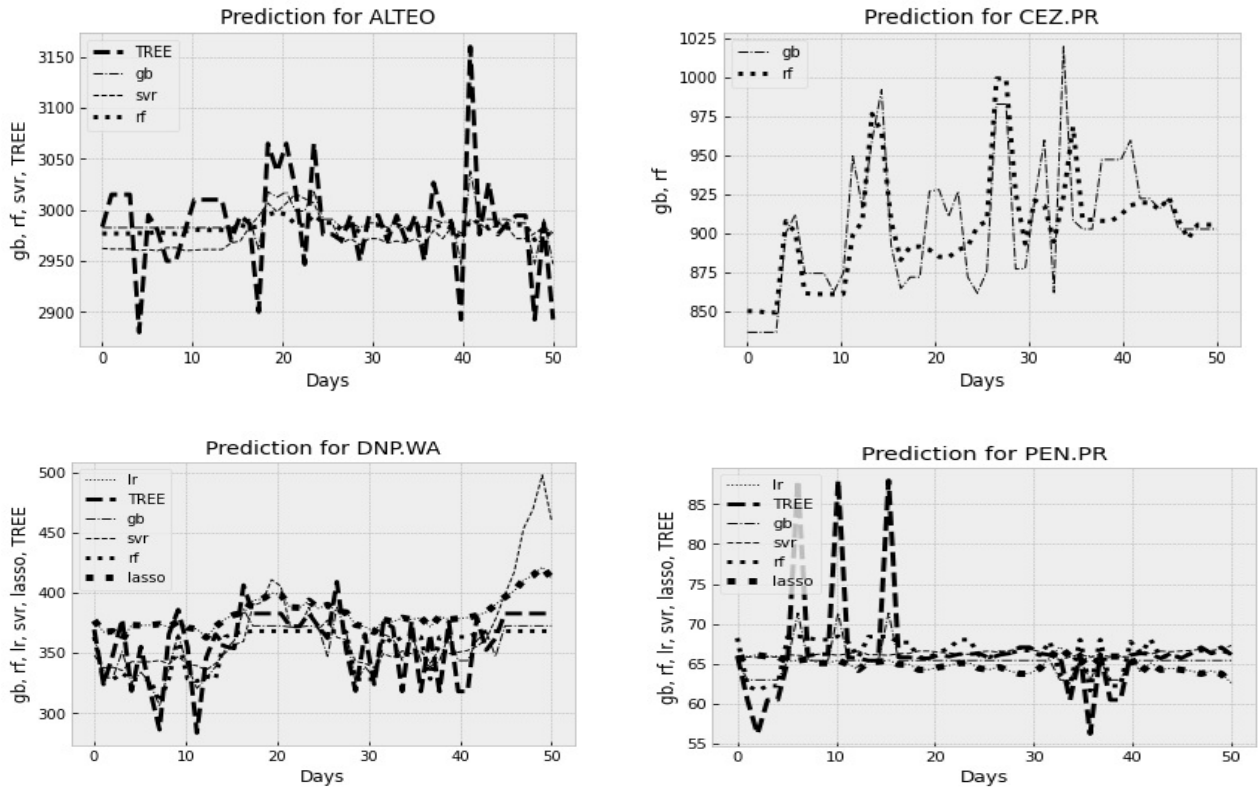



Figure 7. Competing elements of the optimal portfolio

Source: own elaboration.

Regarding other industries, patterns have become more stable, while the applicability of prediction models remains fairly unchanged (Figure 7). At the same time, confidence in the models remains at the same high level (Table 4).

By summarizing the findings of the prognostic analysis, we can draw a preliminary conclusion. Based on our predictive models, we have compelling reasons to consider investing in the proposed IT entities. They are predictable and show an upward trend.

## The Ukrainian IT stock market perspective

The appearance of the Ukrainian IT sector is anticipated. We can model its entry by supplementing the existing agricultural and energy sector firms with Polish IT companies that share a similar business orientation. Considering the significant perception and experience of such Ukrainian businesses in the world, we consider such inclusion to be justified.

Thus, the portfolio is comprised of [('AGT.WA', 0.0), ('KER.WA', 0.0), ('KSG.WA', 0.0), ('OVO.WA', 0.0), ('IMC.WA', 0.0), ('AST.WA', 0.0), ('MHPC.IL', 0.0), ('MLK.WA', 0.0), ('CLE.WA', 0.0), **('IFI.WA', 0.49001)**, **('LVC.WA', 0.50489)**, **('SGN.WA'**, 0.00511)]. Stock Start Date: 2012–01–01; date of study: 2023–03–30. The results of the study are

the following: Expected annual return – 32.6%, Annual volatility – 31.2%, and Sharpe Ratio – 0.98.

Evidently, this financial initiative can be viewed as successful. However, it must be taken into consideration that there are almost no Polish IT companies that are directly comparable to the Ukrainian ones. Nevertheless, by studying the nature of the business and its components, this emulation allows us to make an overall assessment.

## Assessment challenges

What investments should one consider in order to make a wise decision? This question typically requires a review of both market research and accounting data. To identify appropriate assets to be included in the analysis of IT companies' weighted average return of assets (WARA), a linear regression was applied to a sample of 34 listed CEE IT companies. The objective is to determine assets that are suitable for WARA analysis, based on their direct or indirect, yet considerable, impact on profitability. Given the broad scope of these parameters, the existing methodology allows the use of the ROA ratio in instances where calculating the weighted average cost of capital (WACC) is impossible.

Table 5. Significance of the companies' IT assets

| Dependent variable/Factors | g_rec_w beta (t, sign.) | int_rec_w beta (t, sign.) | wc_rec_w beta (t, sign.) | t_rec_w beta (t, sign.) |
|---|---|---|---|---|
| WACC | – 0.372 (–2.3, 0.02) | – 0.009 (–0.06, 0.9) | – 0.09 (–0.4, 0.68) | – 0.26 (–1.1, 0.26) |

Notes: Adj. $R^2$ = 0.339, F (Sig.) = 6.13 (0.001). g_rec_w, int_rec_w, wc_rec_w, t_rec_w – relative weights of goodwill, intangible assets, working capital and fixed assets; goodwill is calculated based on the annual FCF for 2018–2020. The Capital Asset Pricing Model (CAPM) method is used to calculate WACC. Data from 34 CEE IT companies was used.
Source: own elaboration based on accounting data from Yahoo n.d.

Taking into account Table 5, it is evident that if we limit ourselves to solely significant assets, then the WARA for IT companies should be determined exclusively based on one asset: goodwill. This is not unexpected since given the impracticality of accumulating material assets in the IT sector. A traditional example proposed to Economics students in assessing the accounting accuracy of Dell or Apple could demonstrate a negative cash conversion cycle (CCC) for these businesses. This suggests that working capital for an IT business is no longer a reliable reflection of its fiscal situation or makes a substantial contribution to its profitability. In light of the chosen approach, the standard deviation of the relative weight of goodwill (0.23) should be used as an enhancement to the WACC. However, considering data availability, other intangible assets

could be incorporated into this model. Nevertheless, when it comes to intangible assets, the concept of market remains a somewhat subjective distinction.

## Impact of crises

Table 6. Impact of crises on company strategy

| Company, type of neural network | Error | Steps | Model accuracy |
|---|---|---|---|
| IFI.WA; 2 neurons | 1.0716 | 20 | 0.86963 |
| IFI.WA; c(6,2) | 1.0723 | 21 | 0.87254 |
| IFI.WA; c(9,9,2) | 1.0730 | 19 | 0.87632 |
| SGN.WA; 2 neurons | 1.3608 | 23 | 0.95869 |
| SGN.WA; c(6,2) | 1.3628 | 25 | 0.95934 |
| SGN.WA; c(9,9,2) | 1.3616 | 17 | 0.95713 |

Notes: c(6, 2) is a model with two hidden layers with six and two neurons, respectively; c(9,9,2) is a model with three hidden layers with nine, nine, and two neurons, respectively. The accuracy of the model shows the percentage of similarity between the real and model values. The model uses the smallest learning rate (SLR) algorithm.
Source: own calculations.

Company strategies are typically assessed using the 3- or 5-factor Fama–French model. With reference to the table of factors for developed or emerging markets, it could be possible to describe the company's behavior in terms of business prospects, conservativeness/aggressiveness, profitability, and the level of risk. Additionally, due to the substantial discrepancy of developing markets, this model is frequently unworkable. Generally, we come to this conclusion due to the non-compliance with the F-criterion. Regarding the figure, the model failed to yield the desired results for Ifirma JSC and Signify Poland Ltd. Therefore, it is imperative to explore non-linear correlations between a company's stock price and the Fama–French components. A neural network, as indicated in Table 6, is a viable option. In fact, we apply the effect of neural networks on the Fama–French factor table by judiciously adjusting the number of hidden layers and neurons in them.

The model's strength lies in its ability to replicate the effects of a crisis (by adding an extra layer with more neurons than the initial layer), revealing the intensity of its impact. If the model's accuracy is significantly changed when the crisis is incorporated into the model, we can state that the impact of the crisis on the business was substantial. Our presumption is that the pandemic and the war started by Russia have increased the number of neurons (factors) from five to nine, thus signifying the presence of four further factors that could affect business performance.

It is important to note that such assessments are not without ambiguity. Our evaluation has indicated that while Ifirma JSC was negatively impacted by the current economic

difficulties, Sygnity S.A. has remained unaffected. This discrepancy can be attributed to the respective nature of each business – with Ifirma JSC functioning as a digital platform for e-commerce and accounting. It is evident that customer issues are directly correlated with this type of business. Meanwhile, Sygnity S.A. combines both the sale of software and hardware, incorporating spatial data, which makes it much more flexible to any type of crisis. The graphical representation of neural networks is quite clear (Figure 8). The case of two hidden layers with 6 and 2 neurons is displayed accurately below.

In this case, although the impact of crises is evident, it is neither significant nor destructive.

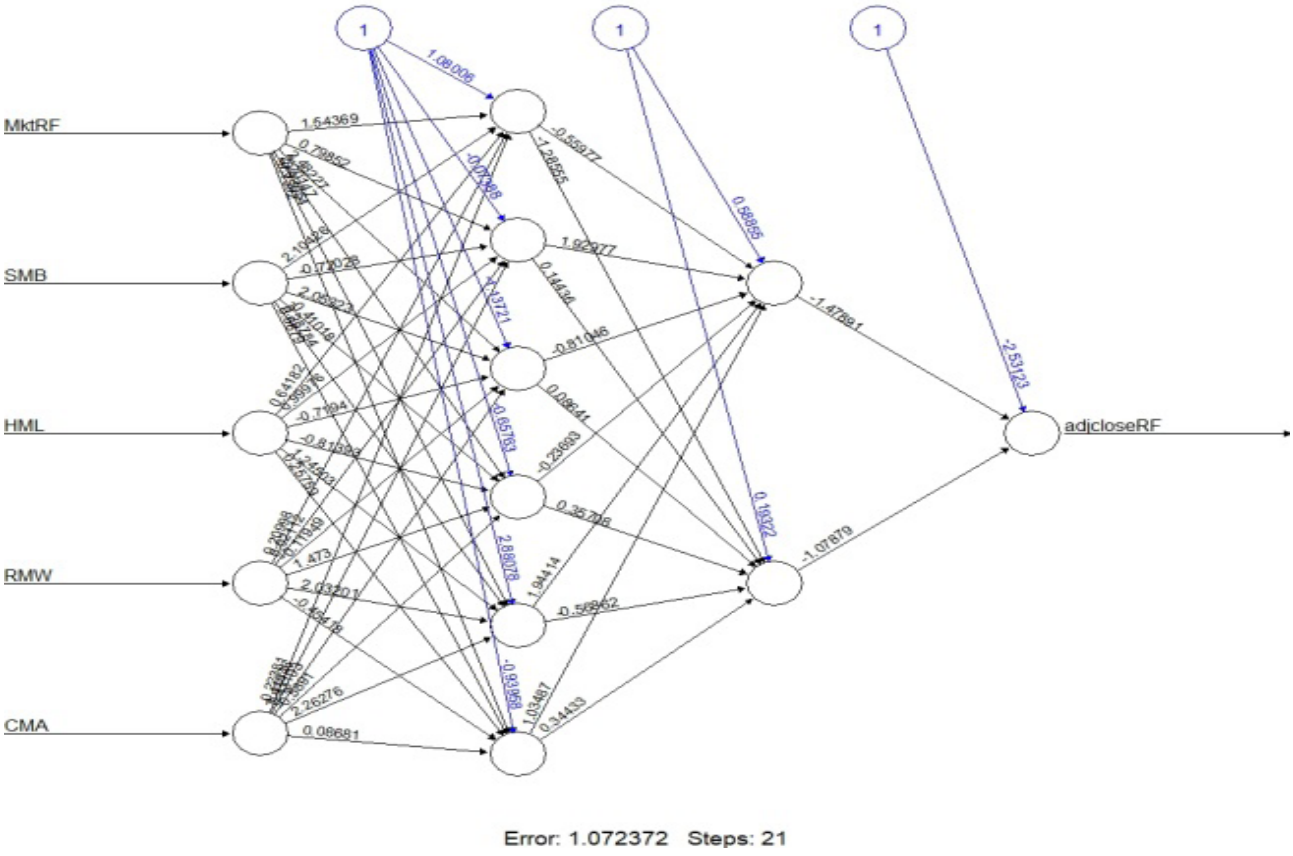



Figure 8. Neural networks in the case of Ifirma JSC

Source: own elaboration.

## Conclusions

Our models indicate that the most profitable investments for businesses in Central and Eastern Europe would be a combination of software, weaponry, the modern energy sector, and a few other industries. To determine an optimal portfolio for this

purpose, the Efficient Frontier technique was employed, focusing on three countries: the Czech Republic, Poland, and Hungary, with a combined portfolio also designed and improved. Both individual optimal portfolios and the combined portfolio contained IT entities. The result was confirmed through the maximization of the Sharpe ratio and the maximization of utility.

The in-depth analysis showed the advantages of companies operating in the software market. Within its framework, the cumulative income and risk of the optimal portfolio ingredients were assessed. In all cases, the IT business withstood the competition offered by other areas.

Machine learning techniques made it possible to verify the specified growth trend and an acceptable level of risk. In fact, machine learning methods proved to be a perfect tool to ascertain whether IT companies from the presented optimal portfolios are predictable businesses worthy of investment. The accuracy of such estimates was more than sufficient.

For the CEE market as a whole, the results suggest that investing in the IT sector should be a top priority. Consequently, the analysis of the German market demonstrates that the CEE markets are following similar paths and emphasizing the same goals.

The successful outcome of simulating the inclusion of Ukrainian IT companies in the national portfolio (using a group of Polish companies as a close analogy in terms of intentions and interaction mechanisms) confirmed the expected success of these companies' shares on the stock market.

However, there are major problems with evaluating the IT assets of companies. A commonly used technique today is WARA analysis, which requires particular attention because of the size of goodwill. Briefly, anyone interested in investing in an IT business must be aware of its reputation. Moreover, if other intangible assets are considered, the question of their lack of appropriate market valuation arises. Furthermore, it is frequently challenging for investors to obtain full knowledge of the strategy behind their chosen investment option.

The use of neural networks and adjusting hidden layers was shown as a useful tool to measure the vulnerability of the selected enterprise to crises. Nevertheless, this approach is sufficiently illustrative only in cases of significant damage to a specific business by the crisis. It may be completely invisible in instances of temporary problems.

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## Priorytetyzacja sektora IT na rynkach akcji w Europie Środkowo-Wschodniej: polityka inwestycyjna, trendy i ukryte perełki

Cel: Głównym celem badań jest przedstawienie rynku Europy Środkowo-Wschodniej jako istotnego elementu globalnego rynku akcji, wykazującego wzorce podobne do krajów rozwiniętych, ze szczególnym uwzględnieniem technologii informacyjnych.
Metody badawcze: Badanie zostało oparte na metodach uczenia maszynowego, analizie ekonomicznej, a także pakietach Python i programie R. Ponadto w celu uzyskania bardziej kompleksowego spojrzenia na rozwój trendów w regionie Europy Środkowo-Wschodniej uwzględniono portfel porównawczy obejmujący niemiecki biznes oraz symulację oceny ukraińskich technologii cyfrowych. Konstrukcja strategii biznesowej zgodnie z podejściem Fama–French została rozszerzona poprzez włączenie sieci neuronowych.
Rezultaty: Wyniki badań przeprowadzonych na podstawie czeskich, polskich i węgierskich firm na giełdach papierów wartościowych sugerują, że polityka inwestycyjna zorientowana na oprogramowanie jest rozsądnym wyborem. Wyniki uzyskane przez spółki IT jednoznacznie wskazują na znaczne korzyści płynące z ich przedsięwzięć giełdowych, a także sugerują obecny trend zaufania inwestorom. Symulacja włączenia ukraińskich spółek IT do krajowego portfela również potwierdza prognozowany sukces. Problem wyceny biznesu IT jest wskazany jako jedna z pułapek inwestowania.
Wnioski i rekomendacje: Zachowanie dominującej pozycji sektora IT, nawet w niepewnych okolicznościach, jest gwarancją stabilnego rozwoju regionu.
Wkład i wartość dodana: Badanie to wnosi wyjątkowy wkład zarówno w ocenę sytuacji, jak i perspektyw sektora IT, poszerzając już istniejący zestaw rozwiązań, nawet w obliczu powtarzających się kryzysów.

Słowa kluczowe: Europa Środkowo-Wschodnia, inwestycje, IT, optymalny portfel, rynek akcji