Universität Zürich[UZH]

Thesis

For the attainment of a

Master of Advanced Studies in Real Estate

Real Estate Investment in CEE Region
Are there any diversification benefits from direct CEE real estate investments to well-established Western European real estate portfolios?

Author: Marek Dobias

Submitted to: Dr. Constantinescu, Mihnea

Date of submission: 28.08.2017

Table of contents

List of abbreviations V

List of figures VI

List of tables VII

Executive summary VIII

1. Introduction 1

1.1 Problem definition 2

1.2 Methods and delimitations 3

1.2.1 Methods 3

1.2.2 Geographical focus 4

1.2.3 Data availability 4

2. Current state of research 5

2.1 CEE region in focus 5

2.2 Time aspects 6

2.3 Direct real estate investments 6

3. Data composition and methodological framework 7

3.1 Boom-bust principle 7

3.2 Economic growth 12

3.3 Qualitative indicators 12

3.3.1 JLL transparency ranking 13

3.3.2 IMD world competitiveness scoreboard 2016 13

3.3.3 GaWC ranking 13

3.3.4 Ease of doing business 14

3.3.5 Fair value index 14

3.4 Direct property index 15

3.4.1 Nominal returns 15

3.4.2 Market value (EUR m) underlying the computation of the index 16

3.5 Methodology 18

3.5.1 Modern portfolio theory 19
3.5.2 Average total return on investment and volatility 19
3.5.3 Weights parameters 20
3.5.4 Covariance 21
3.5.5 Risk of a portfolio 22
3.5.6 Portfolio return 22
3.5.7 Sharpe ratio 23
3.5.8 Correlation 23
4. Results and analysis 25
4.1 Qualitative analysis 25
4.2 Modern portfolio theory 28
4.2.1 Return index 28
4.2.2 Average total return on investment and volatility 33
4.2.3 Covariance matrix 34
4.2.4 Correlation analysis 35
4.2.5 Optimal portfolio analysis 36
4.3 GDP analysis 37
4.3.1 GDP correlations 39
4.3.2 Correlation of GDP and real estate returns 40
4.4 Hypothesis verification 41
4.4.1 Results of qualitative analysis 41
4.4.2 Quantitative comparisons 42
5. Conclusions 44
5.1 Discussion 44
5.2 Prospects 45
Bibliography 47
Appendix I.: Homeownership rate in selected European countries in 2015 50
Appendix II.: Covariance matrix 51

Appendix III.: Poland investment volume 2007 – 2017 52

Appendix IV.: Investment volumes in Europe in 2016 53

Appendix V.: Offices in Europe in 2016 54

Appendix VI.: Returns - IPD data 55

Appendix VII.: Unemployment rate in Europe in the 1st quarter of 2017 56

Appendix VIII.: Inflation, annual growth rate in %, 2007 – 2016 57

Appendix IX.: UK IPD property equivalent yields, 10-year and index-linked gilt yields compared on an annual basis, 1981–2013 58

Appendix X.: Lagged cross-correlation of real estate return and GDP growth 59

List of abbreviations

CBD	Central Business District
CEE	Central and Eastern Europe
ECB	European Central Bank
FDI	Foreign Direct Investment
GaWC	Globalization and World Cities Index
GDP	Gross Domestic Product
IMD	Institute for Management Development
IPD	Investment Property Databank
MPT	Modern Portfolio Theory
MSCI	Morgan Stanley Capital International
OECD	Organisation for Economic Co-operation and Development

List of figures

Figure 1: Available Capital 2
Figure 2: Real estate market cycle vs. economic cycle with average annualized UK returns since December 1986 in % 8
Figure 3: Impact of low interest rates shown in the four quadrant diagram 9
Figure 4: Simulation of GDP growth shown in the four quadrant diagram 11
Figure 5: Nominal rates of return and consumer price inflation 15
Figure 6: Fair value index; Number of markets in each category by region/country 28
Figure 7: Return Index 29
Figure 8: IPD Returns 30
Figure 9: European office total return forecast for 2017 31
Figure 10: Returns of CEE countries and Switzerland 32
Figure 11: Historical CEE investment volume in € bn 32
Figure 12: Average total return and volatility over 3, 5, and 10 years 34
Figure 13: Correlation matrix of direct real estate return index 35
Figure 14: Optimal portfolio Analysis 37
Figure 15: GDP Data 38
Figure 16: GDP Growth Index 38
Figure 17: Correlation Matrix of GDP growths 39
Figure 18: Recent and forecast GDP growth (yoy, %) in the CEE-6 countries 45

List of tables

Table 1: Method overview 3
Table 2: IPD Portfolio structure and market values 16
Table 3: Sectorial constitution of index portfolios 17
Table 4: Correlation Legend 24
Table 5: List of investigated countries 25
Table 6: Return Index Table 29
Table 7: Average total return and volatility 33
Table 8: Correlation of real estate returns and GDP growth 40

Executive summary

Present thesis is investigating commercial real estate investments in Central and Eastern Europe in the time period of 2007 until 2016. The situation on this recently "discovered" market by global real estate investors is analysed with the help of quantitative and qualitative methods. Based on direct returns data an optimal European portfolio is calculated using modern portfolio theory. By maximising the Sharpe ratio we find out the role and position of individual countries of this region. Besides, quantitative and quantitative analysis of economic data of each country is analysed and put into relation with real estate returns with help of cross-correlation analysis.

1. Introduction

The IMD World Competitiveness Scoreboard 2016 states that countries of the Central and Eastern Europe (CEE) became more attractive locations for many companies and have made the most progress in economic competitiveness, states NZZ (Kapp, 2016). According to European Fair Value Index CEE countries have the highest share of under-priced real estate markets (Gralin, 2016, p. 2) and thus they are very attractive opportunities for investors. Richard Curran from CBRE Research (2016) states in Real Estate Market Outlook: "The performance of the Czech real estate market shows no sign of slowing down in 2017. We believe leasing and investment volumes will continue to rise in line with the continued strong macro economic performance of the country. This is the place to be in 2017" (p. 3). The Wüest Partner Global Report (2016) states: "the sustained buoyant sentiment on Prague's real estate market has been carried over into the second semester of 2015. While prime rents showed no major chances, the vacancy rate continued its descent" (p. 3). In the same article Poland is identified as one of most attractive market within Europe for real estate investments for next years. As in previous years, investors focus remained on Poland as commitments achieved their highest level in a decade, with retail property deals accounting for the bulk of the transactions. The sustained inflow of European and overseas capital will ensure that trading continues at its current brisk pace in 2016 (Wüest Partner, 2016). Simultaneously, one of the biggest property groups operating mainly in the CEE region has identified Hungary as next great opportunity in 2017. In the local economic journal (Vacha & Mikulka, 2017) the head of CPI Property Group stated that they are very confident about Budapest because it was long underestimated and investors were very cautious in investing into Hungarian properties due to mainly political instabilities. Taking into account the on-going deals across all real estate asset classes property investments in the three major real estate markets of CEE region have added up to over €4 billion in 2015 and €4,5 billion in 2016 for Poland (Cwiklinski & Wojtczak, 2017, p. 19), followed by €1,9 billion in 2015 and astonishing increase on €3,8 billion in 2016 for Czechia (Hallett, 2016). Hungary shows rather humble numbers in 2015 with €800 million, but doubled in 2016 with €1,7 billion[1] (Robinson, 2016, p. 5).

This was just a short overview of the most actual reports and tendencies in the CEE real estate markets from the most recent months. Despite these positive claims and

[1] For a complete overview and some extended information (investment volumes, vacancy rates, prime rents, net yields etc.) on the current situation on the European market you will find some exhaustive graphics in the Appendix III., IV., and V..

encouraging predictions it is still not that common to have Eastern European properties in Western European portfolios and there is still a limited number of global real estate investors investing in Eastern European real estates, as proven by recent research. The research publication "The Great Wall of Money" shows in Figure 1 that the available capital[2] for investments in CEE countries is still comparatively insignificant compared to Western European countries for 2017 (Wakefield, 2017, p. 11).

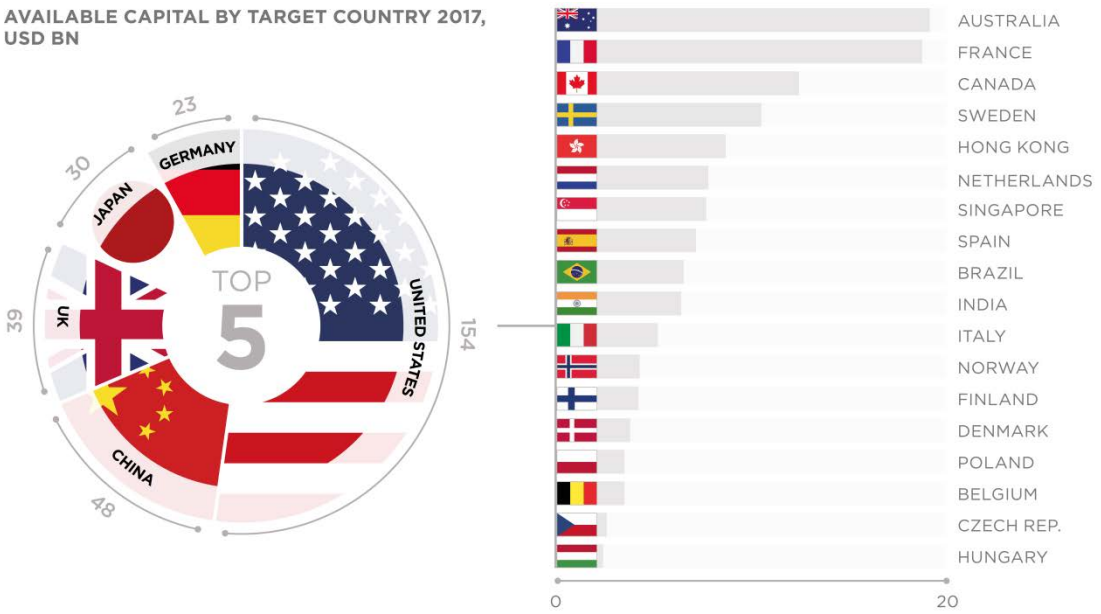


Figure 1: Available Capital (Wakefield, 2017, p. 11)

1.1 Problem definition

"With established office markets such as London and Paris achieving yields of circa 3 per cent at the end of December 2014, investors have the propensity to double their returns in Warsaw or Prague for only slightly higher risk dynamics" (Haran, McCord, M., Davis, McCord, J., Lauder, & Newell, 2016, p.28). There is less of a risk perception today on these markets and which has resulted in the pricing differential looks attractive. Hence, in search for higher returns these markets have been focused on by a wider spectrum of international professional real estate investors. In addition to the market stability offered by these countries they also claim to have steady economic growth prospects thus numbers of real estate investments especially in Poland have raised massively in 2015. These countries have been recognised as a good investment opportunity and they will be consequently the subject of this thesis. The nature of such risk premiums for investing in these lesser established markets could lie in several

[2] Available capital is the amount of capital (equity + debt) estimated to be available for investment in any one particular year.

factors. The problem could lie in several soft factors, be it political and legal insecurity, language barriers, not enough investment opportunities, low maturity of the market, low transparency, poor business environment, or high corruption. Secondly there are facts and figures to be analysed to find out how these countries perform in comparison to more developed western part of Europe.

The latest economic crisis showed us how important the diversification in a portfolio is. First it is essential to understand the principle of a boom and bust of real estate markets. We will look at the theoretical principles and model in the section 3.1 in order to see whether there is a possibility for diversification in the CEE? In present thesis portfolio diversification benefits from incorporating three Eastern European countries into established Western European portfolio will be examined. The focus of this research is based on following hypothesis: are there any diversification benefits from direct CEE real estate investments to well-established Western European real estate portfolios?

1.2 Methods and delimitations

This research is analysing indicators of several countries in order to compare the performance of their real estate markets. Following subsection gives short overview over methods used in this thesis.

1.2.1 Methods

Besides qualitative, statistical analysis will be used, and the boom-bust model with which the last ten years of turbulences on the European real estate markets will be explained. With help of the modern portfolio theory including calculation of targeted values listed in Table 1 as described in portfolio theory (Geltner, Miller, Clayton, & Eichholtz, 2013, p. 538) we aim to find out whether there are diversification possibilities in CEE countries.

Input values	Targeted values
Qualitative values from rankings and benchmarks	Qualitative analysis
Economic growth over ten and twenty-five years	Volatility
Annual returns over three, five and ten years	Minimum Variance
	Sharpe Ratio
	Covariance
	Correlations

Table 1: Method overview

Detailed descriptions of these methods as well as their advantages and disadvantages are presented in the third chapter.

1.2.2 Geographical focus

The whole European continent is the scope of this research; however the focus of this study lies on the CEE region. This is a politically defined term for a group of countries in Central Europe, Southeast Europe, Northern Europe, and Eastern Europe, which were after World War II until 1989 part of the communistic bloc. In the past three decades these countries have gone transition process and most of them entered the European Union in order to converge with the economically stronger Western countries and hand in hand stabilize the peace in Europe. Some of these CEE countries have meanwhile attained the economic levels of Southern Europe in past few years and they are perceived to be relatively stable, similar to western markets. Note also that Czechia is since 2017 the new official short name for Czech Republic and so will be used also in this thesis. However, in some graphs, e.g. in the Organisation for Economic Co-operation and Development (OECD) statistics or some research reports Czechia may be identified as Czech Republic.

1.2.3 Data availability

In section 3.4 the data source for direct real estate returns used for the statistical analysis performed in this thesis is described. To begin it should be mentioned that the ability to assess and evaluate real estate market trends has to some extent been curtailed by availability of these values and limitations in use of these data series. There are mature markets which enjoy a relatively long period of market transparency and thus data are available for longer period of times and for each sector separately. Large markets like the one in the UK or in France offer as well data quarterly or biannually compared to smaller countries with less transactions where these data are only provided annually. Consequently, and to allow for like-for-like comparison across the markets annualised returns of this research encompass the period 2007-2016 inclusive. Furthermore there are sectorial data for most of the countries however, the repartition raster is not uniform, so the comparison between countries is not consistent. In the subsection 3.4.2 in Table 3 we see that the index sectorial constitution is by some countries divided into five groups in contrast to other countries with only two groups and the rest of sectors lie in the group called “other”. Besides, these data are not public and it is difficult to obtain them.

2. Current state of research

There is a lot of literature on the theme of international investment universe, however there is very little focused on the CEE region. Commercial property investments as an investment class do not benefit from the same status in CEE countries as it has in more developed countries like Switzerland, Germany or the United Kingdom. Therefore, this also translates into the amount of research papers and academic literature with focus on this region. Nevertheless, growing interest of professional investors in the CEE region in the last couple of years has triggered the need for more sophisticated research on this theme. This thesis makes reference to several of the most recently published academic research papers and research articles of professional investment bodies and consultancies.

2.1 CEE region in focus

The starting point of this thesis is the academic research paper “European emerging real estate markets” (Haran, et al., 2016) which describes the method which is used also for this research paper. Similar to that this analysis is centred on the performance dynamics of three key European emerging real estate markets namely the Czechia, Hungary and Poland as a benchmark for CEE countries. It determines the rationale for including emerging real estate markets within a Pan-European investment portfolio based on data from 2006-2013. Haran’s article (2016) as well as several other reports state that the central issue of investors is the deficient transparency of these markets (p. 47). This issue will be looked at in detail within the qualitative analysis in section 4.1.

The result of this study suggests that the divergence in recovery timelines across European commercial real estate markets facilitates cyclical exploitation of markets which when combined with distressed asset acquisition presents significant arbitrage opportunities. Real estate investors in the 18 months to the end of December 2014 have actively expanded their investment horizons beyond the conventional “safe havens” in order to bolster the returns performance of their portfolios. In the subsequent section 3.1 a closer look at the recovery timelines is taken.

The findings from this research determine that whilst CEE markets may constitute circa 10 percent of the European market in capitalisation terms, emerging markets afford specific investment characteristics which differentiate them from the more developed real estate markets across Europe. Firstly, it is the specific niche sectoral dynamics of each market. Then it is the developmental diversity resulting in different levels of maturity in this region. This has been observed on high covariation between

investigated countries. The cross-correlation between emerging markets has clearly shown different maturity of real estate markets. With the application of lag-lead correlation it has been proved that although these markets have high covariance between each other they are at different points on the real estate recovery cycle. In comparison, this principle will be applied and the relationship of real estate market performance with overall country economic performance will be reviewed. From this, any implications which can help predict the future of returns will be identified. The major finding of this report is also that the three emerging markets bring added value to European portfolio if the primary investment objective is to minimise risk exposure. That means that emerging markets are bringing into the portfolio diversification benefits through their relative low volatility.

2.2 Time aspects

This time aspect is also the central theme of the article called “After the Fall” (Lizieri, 2013) where the relationship between real estate returns and other asset classes varies over time. In search for diversification, correlations are examined with the help of Markowitz optimizer framework during bear markets in order to be prepared for next crisis as the one in 2007. He states that “the time-varying dependence between real estate returns and the returns from other asset classes under consideration could compromise results from standard optimization exercises; expected portfolio returns might be systematically overstated while risk - particularly downside risk - might be understated” (p. 43). In the conclusions Lizieri (2013) suggests that “shocks - negative shocks - in equity returns are transmitted to real estate returns and have a significant effect. A risk management strategy needs to account for these time-varying influences” (p. 56). An attempt to adopt this concept will be pursued in order to analyse the relationship of economic growth and direct real estate investment returns.

2.3 Direct real estate investments

The article called global perspective on pension fund investments in real estate is analysing the true performance of real estate investments at the level of institutional investors (Andonov, Kok, & Eichholtz, 2013, p. 40). Essentially, it demonstrates the mechanism through which pension funds invest in real estate and suggests that they should avoid disintermediation and aim for the shortest possible investment chain. This only strengthens the hypothesis that direct investments in CEE countries could be indeed suitable as a diversification alternative, even for pension funds.

3. Data composition and methodological framework

There are several country quantitative indicators, which help and guide an investor through the analysis, such as economic performance, unemployment, inflation, net birth rate, net immigration, and many others. For professional real estate investors there are some other more specific data such as rent levels, vacancy rates, yield premiums, etc. All these data are available countrywide or regional. Besides geographical aspects, these can be further detailed across sectors – office, housing, retail, etc. In addition to quantitative data investors usually also consult qualitative data which can be found via various rankings and indexes.

In terms of real estate investments there are three main factors in terms of investment performance; position in the cycle at purchase, economic growth and inflation, ranked in that order. Inflation is an important driver of nominal returns but not the dominant one. Due to the fact that inflation in Europe is at a record low since 2013, it therefore seems that economic growth is the key driver for real estate performance. These findings and the impact of inflation on real estate returns, or in other words so-called inflation-hedging qualities of real estate investments have been further explored by economists (Blake, Goodwin, McIntosh, & Simmons, 2011, p. 6). The quantitative analysis of this research focuses not only on the return performance but also on the economic performance of the chosen European countries. A detailed analysis of direct property returns over last 10 years between 2007 and 2016 is performed. In subsection 4.3.2, these two data series are put into a correlation analysis in order to investigate dependencies between these indicators. The period relevant for such correlation analysis between economic growth and real estate returns is the same 10 years. Additionally, correlations of economic growth between countries are examined over the period of the last 25 years between 1991 until 2016. Furthermore, a qualitative analysis of diverse qualitative indicators is performed. However, this chapter will begin with the theoretical framework through which the thesis tries to assess what happens on the real estate market during the economic cycle and what influence it has on real estate total returns.

3.1 Boom-bust principle

The cyclicality of real estate markets is a well-known concept in real estate literature. Cyclical markets are real estate markets that tend to have larger price moves up and down over the years. Property values move up and down like a roller coaster ride with noticeable peaks and troughs. In this section, the influence of cyclical markets on real estate returns will be reviewed.

The chosen time period of ten years (2007 - 2016) in this research is no coincidence. In the last ten years, markets have experienced the complete set of a real estate cycle movements: starting with the peak into bust, through recovery into boom. The effect of the economic cycle on real estate returns has been statistically proven and is demonstrable in Figure 2, which shows the magnitude of such impact. According to Garcia and Kaufmann (2014) "returns on direct real estate investments have been highest in periods of fundamental recovery. It is thus crucial for investors to get into the recovery cycle early to benefit from above-average returns. Timing matters because, even in the boom period, returns tend to be smaller than in the recovery stage" (p. 25). Figure 2 shows each part of such a real estate cycle with the explanation what occurs on the real estate market. Based on this boom-bust model we will try to identify similar patterns in real estate return indexes of different countries in subsection 4.2.1. Certain indexes can clearly identify similar co-movements as shown on this model, yet some show rather steady behaviour.

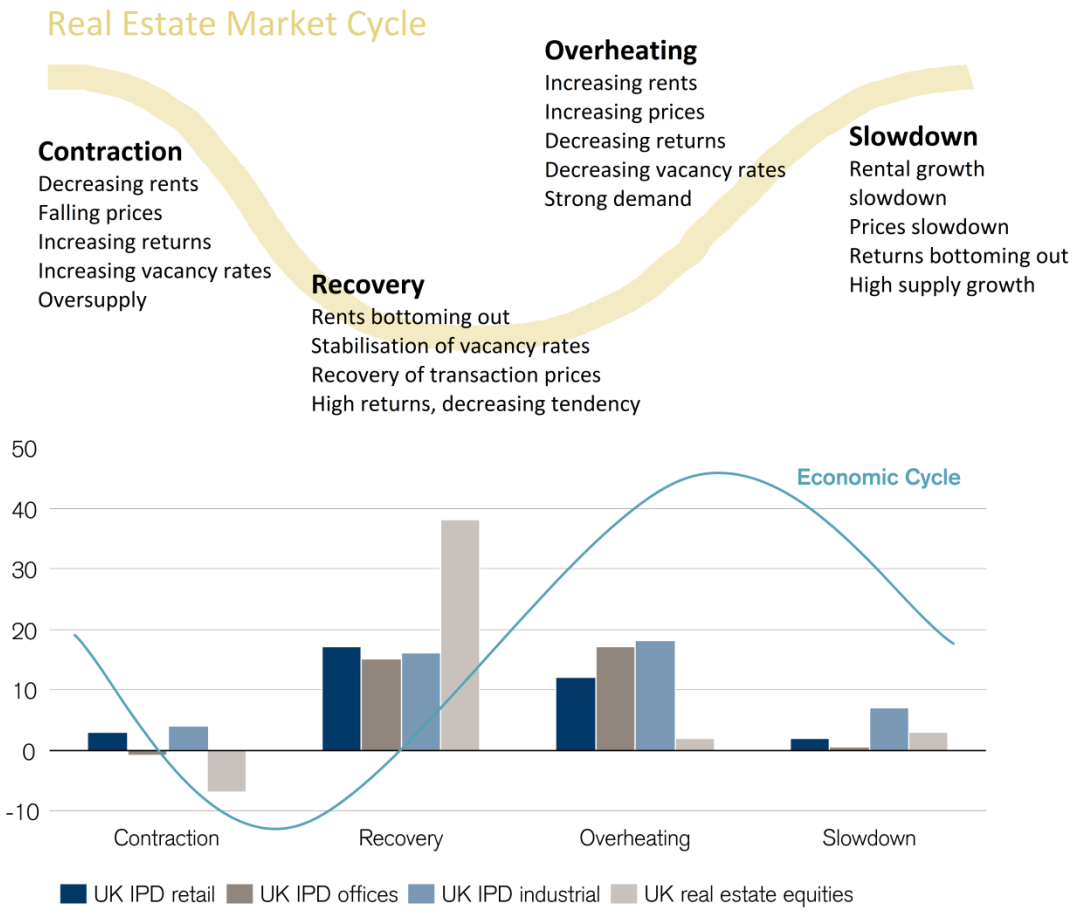


Figure 2: Real estate market cycle vs. economic cycle with average annualized UK returns since December 1986 in % (Garcia & Kaufmann, 2014, p. 25)

In order to understand the search for equilibrium, meaning what is happening during the boom and bust phase of the real estate market cycle one has to consult the conceptual framework of real estate markets (DiPasquale & Wheaton, 1992, pp. 181-198). Figure 3 depicts the three components of the system: the space market, asset market and development industry. The additional stock adjustment curve in the fourth quadrant links the amount of newly constructed space and the existing supply of space. This graph allows for the simultaneous examination of the effect on the long-run equilibrium within all three components. The rectangle whose side are horizontally and vertically connected between these four functions represents the equilibrium. Where the sides of this rectangle cross the four axes represents the equilibrium stock of built space C*, rent R*, property prices P*, and the rate of new construction in the market C* (blue points).

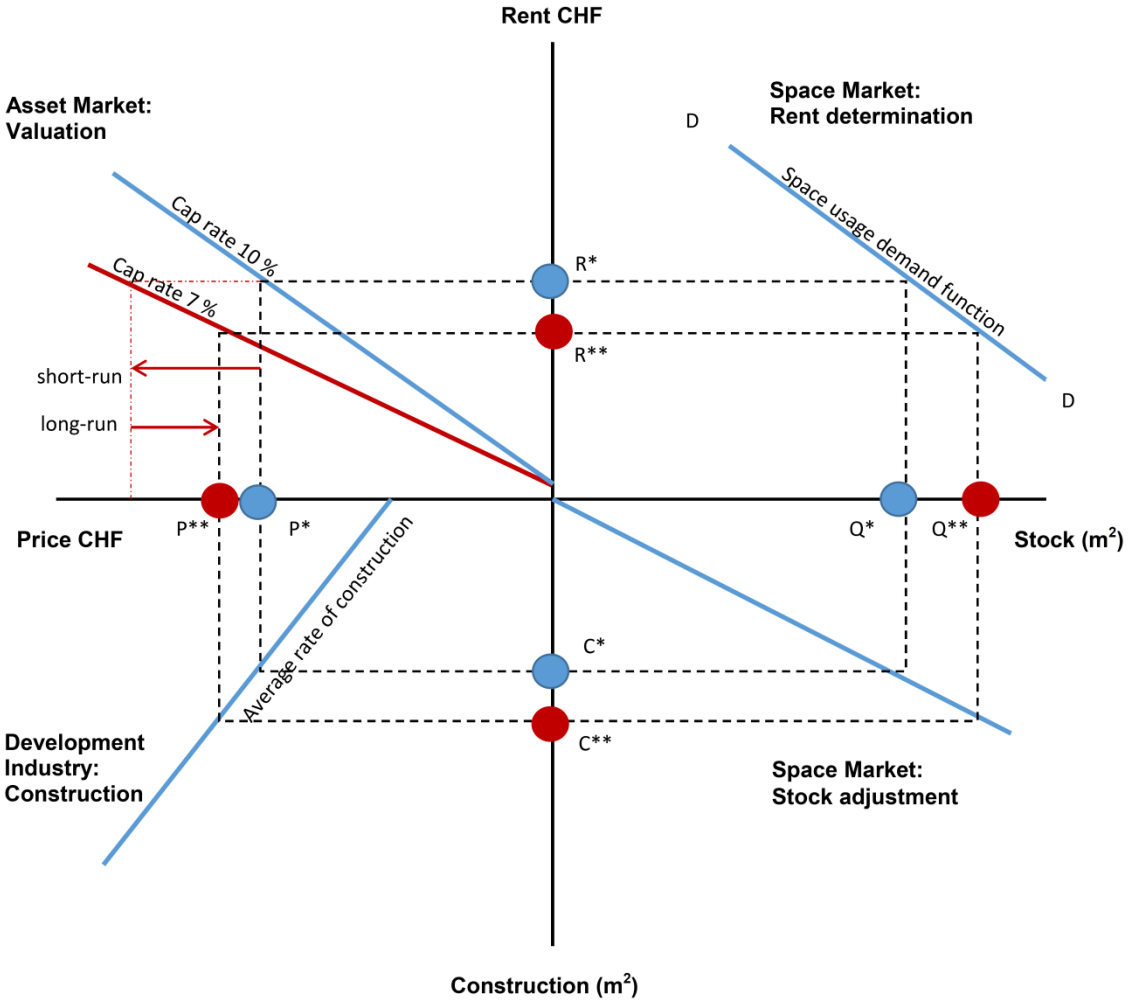


Figure 3: Impact of low interest rates shown in the four quadrant diagram (DiPasquale & Wheaton, 1992, pp. 181-198)

As a result of the financial crisis in 2007, one of such boom-bust triggers in 2009 was decreasing interest rates as a product of monetary policy of European national banks.

They were reacting to a deflation threat and they were stimulating the recovery phase of the economy. As bond rates started to fall, cap rates on the real estate market followed. In the example presented, suppose that the interest rates decreased and the prevailing cap rates have moved down three points from 10 to 7 percent. This represents a substantial upward revaluation of property. After short-term price shock, the new long-term equilibrium is found at P**. The new rectangle based on the new 7% cap rate function is now connecting all four quadrants and creating the new long-term equilibrium on the market. Note that this new equilibrium involves a substantial increase in the amount of built space, which reflects the effect of a real estate development boom that brings the stock of space up to the new Q** level. This is the physical capital result of the flow of financial capital into the real estate asset market caused by the shift in investor preferences toward real estate assets. This is an actual depiction of the last five years in Europe, which will be analysed further in subsection 4.2.1. As it is now known, according to the boom-bust model returns are in this case decreasing. Due to new inflowing capital into real estates, real estate prices are increasing and as a result we can expect stagnating or decreasing rents. Even though returns are decreasing, they are still beating other investment classes with similar risk/return ratios as the difference between total return and any other investment alternative for example bonds is historically at the highest point, for reference see Appendix IX..

The question is what happens in subsequent years when the interest rates will start to increase and the capital will flow out into other traditional investment classes like stocks and bonds. Is there a next bust coming and does that impact the whole European continent?

- What are the differences between countries and is there any diversification possibility within the European region?
- Can the real estate markets of CEE countries be the new alternative for investors?

When building a long-term real estate investment portfolio the idea is to identify and choose wisely, namely, countries which offer the best diversification opportunities. Considering that the low interest rates phenomenon is widespread throughout Europe one has to look at other performance indicators or influences which can help distinguish

between countries and find those which could behave differently than others in the future and balance possible losses.

The most distinguishing factor is the productivity of the country and its growth – positive or negative. The four quadrant diagram can also simulate this effect and different results are attained when decreasing the cap rate. In the above example it can be observed that when the cap rate is decreased, the mass of capital flowing into the real estate system expands. In contrast to that, Figure 4 shows that the economic growth stimulates the demand for space. This results in shortage of existing space stock Q* and that leads to higher rents R***. By stable cap rate we become higher P***, which stimulate higher construction C*** and thus new space stock Q***. In the long run it means higher rents and higher property prices, which leads to higher total returns.

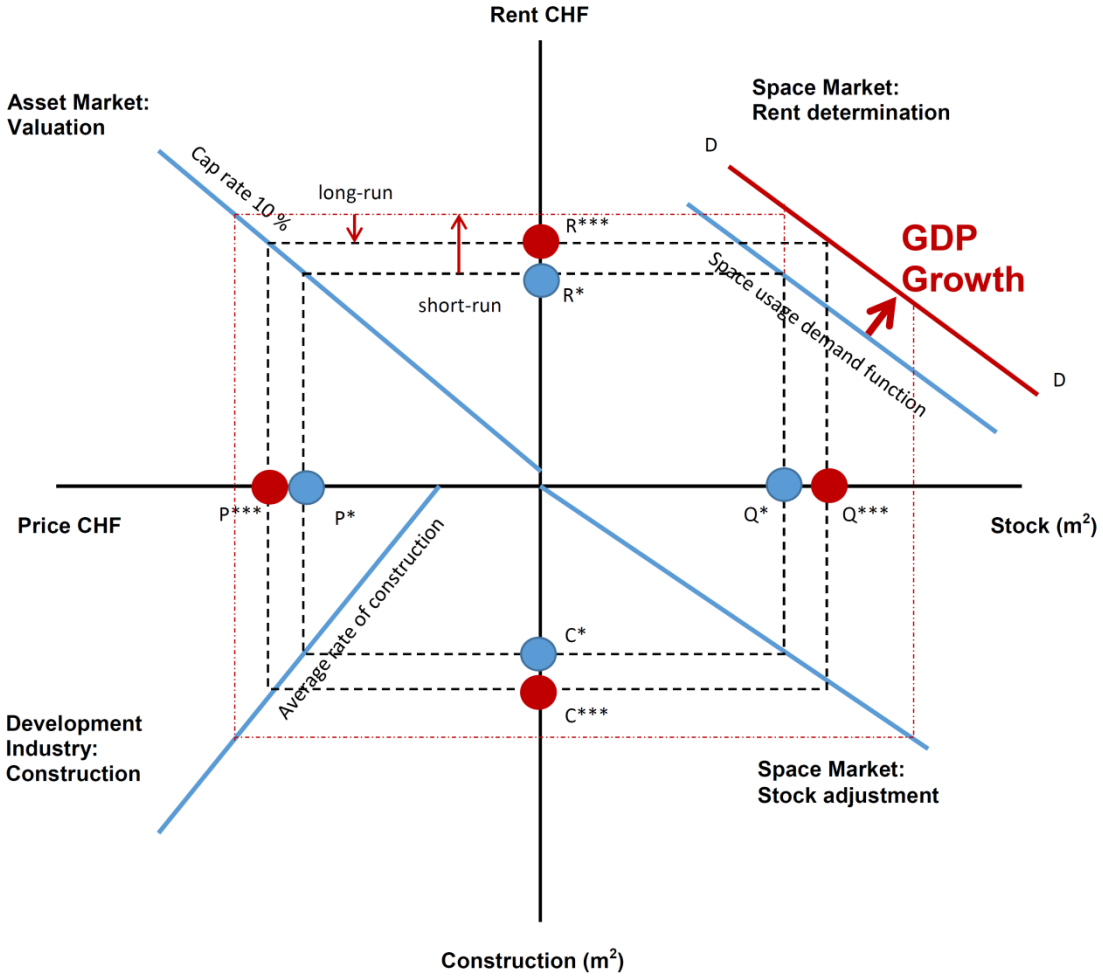


Figure 4: Simulation of GDP growth shown in the four quadrant diagram (DiPasquale & Wheaton, 1992, pp. 181-198)

3.2 Economic growth

Gross Domestic Product (GDP) is one of the primary indicators used to gauge the health of a country's economy. It represents the total dollar value of all goods and services produced over a specific time period; you can think of it as the size of the economy. It is the monetary value of all the finished goods and services produced within a country's borders in a specific time period. In this study real GDP per head in dollars per year will be used. While nominal GDP ignores inflation and deflation real GDP is a better measure for comparison.

Property and inflation research report (Blake et al., 2011, p. 6) states several implications, which are relevant to this study. Firstly, GDP growth next to inflation is one of the major factors in terms of investment performance. The total returns to the different sectors and to alternative assets, and their relative volatility, behave differently in the face of changes to inflation and GDP growth. In the second part of this study the relationship between GDP and real estate total returns will be examined; additionally, it will be reviewed how this relationship differs from country to country. Furthermore, findings of this study show that the best scenario for property is the High Growth-Low Inflation associated with the non-inflationary constant expansion era. This is the situation that can be recently observed in the CEE region[3].

3.3 Qualitative indicators

There are several other important indicators which an investor reviews when comparing investments in different countries. In addition to the analysis of the economy indicators, investors look also in detail at the quality indicators. For this review, five of the most useful rankings and indicators have been chosen. These clearly depict the level of risks when doing business in countries and allow investors the ability to compare amongst countries.

The importance of these quality indicators and their impact on the performance of the investment may be initially unclear; however, these indicators carry valuable information, mostly non-numerical data, which are usually difficult to assess and compar. Thus, they play a key role when assessing risk during investment decisions and from that resulting risk premium. There are indicators for political risks, governmental efficiency or legal issues during transaction process or more specifically for example the enforceability of contracts.

[3] See Appendix VIII.

Furthermore, this data have also direct impact on some components of our four quadrant model and thus on the total performance of real estates. Most obvious are factors, which are directly linked to eventual GDP growth and thus influencing the space market quadrant as previously highlighted in section 3.1. These are diverse economic performance and business environment indicators, as well as for example the market competitiveness. For that there are two business oriented rankings of Institute for Management Development (IMD) and Doing Business index. The demand deviations in space market and more specifically in the office market in global cities is also very well analysed in Globalization and World Cities Index (GaWC). For the asset market the pricing of properties is crucial and this is monitored by the Fair Value Index measuring the price levels on various real estate markets. The development industry and construction quadrant is influenced by regulatory and legal constraints such as land use planning, building and construction controls, development and construction legislation and building permit processes. These can be found in the Jones LaSalle Transparency Index. All these will be described detailed in the following subsections and results discussed further in section 4.1.

3.3.1 JLL transparency ranking

JLL Global Real Estate Transparency Index is an essential guide for companies operating in foreign markets. It provides comprehensive country comparisons allowing real estate investors, developers and corporate occupiers to evaluate the complexities and risks associated with operating or investing in foreign markets. It covers five main influence fields. These are real estate performance measurement, data availability, governance, transaction processes, and legal and regulatory environment.

3.3.2 IMD world competitiveness scoreboard 2016

The IMD ranking is based on the evaluation of statistical and economic data together with a survey among business leaders. There are four areas assessed: economic performance, political and governmental efficiency, business efficiency and infrastructure. The economies are ranked from the most to the least competitive. The scores shown in Table 5 on page 25 are actually indexes (0 to 100) generated for the unique purpose of constructing charts and graphics.

3.3.3 GaWC ranking

Lizieri and Pain (2014) suggest that the “analysis at the national level is also, to an extent, misleading due to the spatial fixity of real estate investment. Real estate investment – whether in the form of development, acquisition or finance and funding –

takes place in particular locations: office investment occurs in and around cities. Thus, the global urban system forms a vital context for an understanding of real estate investment flows" (p. 441). To investigate this matter GaWC perform research of the external relations of world cities and thus examines the city's interconnectedness in the space of flows. It is the leading think-tank on cities in globalization and has diversified into related subjects where concern for intercity relations intersects with research on issues concerning, for instance, international business, sustainability, urban policy, and logistics.

3.3.4 Ease of doing business

Doing Business project provides objective measures of business regulations and their enforcement across 190 economies and selected cities at the subnational and regional level. This project was launched in 2002 and it looks at domestic small and medium-size companies and measures the regulations applying to them through their life cycle. (Doing Business, 2016, p. 1) Even though the methodology is not explicitly designed for the purpose of foreign direct investments (FDI) Anderson and Gonzales (2012) presents evidence of a significant relationship between the Doing Business indicators and FDI flows. Cross-country correlations show that FDI inflows are higher for economies performing better on the Doing Business indicators (p. 49).

3.3.5 Fair value index

The Cushman & Wakefield Fair Value Index launched in August 2010 measures the attractiveness of European property markets on a relative pricing basis compared to government bonds. It assumes a five-year hold period. Fair value is the value at which an investor is indifferent between a risk free return and the forecast return from holding property, taking into account the extra risk of investing in the property asset class. When a property price is at fair value, an investor is being adequately compensated for the risk taken in choosing to purchase real estate; similarly, when the property price is below the fair value price, an investor is being more than compensated for the risk taken in choosing to purchase real estate. When buying at or below fair value, an investor does not necessarily buy at the bottom of the market. Fair Value analysis focuses on prime assets and a five-year investment horizon, and hold for the market overall; individual transactions may provide opportunities and risks beyond the average market view (Gralin, 2016, p. 2).

3.4 Direct property index

This study utilises data from the Investment Property Databank of the Modern Index Strategy Indexes (MSCI) to measure direct property market performance. For more than 40 years, MSCI's research-based indexes and analytics have helped the world's leading investors build and manage better portfolios. MSCI serves 98 of the top 100 largest money managers. They produce and compute real estate market return measures and performance benchmarks to address the needs of real estate and multi-asset class institutional investors. IPD (Investment Property Databank) property market indexes are based exclusively upon retained standing investments in completed properties. (MSCI, 2014, S. 4). Total returns are annualised over three-, five- and ten-year periods to provide a relative comparison of the different Western European portfolios over short, medium and long-term positions. Sector weights are calculated by aggregating the capital value of individual assets across the main property types. This illustrates the composition of the index and whether there is a heavier concentration in a particular property sector thus having a greater impact on the overall index performance (MSCI, 2017, S. 2).

3.4.1 Nominal returns

Annual IPD returns re shown in Appendix VI.. These build the basis for the modern portfolio analysis in this paper. The direct property index is computed at the building level and excludes properties held indirectly through investment funds, the impact of debt, fund management fees, taxation and cash. For comparison reasons of cross border investments the research is based on nominal returns. The concept of nominal and real returns is shown on the following Figure 5.

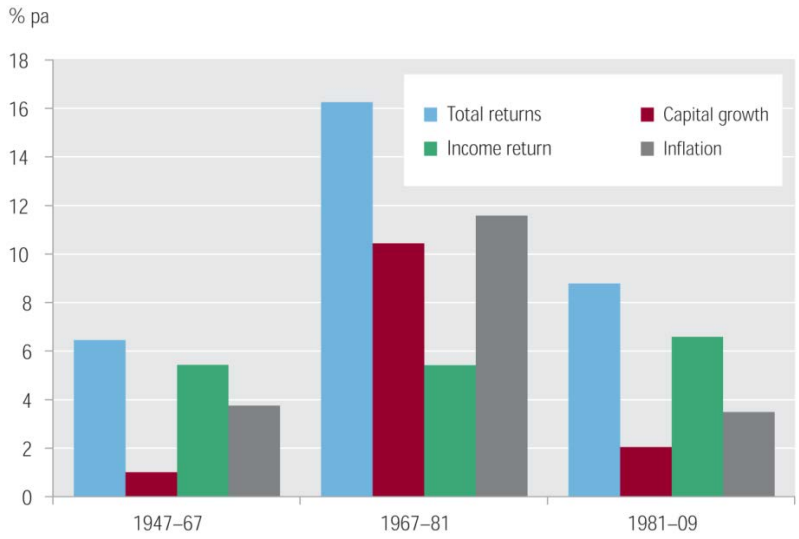


Figure 5: Nominal rates of return and consumer price inflation (Blake et al., 2011, p. 15)

The impact of inflation on real estate returns is exhaustively described in article called property and inflation (Blake et al., 2011, p. 6). Furthermore, currency could possibly have an even more significant impact on nominal returns than inflation. Currency hedging between Eurozone countries would be zero; on the other hand, from Switzerland to Poland, there would be much higher fees needed. Allowing a minus 0,5% or 1% for the currency-hedging of the portfolio could be an option, however, as this research looks objectively at cross-border investments, to stay neutral, any currency hedging premiums is rejected. Nevertheless, this issue has to be looked at in every case separately.

3.4.2 Market value (EUR m) underlying the computation of the index

The following Table 2 shows the structure and a market value of portfolios underlying the computation of the index in millions of Euros.

	Market Value (EUR m)	Nr. of Portfolios	Nr. of Properties	Av. Property Value (EUR m)
Switzerland	86.366,06	37	4014	21,6
Czechia	2.013,00	14	111	18,1
Poland	4.796,00	23	210	22,8
Hungary	732,00	9	57	12,9
Germany	50.312,00	90	1796	28,0
Austria	6.582,00	15	334	19,7
Belgium	5.957,00	23	238	25,0
Denmark	6.762,37	90	1796	3,8
Spain	20.501,00	40	511	40,1
France	127.829,00	109	5944	21,5
Italy	18.163,00	53	1512	12,0
Netherlands	38.228,00	72	4027	9,5
Norway	13.642,42	16	429	31,8
Portugal	7.249,00	30	572	12,7
Sweden	72.676,29	48	3937	18,5
Ireland	8.519,00	13	440	19,4
U. Kingdom	229.768,18	272	22530	10,2

Table 2: IPD Portfolio structure and market values (MSCI, 2016)

It is to be expected that the significance of the index varies from country to country. This could be due to size of the market, transparency level or maturity of the real estate market in the corresponding country. The first batch of countries with very high level of maturity and transparency such as Switzerland, the United Kingdom, France, Germany, Netherlands and Sweden has thousands of properties underlying the index portfolio. The remaining countries have a rather moderate number of properties in the index portfolio, relative to the size of the country. Thus, data from these countries are of a

poorer quality and require further analysis and verification. One of the outliers could be data from Denmark where the average property value is about five times lower than the rest. This could have an influence on the results as obviously the building parameters in the portfolio are not comparative to portfolios of other countries. The same we could also say about Spain with relatively few buildings with relatively high average property value reaching the double of the average. This means that the data of Spanish IPD portfolio are probably mostly from high-rise or relatively huge complexes and the data significance in relation to for example Portugal is questionable. Also, the number of portfolios and number of properties of all three CEE countries is relatively low; this is due to the low maturity and size of the market. The transparency of these markets was some years ago also a problem, however nowadays not anymore.

	Retail	Office	Industrial	Residential	Hotel	Other
Switzerland	15,6%	29,8%	2,0%	47,2%	1,3%	4,2%
Czechia	18,6%	40,5%	38,0%			2,9%
Poland	37,7%	30,5%	30,9%			0,9%
Hungary		31,8%	41,0%			27,2%
Germany	28,3%	45,0%	8,3%	11,3%	3,6%	3,5%
Austria	17,9%	39,0%	2,1%	27,5%	2,1%	11,4%
Belgium	14,4%	58,5%	7,3%			19,8%
Denmark	24,5%	62,2%	1,7%	9,3%		2,3%
Spain	37,6%	45,4%	7,7%			9,3%
France	19,0%	56,5%	5,2%	11,5%	0,7%	7,0%
Italy	24,6%	56,2%	4,5%	9,0%	2,9%	2,8%
Netherlands	22,3%	13,4%	6,4%	54,2%		3,6%
Norway	20,8%	63,2%	5,7%		4,2%	6,1%
Portugal	69,2%	16,3%	5,9%			8,6%
Sweden	14,8%	50,9%	4,1%	16,0%	2,2%	12,1%
Ireland	22,7%	67,9%	5,6%			3,8%
U. Kingdom	40,8%	26,5%	16,9%	6,0%	2,0%	7,8%

Table 3: Sectorial constitution of index portfolios (MSCI, 2016)

In order to dig deeper the sectorial constitution of the portfolios should be examined. In the Table 3 we can see the different focus, the real estate investment markets have, in each country. First interesting observation is that very developed and strong real estate markets with good performance in Switzerland, Netherlands and Austria do have very high share of the portfolio investment in residential sector. It is due to the low home ownership rate, which means high rent rate (see Appendix I.). The solid lease market is based on good legal stability and flexible workforce, which is mostly the opposite in CEE countries. There are very few residential investments in the CEE region as the home ownership rates in these countries are traditionally much higher than in Western

Europe. This is slowly changing as well, mostly in CBDs (Central Business Districts) of major CEE cities like Warsaw, Prague or Budapest have become regional hubs for international companies and their service or shared centres. These need international flexible workforce, which consequently leads to the boost of the residential lease market. However, a systemic risk with office investment in such global cities has been extensively studied. The evidence examined shows a very clear concentration of office investment, strongly associated with a city's global and financial status. It also demonstrates that return volatility is linked to global financial status and that there is a strong common factor in city office market returns (at least for Europe), with the strength relating to the degree of integration with the global financial and producer services networks (Lizieri & Pain, 2014, p. 452).. In the section 3.3 we looked closely at the GaWC ranking in which Warsaw and Prague are in last ten years usually ranked in the Alpha group of cities. This can be seen by an increasing share of office investment in these countries. As much as in office there is an unusually large portion of the investment share in industrial buildings. These are for example large logistic centres of big communication and distribution companies, which were erected in recent years in CEE countries due to relatively low land prices and cheap workforce. These centres act as a distribution centres for the whole of Central and partly also for Western Europe.

3.5 Methodology

The analysis of market data is performed on a portfolio level, or so called macro-level. Investment decisions on macro-level are considering overall investment portfolio which includes an investor's entire net wealth. In this research, this portfolio is reduced to direct real estate assets and proceeded analysis and comparisons are performed with regional focus of investments. Mixed asset portfolio in the sense of portfolio incorporating indirect real estate investments as well as other asset classes (shares, bonds, and alternatives) is not dealt with in this thesis.

The macro-level investment decision concept, or in economics literature (Schulte, 2008, p. 783) known as the portfolio level of the real estate investment management envelopes two main operational arenas, which refer to investor's decision and management of many individual properties, so called aggregates of properties. Firstly, it is the strategical level where portfolio strategy is defined and updated. It consists of long-run decisions, where general direction and objectives are set for the portfolio. On the other hand, there is the tactical level where investors seek for short-term opportunities using the momentum in markets. In other words, it is about the right timing when buying and

selling properties and furthermore using econometric forecasting of the space and asset market. This thesis focuses on the strategical part of investment management, where overall allocations are specified.

3.5.1 Modern portfolio theory

For strategic allocation the most widely used tool is modern portfolio theory (MPT), a hypothesis designed by Harry Markowitz. It is an investment theory based on the idea that risk-averse investors can construct portfolios to optimize or maximize expected return based on a given level of market risk, emphasizing that risk is an inherent part of higher reward. It is one of the most important and influential economic theories dealing with finance and investment (Geltner et al., 2013, pp. 520-542). The goal is to find the ideal portfolio of with ideal weighing of assets. This will be computed based on series of historic returns. The iteration process is calculated with focus on either optimising the risk/return ratio (Sharpe ratio maximisation) or minimising the standard deviation of the portfolio (Minimum variance). In the statistical analysis both have been computed, however in this thesis we focus on the Sharpe ratio coefficient. Detailed results of minimizing risk exposure can be seen in Haran's research article (Haran, et al., 2016, p. 45).

3.5.2 Average total return on investment and volatility

The most basic and complete measure of periodic return is so called total return. It includes the positive or negative change in the capital value of the asset during the period and any income or expenditure paid in or out by the asset to the investor during the same period. In this thesis total return is referred to the period of one year, so called annual return.

$$r = \frac{CF_t + V_t - V_{t-1}}{V_{t-1}}$$

where r equals the total return on the asset

CF_t equals the net amount of cash flow or income paid out during period t

V_t equals the market value of the capital asset as of the end of period t

V_{t-1} equals the market value of the capital asset at the end of previous period

However, the main issue of investors apart from the expected rate of return on their investment is the risk, which accompanies such investment. Qualitative evaluations are

very individual and do not provide comparativeness between assets. In order to compare and evaluate risk of any investment the investor tries to quantify how probable it is that he receives every period his expected return. In modern theory this risk is put in direct relation to the expected returns and the probability of loss of such return. The most widely used statistical measure is standard deviation known as well as the volatility. It is shows the probability distribution of the future return possibilities.

$$\sigma = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}(r_t - \bar{r})^2}$$

where σ equals the standard deviation

T equals the number of all investigated periods

r_t equals the return during period t

$\bar{r}$ equals the mean of all return values

3.5.3 Weights parameters

Some limitations of the methodology need to be highlighted. There are many assumptions and conditions behind the concept which are in effect its deficiency when applied in real world conditions. One of the market related issues in this theory is the assumption of a perfect equity market. Firstly, there are ideal market conditions as perfect divisibility of assets, free accessible information, no tax, transaction costs or market access restrictions. This is followed by unlimited credit funds and unlimited investment possibilities. The latter condition is however, the impetus for this thesis. As we know real estates are a limited good and the number of available investment possibilities goes hand in hand with the pricing of such commodity.

In Switzerland and many Western European cities this has been an issue in recent years as there is very narrow supply of investment real estates or they were overpriced. Despite the moderate economic growth of the past few years, the office property market in Switzerland has shifted to a position of oversupply of space. In residential sector, supply is galloping ahead of demand for space (Boppart, Fries, Hasenmaile, Hürzeler, Kaufmann, Lüthi, Rieder, & Dr. Waltert, 2016, p. 23). These are not very favourable conditions for new real estate investments. Hence, the focus of this thesis is the question whether CEE countries can eventually offer an adequate alternative for diversification of Pan-European portfolios.

In order to make the step between ideal market with unlimited investment opportunities and the reality we can do this with use of computational restriction in implementing a maximum possible weight percentage of the corresponding country allocation within the overall portfolio. This can be done either evenly or gradually depending on factors such as country size, number of inhabitants or size of real estate investment market. In this paper the allocation is limited evenly between all countries. Our focus lies on CEE countries and their positioning with regard to the whole continent. The chosen percentage of 8% is a result of an iterative method. The goal of the iteration was to find out the right weighing where CEE countries play their role in such pan European portfolio and thus we can observe exactly the moment where their input into the portfolio is the greatest.

3.5.4 Covariance

The covariance matrix shows us how two indexes move together on average. If there is a positive covariance, the two indexes tend to move together. When one has a high return, the other tends to have a high return as well. If the result were negative, then the two indexes would tend to have opposite returns – when one had a positive return, the other would have a negative return. In this thesis we use covariance to find the standard deviation of a mixed portfolio and correlation, which gives investors better insights in co-movements. For calculation of a sample we use excel formula COVARIANCE.S(), which correspond to the mathematical formula:

$$COV_{ij} = \frac{1}{T-1}\sum_{t=1}^{T}\left[(r_{it} - \bar{r_i})(r_{jt} - \bar{r_j})\right]$$

where COV_{ij} equals the historical covariance between asset i and j

r_{it} equals return of asset i the return during period t

r_{jt} equals return of asset i the return during period t

$\overline{r_i}$ equals the mean of all return values of asset i

$\overline{r_j}$ equals the mean of all return values of asset j

T equals the number of all investigated periods

3.5.5 Risk of a portfolio

The standard deviation of portfolio is the measure of risk, and along with the covariance matrix, is essential when calculating the Markowitz optimization algorithm. Typically, you would want to invest in countries with markets that move in opposite directions. If the chosen countries move in opposite directions, then the risk will be lower while providing the same amount of potential return on average.

$$\sigma_p = \sqrt{\sum_{i=1}^{N}\sum_{j=1}^{N} w_i w_j COV_{ij}}$$

where σ_p equals the standard deviation of the portfolio

COV_{ij} equals the historical covariance between asset i and j

w_i equals weight (or share) of the asset i in the portfolio

w_j equals weight (or share) of the asset j in the portfolio

N equals the number of constituent assets in the portfolio

3.5.6 Portfolio return

Portfolio return is the monetary return experienced by a holder of a portfolio. Generally, portfolio returns can be calculated on a daily or long-term basis to serve as a method of assessing a particular investment strategy. Cash flows and capital appreciation are the main components of portfolio returns. Portfolio returns can be calculated through various methodologies such as time-weighted and money-weighted returns. In present thesis portfolio return is calculated on annual basis as the weighted average of all returns on assets included in the portfolio. The individual weights are proportional to the share the corresponding asset value on the overall portfolio value.

$$r_p = w_1 r_1 + w_2 r_2 + \cdots + w_N r_N$$

where r_p equals the rate of return on the portfolio

w_i equals the weight (or share) of the asset i in the portfolio

r_i equals the rate of return on assets i in the portfolio

N equals the number of constituent assets in the portfolio

3.5.7 Sharpe ratio

The Sharpe ratio is the average return earned in excess of the risk-free rate per unit of volatility or total risk. We use it to compare the change in a portfolio's overall risk-return characteristics when a new asset, in our example a new country is added to it.

The higher the Sharpe ratio is the better. Although one country is showing up as a risky investment as a standalone exposure, it could actually improve the risk-return characteristic of the combined portfolio of other countries, and thus adds a diversification benefit. Consequently, if the addition of the new investment in a new country lowered the Sharpe ratio, it should not be added to the portfolio.

There are some alternative risk-adjusted return methodologies as the Sortino ratio, Return over Maximum Drawdown, and the Treynor ratio. Sharpe ratio is however most widely used in the real estate industry and relevant scientific papers (Haran, et al., 2016). There are two types of Sharpe ratios, the ex-ante and the ex-post. The first one is calculated with expected returns; however we use the latter one which we calculate with realised returns.

$$SR = \frac{r_p - r_f}{\sigma_p}$$

where *SR* equals the Sharpe ratio

r_p equals the rate of return on the portfolio

r_f equals the risk-free return rate

σ_p equals the standard deviation of the portfolio

3.5.8 Correlation

Similar to covariance the correlation shows how two investments move together, but with the advantage that correlation determines also the intensity of this relationship and so different return series can be put in relation to other investment classes. Correlation is calculated by putting covariance in relation to standard deviations of each return series:

$$C_{ij} = \frac{COV_{ij}}{\sigma_i \sigma_j}$$

where C_{ij} equals the correlation between asset i and j

COV_{ij} equals the historical covariance between asset i and j

σ_i equals standard deviation of the asset i

σ_j equals standard deviation of the asset i or j

The correlation has the same sign as the corresponding covariance but is always a measurement value between -1 and 1, and it adds a strength value on how the returns move together. If the correlation is 1, they move perfectly together, and if the correlation is -1, investigated returns move perfectly in opposite directions. If the correlation is 0, then they move in random directions from each other. In order to facilitate the overview of the whole matrix a legend has been set based on following value indicators shown in Table 4.

HIGH CORRELATION	
min	0,70
max	0,90
min	0,9000001
max	0,9999999

LOW CORRELATION	
min	-0,3
max	-0,1
min	-0,1
max	0,1
min	0,1
max	0,3

not relevant	
Min	-1
Max	-0,91
Min	-0,9
Max	-0,8

Table 4: Correlation Legend

The results are interpreted with the help of light and full red or green colours. Full red colour represents extreme correlation of two assets or two data sets. Correlation over 0,9 are very high and these two assets are almost perfectly moving together. The light red colour depicts still relatively high correlation where two assets pursue the same fluctuating tendency but are a bit more independent of each other. The same applies for the situation of the middle of the correlation spectrum. The light green colour indicates a lack of systematic relationship up to full green colour representing total independency of the two data sets. The opposite negative spectrum is not indicated as these negative values are irrelevant to this research.

4. Results and analysis

In this section we start with the analysis of CEE countries in relation to the rest of Europe with the help of economic performance benchmarks and various indexes. Subsequently, the statistical analysis is performed and finally, the interpretation of results. In the first section the comparison of countries based on their annual returns is presented. In the second section, countries will be compared based on their overall productivity and the link between the country's productivity and the real estate total return performance will be sought.

4.1 Qualitative analysis

In the Table 5 lists all countries and their performance indicators expressed in GDP per capita in USD (Organisation for Economic Co-Operation and Development, 2017b), and four major indicators relevant for real estate investments. The explanation of indexes and corresponding references of the table are mentioned below in separate subsections.

Data for 2016		**GDP per capita**	**JLL Transparency**		**IMD Comp**	**GaWC capital city**	**Ease of doing Business**	
Country		(USD)	Sc.	Group	Score	Group	Tot.	R.P.
Switzerland	CH	75727	1,9	Transp.	98,0	Alpha -	31	16
Czechia	CZ	21703	2,1	Transp.	76,1	Beta +	27	31
Poland	PL	14861	1,9	Transp.	71,3	Alpha	24	38
Hungary	HU	14845	2,3	Transp.	62,6	Beta +	41	28
Germany	D	45654	1,7	Highly t.	88,6	Alpha	17	79
Austria	A	47749	2,2	Transp.	80,2	Alpha -	19	30
Belgium	BE	45618	1,9	Transp.	80,7	Alpha	42	131
Denmark	DK	60291	1,9	Transp.	91,8	Beta +	3	12
Spain	E	31433	2,1	Transp.	69,3	Alpha	32	50
France	F	42155	1,3	Highly t.	73,5	Alpha	29	100
Italy	I	34271	2,1	Transp.	68,7	Alpha	50	24
Netherlands	NL	52076	1,5	Highly t.	91,3	Alpha	28	29
Norway	N	89766	2,0	Transp.	90,1	Beta +	6	14
Portugal	P	22338	2,3	Transp.	66,4	Alpha -	25	27
Sweden	S	56278	1,9	Transp.	92,4	Alpha -	9	10
Ireland	IR	68066	1,6	Highly t.	91,5	Alpha -	18	41
U. Kingdom	UK	41644	1,2	Highly t.	83,3	Alpha	7	47

Table 5: List of investigated countries

GDP

In the Table 5 the GDP per capita in USD is displayed. In the pool of countries, there are the strong countries such as Norway, Switzerland, Denmark and newly Ireland with over 60'000 USD in 2017. The second group are countries over 40'000 USD with Austria, Sweden, Netherlands, Belgium, France and UK. The last group under 35'000 USD represents Italy, Spain, Portugal, Czechia, Poland and Hungary. In section 4.3 the GDP performance of all countries during last 25 years is analysed in detail.

JLL Transparency Index

One of the main reasons why for example Swiss pension funds do not want to invest money abroad is according to the study of Lucerne University (Trübestein, 2015, p. 73) on the non-transparency of these markets, the currency risk as well as political and legal risks. However, consulting the transparency ranking of Jones LaSalle the opposite is observed. On Table 5 is seen that interestingly many European countries have a higher ranking on the transparency index than Switzerland (Global Real Estate Transparency Index Team, 2016). According to this survey in 2016 the transparency universe within Europe is well-balanced. The highly transparent markets are dominated by English speaking countries. From Europe, it is the United Kingdom and Ireland followed by France, Netherlands, Finland and recently also Germany moving to the top tier for the first time. The transparency gap between Eastern and Western Europe has been finally overcome. CEE countries feature strongly among the top improvers. Poland has moved to the cusp of high transparency and is positioned next to Czechia, Hungary and rest of the investigated countries in this second transparent group. Interestingly also, three CEE countries, namely Slovenia and Serbia and Bulgaria were the top improvers globally since 2014. This thus demonstrates the future potential of CEE markets.

IMD World Competitiveness Scoreboard

The situation in Europe is according to the IMD favourable, as all European countries have made progress in the ranking compared to the rest of the world since 2015 with the exception of Norway and Germany. In 2016, the CEE countries are the big winners. Besides solid placement of Czechia and Poland, Estonia ranked 31 even though this was the first time this was examined. Lithuania improved by 6 ranks, and Hungary improved despite the political tensions by two places. These countries are systematically supporting innovation and economic friendliness; thus they are becoming attractive locations for many companies from the service sector.

GaWC Ranking

One of the important factors when evaluating investment risks is that of risk related to the city's interconnectedness. This is measured by the GaWC ranking. This study suggests that the analysis at the national level is, to an extent, misleading due to the spatial fixity of real estate investment. Real estate investment – whether in the form of development, acquisition or finance and funding – takes place in particular locations, for example office investment occurs in and around cities. Thus, the global urban system forms a vital context for an understanding of real estate investment flows.

The results are not surprising; the concentration of office investment is strongly associated with city global and financial status. However, such global cities are thus potentially most exposed to risk associated with international financial markets. Study suggests that the systemic risk - contagion and common factor - means that investment in global cities (higher ranked) as London or Paris is risky and not apparently compensated by return. There are portfolio implications for investors who may look to reduce risk by building more diversified portfolios or investing in lower order cities such as CEE capitals (Lizieri & Pain, 2014, p. 452). For more in depth analysis sectorial data (office sector) are necessary.

This rating is published every two years and in the investigated period between 2006 and 2016 capital cities of CEE countries have achieved high positions in this rating. With one exception Warsaw and Prague have been always placed in the Alpha group and Budapest in Beta Group, which means these cities are structurally very similar to other Western European capitals. Only at the last rating period in 2016 Prague was classified as a Beta city. Whether this high ranking is positive or negative for real estate returns and real estate investors searching for diversification is a question.

Doing Business

Economies are ranked on their ease of doing business, from 1–190. A high ranking in the ease of doing business ranking means the regulatory environment is more conducive to the starting and operation of a local firm. The rankings are determined by sorting the aggregate distance to frontier scores on 10 topics, each consisting of several indicators, giving equal weight to each topic. The rankings for all economies are benchmarked to June 2016.

In Table 5, the left column represents the total rank in ease of doing business and the column to its right shows data for the subtheme registering property. In total ranking the CEE countries are reaching same levels as countries in Western Europe.

Fair Value Index

In Figure 6 data from the first quarter of 2016 show that Western Europe have the majority of their markets classified as fairly priced, while the UK still has 20 fairly priced markets, and is further ahead in the cycle. For this research, the most interesting fact is that all CEE countries including Baltics with exception of Warsaw and Kyiv are underpriced.

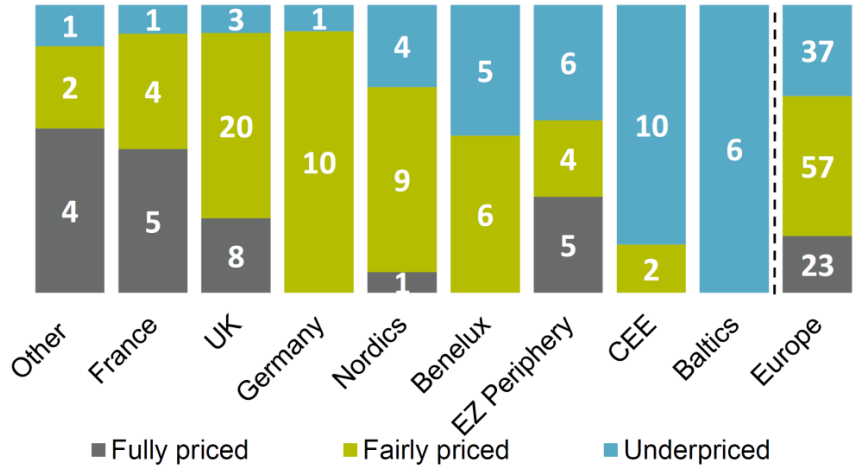


Figure 6: Fair value index; Number of markets in each category by region/country (Gralin, 2016, p. 2)

4.2 Modern portfolio theory

Firstly, the direct property data set is reviewed, and then the performance of countries based on their annual returns is compared. The overall total return and the corresponding volatility over 3, 5 and 10 years is calculated. In the second section, the modern portfolio analysis building the covariance and correlation matrix is executed. The goal is to create an ideal portfolio using the maximization of the Sharpe ratio.

4.2.1 Return index

Table 6 shows the first analysis of returns on the index level over the last ten years between 2006 and 2016. Initially, it can be seen that the best performing countries, meaning the highest cumulative returns on direct real estates over the past ten years have been achieved in traditional markets for instance Switzerland and France. New interesting markets like Poland have also achieved values of over 180 points. On the other hand, poor overall performance over ten years has been registered in Ireland and Hungary with values around 120 points.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CH	100,0	107,3	114,1	120,3	127,7	137,8	147,5	156,2	164,4	175,1	185,9
CZ	100,0	116,3	115,3	109,8	113,4	122,5	127,3	131,8	141,1	153,3	166,0
PL	100,0	116,0	121,5	117,4	126,3	139,6	147,3	153,8	162,9	173,9	181,9
HU	100,0	114,0	110,8	96,3	97,4	102,3	100,2	102,1	106,1	114,8	121,9
D	100,0	106,2	109,4	111,5	115,9	122,1	127,4	133,6	141,4	153,2	164,7
A	100,0	105,8	109,1	113,9	121,2	129,0	137,6	146,0	153,5	162,3	171,5
BE	100,0	109,6	114,2	117,7	123,2	129,4	135,0	139,5	148,8	161,3	170,3
DK	100,0	110,5	114,3	117,1	123,0	128,9	133,9	138,3	145,8	157,2	169,3
E	100,0	113,3	109,0	98,2	101,3	103,6	101,0	101,1	109,7	126,2	144,3
F	100,0	118,0	117,1	114,4	125,5	135,7	144,7	152,2	161,5	175,4	189,6
I	100,0	111,0	115,1	117,5	123,8	128,7	130,8	133,5	138,6	144,3	149,7
NL	100,0	111,7	115,3	114,1	118,9	123,2	124,6	124,9	129,8	139,8	155,2
N	100,0	118,2	114,4	119,3	129,0	139,2	146,3	153,9	166,7	186,0	205,4
P	100,0	112,8	115,5	117,2	122,6	123,2	123,4	125,1	133,5	147,1	164,4
S	100,0	115,5	111,7	112,9	124,5	137,4	146,2	156,3	169,4	192,8	219,7
IRL	100,0	109,7	71,0	54,7	53,4	52,1	53,8	60,4	82,2	102,9	115,9
UK	100,0	97,6	76,3	78,7	90,5	97,9	101,6	113,0	133,0	150,7	156,6

Table 6: Return Index Table

When the table is presented in the form of a graph as depicted in Figure 7, the contrasting performance dynamics across the European continent can be identified. Nevertheless, certain co-movements particularly in bust years 2007-2009 or boom years from 2014 onwards can be identified. These co-movements between countries are analysed in detail with help of the correlation analysis further in the subsection 4.2.4.

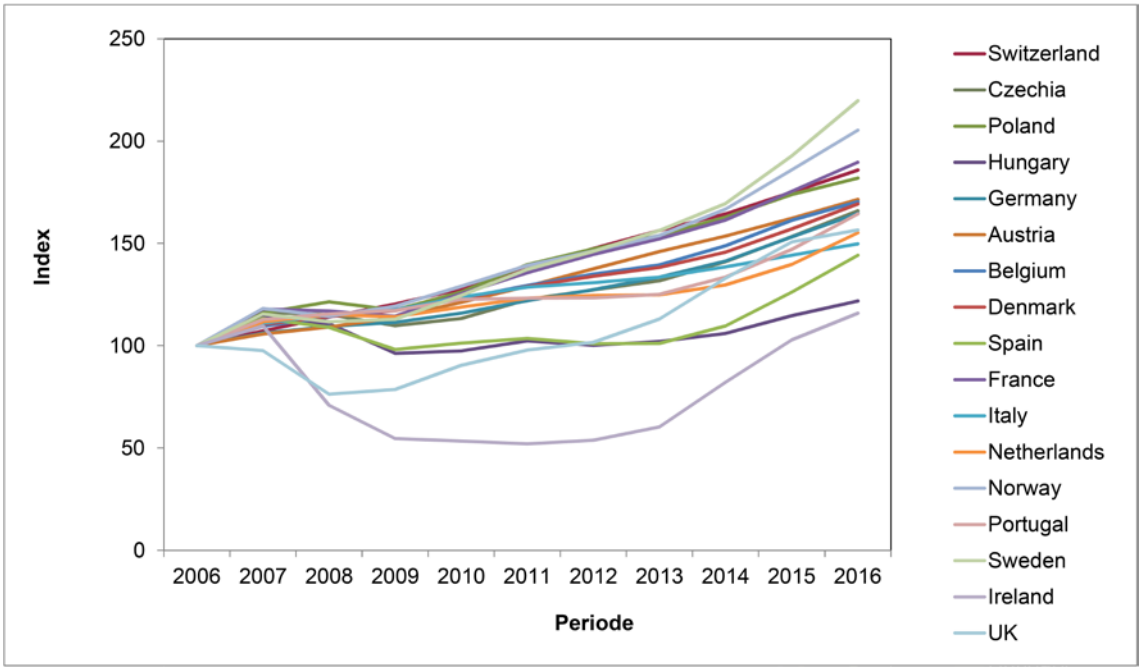


Figure 7: Return Index

In section 3.1 the behaviour of real estate markets based on a boom-bust model was described. In this research one can observe this behaviour of real estate returns on a country level. The best example could be seen in countries like the United Kingdom, Ireland, France or Spain where a distinct decrease in first periods followed by increase in latter periods of time could be observed. When compared with previously presented Figure 2, it is clearly visible in the case of the United Kingdom or Ireland the periods of bust in years of 2006 up to 2008, with the later recovery and finally the new bubble appearing in 2014. This co-movement could be also observed for France and Spain, however, at a less pronounced level. Nevertheless, Spanish performance in last three years appears as if it were approaching another bubble, which may come faster and sooner than in France. This could be explained by the comparison of the overall productivity of these two countries and its correlation to the real estate sectors. In subsection 4.3.2 you can see that correlation of GDP and real estate returns is very high in both countries. Upon consultation of Figure 15, which shows annual GDP growth, it should be noted that France has registered productivity stagnation in years between 2014 and 2016. In comparison, Spain grew by over 3 percent a year, thus, its total return performance is significantly better than in France.

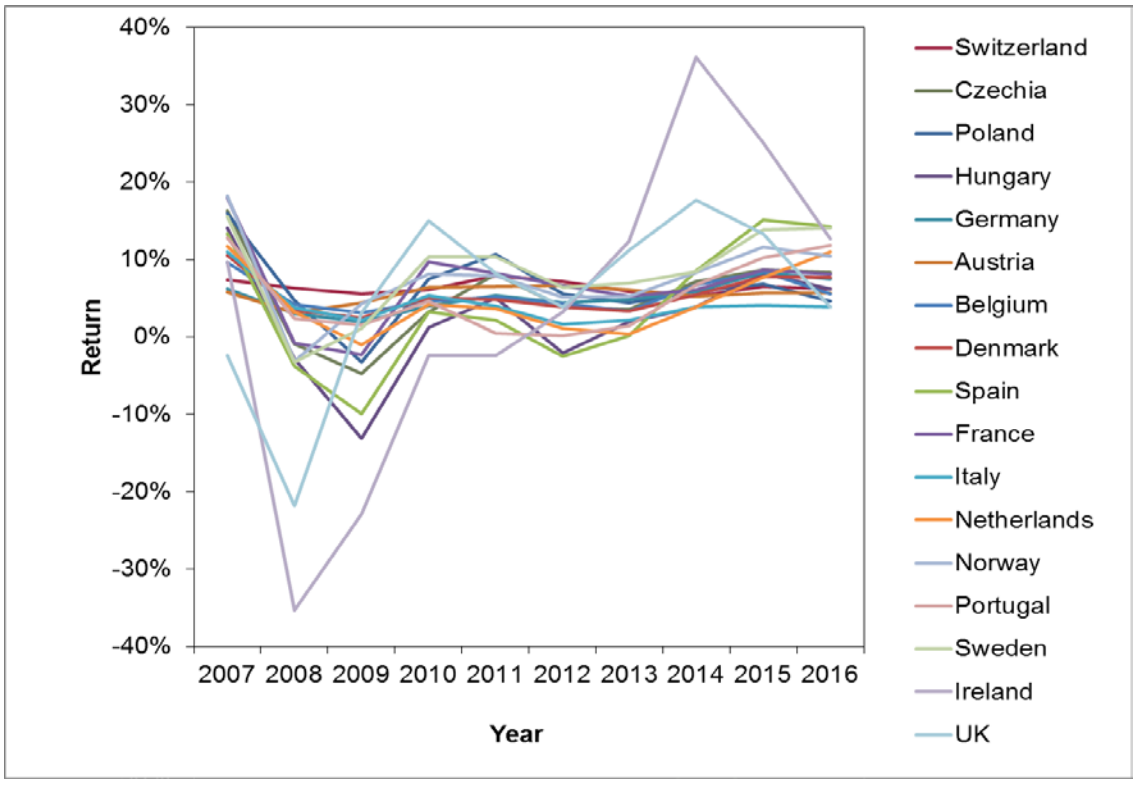


Figure 8: IPD Returns

In Figure 8 it can observed the immense volatility of the United Kingdoms and Irish market. On the other extreme the dark red line represents the performance of

Switzerland, which was delivering steady total returns throughout the stormy years during which the rest of Europe was struggling with the crisis and trying to reclaim the lost gains. Unfortunately, there is no data repartition of the IPD returns into capital and income gain. However, the following Figure 9 shows such repartition related to an example based on forecasts of total returns for 2017. This presumes that the economy is relatively stable, meaning there are no major changes in vacancy rates or rapidly falling or increasing rent levels, it is clear that the volatility is mainly product of capital appreciation and depreciation.

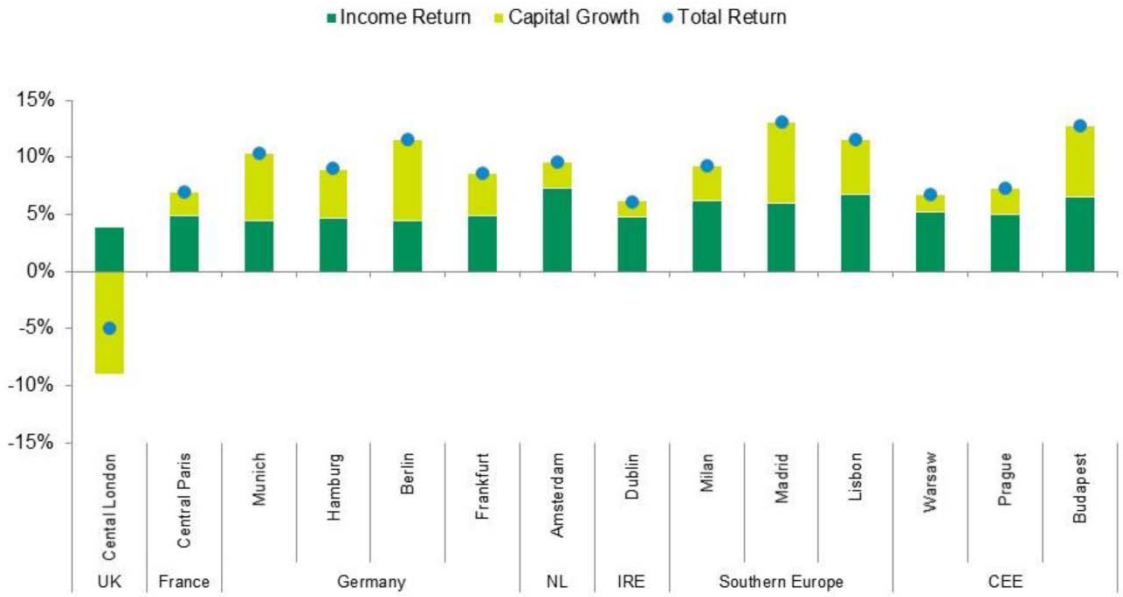


Figure 9: European office total return forecast for 2017 (BNP Paribas Real Estate, 2017, p. 2)

It seems that CEE countries are rather calmer markets with relatively steady returns. The question could be the quality and the amount of data as described in 3.4.2, which could have a significant impact on the volatility calculations. The magnitude could be also dependent on the amount of transactions, which are still lower than on the mature markets. Nevertheless, if only the real estate markets in the CEE region were reviewed as depicted in the Figure 10, then further compared to an extremely stable Switzerland, it will be observed that the cyclical pattern is the same as that of more mature markets; merely the magnitude is much lower. From this, another phenomenon linked to the timing of the cycles, the so-called lagged correlation can be seen. It can be discerned that the United Kingdom, Ireland and Sweden are somehow taking the role of pioneers in the whole real estate cycle. Their negative peak is in 2008 and the rest of countries with a lag of one year follows them. CEE countries are negatively peaking clearly in 2009. This will be described in detail in the subsection 4.2.4.

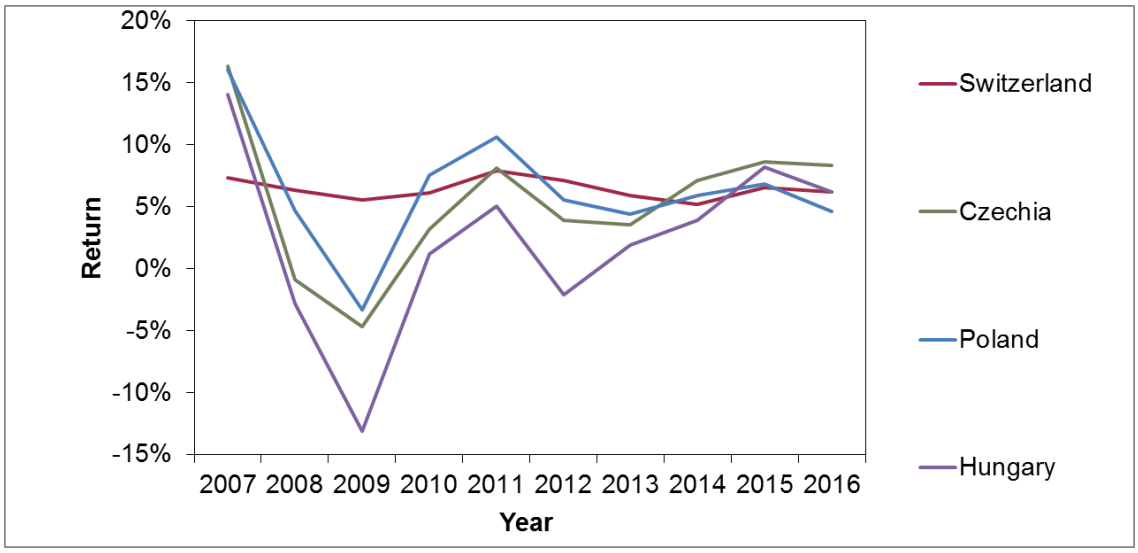


Figure 10: Returns of CEE countries and Switzerland

Furthermore, these real estate returns can be reviewed in relation to the effective investment volumes. In Figure 11, historical investment volumes of six CEE countries are depicted. Besides the three investigated countries, data of Hungary, Slovakia and Bulgaria are also included. As their share is only about 10-15% of the total value depicted, the resulting tendency will not change. The highest peak with the total amount of €13 billion in 2007 is noted, whilst the lowest point of €2,9 billion in 2009, all this corresponds well with real estate return indexes for the years in assessed. Interestingly we also identify on both graphs the slowdown in 2012. In 2016 CEE commercial real estate markets were experiencing growth in the investment amounts; however this was clearly in contrast to the declining tendency of returns as illustrated above in Figure 10.

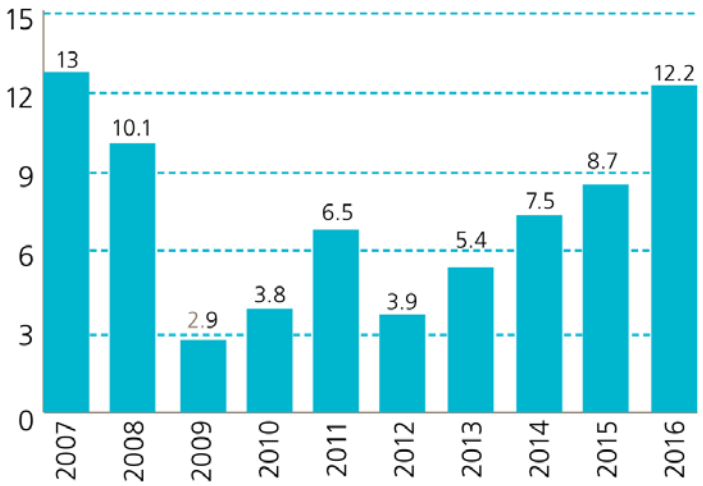


Figure 11: Historical CEE investment volume in € bn (Robinson, 2016, p. 4)

For more details on the largest CEE market, Poland, see Appendix III. CEE is presently defying the weakening investment cycle in Western Europe. Preliminary numbers for

Czechia for the end of 1Q 2017 stand at €1,4 billion, according to Colliers International estimates (Robinson, 2016, p. 4). This represents double growth compared with previous period. The region has started the year well. Considering that the pattern seems to be similar to the one of returns depicted in Figure 10, an interesting question can be asked. Could it be that we are once more standing at the peak or boom of such cycle?

4.2.2 Average total return on investment and volatility

Average total return and volatility depicted in Table 7 is calculated using formulas from subsection 3.5.2. It depicts the different market dynamics across the whole European region. During the 10-years period, Sweden and Norway have experienced extraordinarily high total returns, approximately 8 %. Very good performance has been also registered in Switzerland, Poland and France with values over 6 %. The rest of countries were somewhere around 5 %. Poor overall performance was registered in Ireland with 3,6 % and Hungary did even worse with 2,2 %. Interesting are the extreme values in Ireland within 3 and 5 years periods with 24,6 % and the latter 17,9 %. Amongst the CEE Region Poland presented the strongest performance.

	Tot. return 3 years	Volatility 3 years	Tot. return 5 years	Volatility 5 years	Tot. return 10 years	Volatility 10 years
Switzerland	5,97%	0,68%	6,18%	0,70%	6,40%	0,83%
Czechia	8,00%	0,79%	6,28%	2,43%	5,34%	5,77%
Poland	5,77%	1,11%	5,44%	0,98%	6,27%	4,90%
Hungary	6,10%	2,15%	3,62%	3,98%	2,24%	7,31%
Germany	7,23%	1,22%	6,18%	1,69%	5,13%	1,95%
Austria	5,53%	0,29%	5,86%	0,52%	5,55%	1,08%
Belgium	6,90%	1,41%	5,66%	2,00%	5,49%	2,14%
Denmark	6,97%	1,36%	5,62%	2,09%	5,43%	2,51%
Spain	12,63%	3,60%	7,10%	8,05%	4,05%	8,51%
France	7,60%	1,32%	6,92%	1,41%	6,74%	5,62%
Italy	3,90%	0,17%	3,08%	1,14%	4,15%	2,66%
Netherlands	7,53%	3,55%	4,80%	4,52%	4,57%	4,30%
Norway	10,10%	1,67%	8,12%	2,96%	7,59%	5,54%
Portugal	9,57%	2,61%	6,04%	5,19%	5,20%	4,86%
Sweden	12,07%	3,18%	9,90%	3,73%	8,34%	5,91%
Ireland	24,63%	11,71%	17,88%	12,82%	3,61%	21,09%
U. Kingdom	11,63%	7,05%	9,98%	6,07%	5,20%	11,34%

Table 7: Average total return and volatility

Looking at the volatilities there is unbelievably low volatility registered in Switzerland with an extremely low value of 0,83 % and Austria with a value slightly over 1 %. This demonstrates without a doubt that the Swiss real estate market has been overrun by

investment capital in past years. Very high volatilities over ten percent in all three periods have been seen in Ireland.

Furthermore time periods from 3 to 5 up to 10 years and the impact of the different periods on the performance values is investigated. In Figure 12 the average total return in relation to its volatility of real estate returns is depicted.

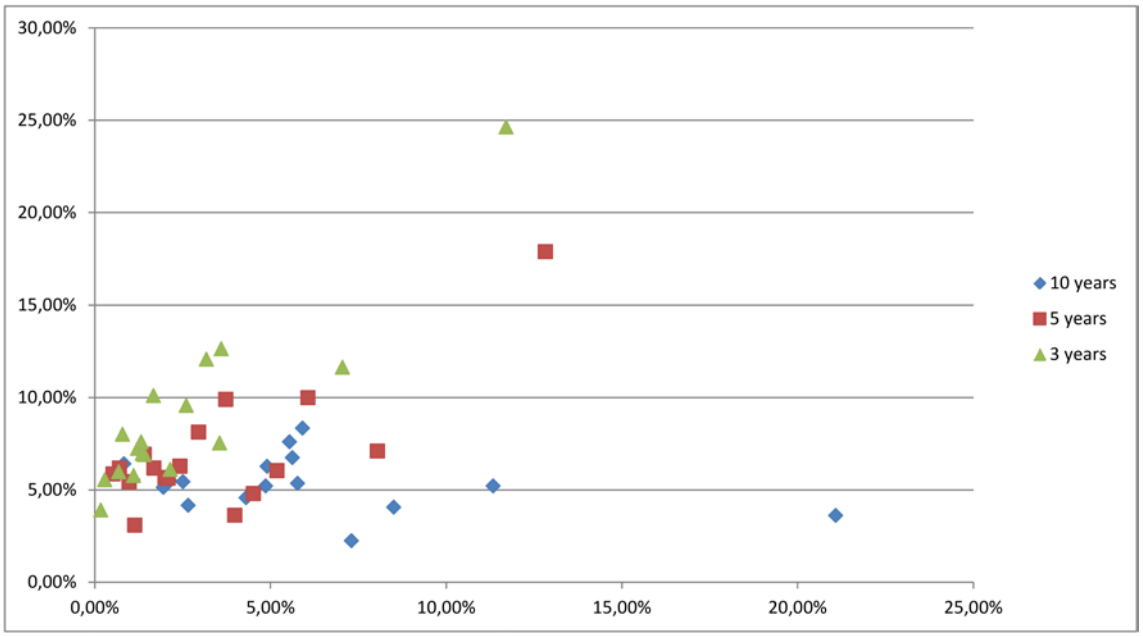


Figure 12: Average total return and volatility over 3, 5, and 10 years

It is basically showing the tendency that the real estate market situation in the period of last five years (2012-2016) depicted with red squares countries were performing better than in the calculated period of ten years (2007-2016), as depicted by the blue diamonds. The same return was available with drastically less volatility. This could be explained by the market crisis in the years of 2008 and 2009. Interestingly, if the period shortened to three years (2014-2016) the volatility for the same return will be further reduced.

4.2.3 Covariance matrix

As a first step, the sets of returns were evaluated against each other and the covariance between each country was calculated using formulas as described in the subsection 3.5.4. The table presented in Appendix II. shows the relationships between the performances of investigated countries. Nevertheless, this covariance matrix cannot tell the intensity of such relationship. It is however the foundation for further calculations of correlations and the optimal portfolio.

4.2.4 Correlation analysis

The calculation and the purpose of correlations were described in the subsection 3.5.8. Using the covariance matrix we can simply calculate the correlation matrix. The covariance product will be divided by the multiple of corresponding standard deviations. As previously mentioned the correlation shows not only the dependencies, but also the magnitude by which returns in corresponding countries correlate in relation to others. The red colouring indicates that the vast majority of countries are showing similar behaviour. Darker red is showing greater magnitude of such dependence.

	CH	CZ	PL	HU	D	A	BE	DK	E	F	I	NL	N	P	S	IRL	UK
CH	1,00	0,51	0,68	0,44	0,22	0,44	0,30	0,34	0,16	0,52	0,36	0,30	0,30	-0,02	0,34	-0,11	-0,22
CZ	0,51	1,00	0,87	0,96	0,80	0,50	0,86	0,90	0,86	0,93	0,73	0,81	0,86	0,71	0,86	0,65	0,22
PL	0,68	0,87	1,00	0,87	0,49	0,43	0,72	0,72	0,60	0,89	0,80	0,64	0,64	0,44	0,64	0,33	0,01
HU	0,44	0,96	0,87	1,00	0,84	0,43	0,83	0,87	0,90	0,88	0,70	0,82	0,76	0,72	0,83	0,64	0,19
D	0,22	0,80	0,49	0,84	1,00	0,42	0,74	0,78	0,94	0,64	0,32	0,76	0,69	0,74	0,83	0,79	0,39
A	0,44	0,50	0,43	0,43	0,42	1,00	0,16	0,27	0,33	0,64	0,09	0,14	0,56	0,04	0,71	0,55	0,69
BE	0,30	0,86	0,72	0,83	0,74	0,16	1,00	0,92	0,84	0,76	0,77	0,81	0,80	0,83	0,71	0,57	0,12
DK	0,34	0,90	0,72	0,87	0,78	0,27	0,92	1,00	0,90	0,85	0,81	0,95	0,88	0,92	0,83	0,52	0,08
E	0,16	0,86	0,60	0,90	0,94	0,33	0,84	0,90	1,00	0,75	0,56	0,89	0,78	0,89	0,86	0,74	0,32
F	0,52	0,93	0,89	0,88	0,64	0,64	0,76	0,85	0,75	1,00	0,78	0,74	0,88	0,63	0,88	0,56	0,29
I	0,36	0,73	0,80	0,70	0,32	0,09	0,77	0,81	0,56	0,78	1,00	0,74	0,71	0,68	0,54	0,15	-0,14
NL	0,30	0,81	0,64	0,82	0,76	0,14	0,81	0,95	0,89	0,74	0,74	1,00	0,73	0,93	0,75	0,39	-0,06
N	0,30	0,86	0,64	0,76	0,69	0,56	0,80	0,88	0,78	0,88	0,71	0,73	1,00	0,75	0,93	0,65	0,44
P	-0,02	0,71	0,44	0,72	0,74	0,04	0,83	0,92	0,89	0,63	0,68	0,93	0,75	1,00	0,71	0,51	0,08
S	0,34	0,86	0,64	0,83	0,83	0,71	0,71	0,83	0,86	0,88	0,54	0,75	0,93	0,71	1,00	0,73	0,55
IRL	-0,11	0,65	0,33	0,64	0,79	0,55	0,57	0,52	0,74	0,56	0,15	0,39	0,65	0,51	0,73	1,00	0,75
UK	-0,22	0,22	0,01	0,19	0,39	0,69	0,12	0,08	0,32	0,29	-0,14	-0,06	0,44	0,08	0,55	0,75	1,00

Figure 13: Correlation matrix of direct real estate return index

The matrix in Figure 13 shows strong regional dependencies. The grouping of countries which influence each other like the ones of the CEE region: Czechia, Poland and Hungary can be observed. The most intriguing countries are the outliers highlighted in the figure above in green or grey. Switzerland and Austria are those who correlate the least with all other countries. These outliers are the best diversifiers for such a portfolio. This is based on a fact that when the majority experiences a bust, they act against it and help to stabilize the incomes. The second example would be the United Kingdom and Ireland. At this point, it would be important to look at Figure 8, the return curve. Through simple observation, it can be seen that the cyclical pattern of the United Kingdom and Ireland is very similar to other countries it would be assumed that the correlation levels are high. However, the correlation matrix in the Figure 13 contradicts this by showing a very low correlation with the other countries. The difference to the first example with Switzerland may lie with timing. In Figure 8 visible lags between the curves can be traced. These curves demonstrate that United Kingdom and Ireland are

peaking you can see that UK and Ireland are peaking one period before the rest of the examined countries. Reverting to the CEE countries, their returns have a very strong correlation with other countries; this would then mean that the diversification abilities in a pan-European portfolio are rather low.

From this analysis, the noteworthy finding is that although there is a proven low correlation, there can still exist some degree of hidden lagged correlation. A more extensive examination of these lags, through the calculation of overlapping periods would provide a more precise answer. Obviously, this can also have very strong influence on results of the optimal portfolio analysis. If a low correlation between two countries is calculated and risk is then diversified by investing in these two countries, there is still the risk of an unfavourable outcome for the investor when these two countries experience a bust one after the other.

4.2.5 Optimal portfolio analysis

This section of thesis provides the relevant information on the manner in which an ideal asset allocation strategy across chosen European real estate markets should be executed. The ideal real estate portfolio is constructed for the entire set of countries based on performance attributes for the period 2007-2016 inclusive.

Firstly, the simulation has been performed without any boundaries related to regional allocation, which means that the possible result could be allocating 100% of capital into a portfolio in one single country. This presents another disadvantage of this concept. Modern portfolio theory tends to produce very extreme results. In practise, such results are unusable. In this example, Switzerland dominated all other countries in the portfolio due to high levels of stability and relatively strong growth, without any critical impact of financial crisis in 2008 on the Swiss real estate market. Also, with impressive results, Austria ranked second best. Using the maximum Sharpe ratio as a target value in the Excel Solver, CEE countries have not attained any allocation share in the portfolio. Only when trying to minimize the volatility of the portfolio, Poland could have entered with very little share in this portfolio. This was executed by minimizing the portfolio risk in Excel Solver.

In order to examine in detail the role of CEE countries within Pan-European investment portfolio the concept of limiting weight conditions of 8% per country must be introduced. This concept was explained in detail in the subsection 3.5.3. This limitation, which can become a very realistic condition when building a European real estate

investment portfolio, demonstrates the exact point when CEE countries are entering the portfolio. Figure 14 shows results in a range around the maximum Sharpe ratio value; the maximum Sharpe ratio was calculated at the value of 5.63 % of portfolio return. Thus, the displayed range has been chosen between 5.00 % and 6.00 %; from this it can be clearly deduced the role of investments in particular countries.

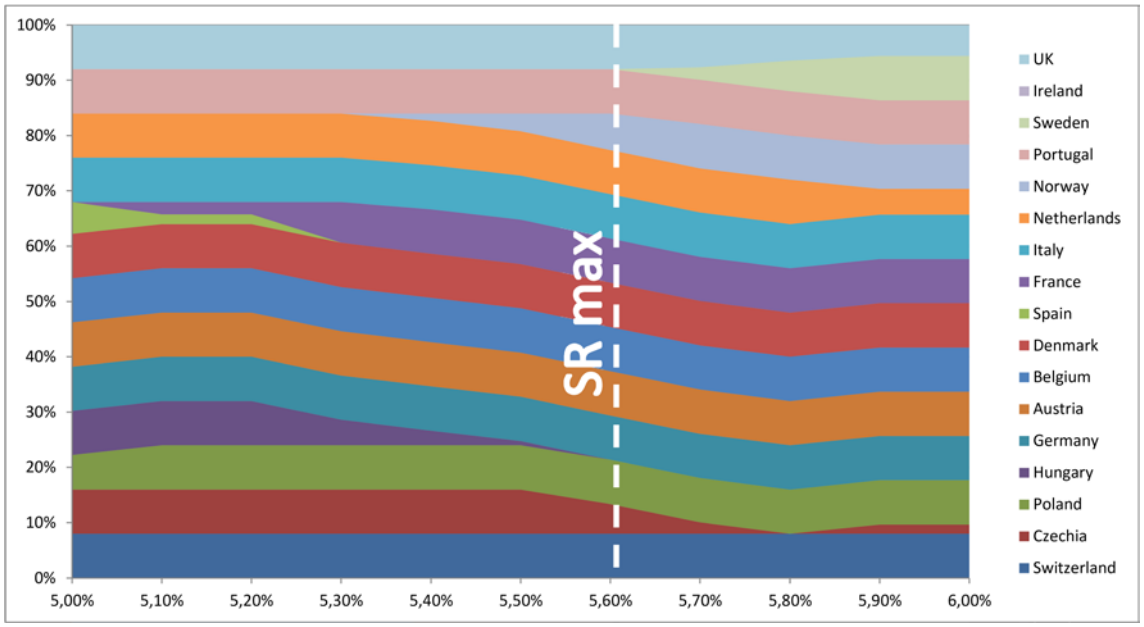


Figure 14: Optimal portfolio Analysis

In this special case, Switzerland and Austria are still noticeably dominating the portfolio but as their share is limited, other countries of the middle field like Germany, Belgium, Denmark, Italy and Portugal are represented with their full stake of 8 %. Only Poland with its solid total returns and relatively low volatility keeps up with these strong countries and could eventually take over the outperformance role. Czechia and Hungary do not offer such performance and they have been positioned somewhere in the lower end of the table. Hence, the graph shows that these two countries can only take over a role of risk diversifier at the lower risk spectrum and are therefore less eligible for Pan-European investment strategy.

4.3 GDP analysis

In subsection 3.5.3 some weaknesses of the modern portfolio theory were highlighted, which refer to assumptions for the ideal model. There are also some other negative conceptual points of modern portfolio theory such as the fact that the future return forecasts are made based on past series of returns, which result basically in extrapolation of the past into the future. The question is whether GDP data could help predict the future of these returns.

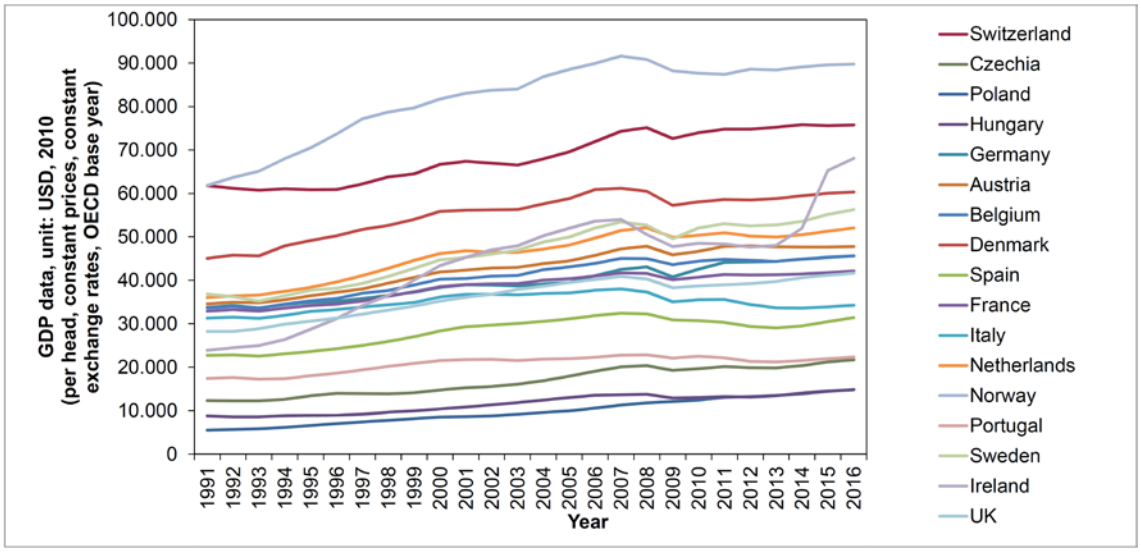


Figure 15: GDP Data

Figure 16 shows that in past ten years the average growth in CEE countries was in relation to Western Europe bit higher. Furthermore, Ireland has made an abnormally striking development in the past twenty-five years and has defied all prognoses. This is probably partly due to the process of switching tax domicile after a merger or acquisition, known as an "inversion". This has increased in recent years, and Ireland has become a popular end destination in these corporate manoeuvres because of its low corporate tax regime (Inman, 2016). It is possible that Brexit will only enhance Ireland's GDP if firms decide to shift their activity and investment from the UK into Ireland.

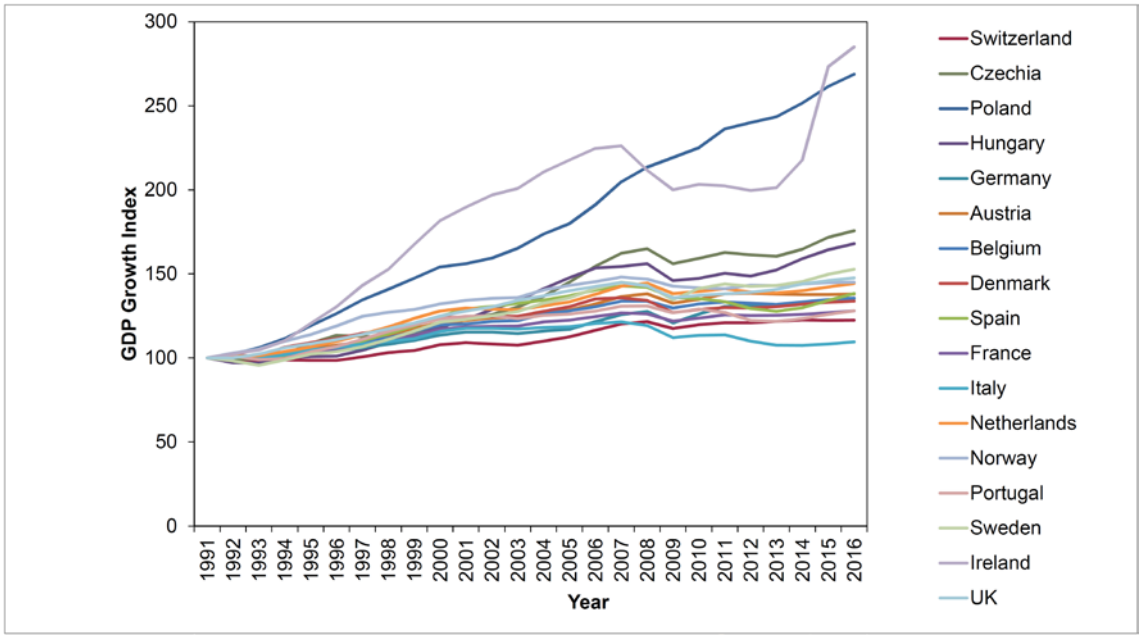


Figure 16: GDP Growth Index

Since the collapse of the Iron Curtain, Poland has experienced remarkable GDP growth. Its devastated economy after forty years of communism has since flourished and is constantly growing without any noted turndown in crisis years. It should be noted however, that the graph in Figure 16 displays the growth index based on economy from 1991. Considering this low economic performance base, it becomes obvious that the growth of these countries should be faster than more developed western countries. In order to converge with the rest of Europe the growth should actually be much more pronounced which is the case of slower growing Czechia or Hungary. As depicted in Figure 15, CEE countries have only pursued the weaker economies of southern Europe, which were severely affected during the crisis years. After Portugal was being surpassed by Czechia, the convergence of GDP levels with Spain and Italy can be expected in coming years. The economies in Czechia and Poland are robust and have very positive outlooks for the next years. This fact is further discussed in section 5.2. By contrast, the situation of Hungary is problematic due to the uncertainty of its political situation.

4.3.1 GDP correlations

Similar to the calculation of the correlation matrix for real estate returns as described in subsection 3.5.8 the same approach with the support of the covariance matrix has been applied for the GDP growth.

	CH	CZ	PL	HU	D	A	BE	DK	E	F	I	NL	N	P	S	IRL	UK
CH	1,00	0,54	0,44	0,62	0,80	0,77	0,70	0,62	0,53	0,75	0,59	0,74	0,32	0,53	0,73	0,12	0,53
CZ	0,54	1,00	0,48	0,60	0,57	0,59	0,58	0,61	0,60	0,53	0,68	0,58	0,39	0,45	0,68	0,39	0,57
PL	0,44	0,48	1,00	0,17	0,40	0,62	0,60	0,48	0,41	0,47	0,49	0,68	0,52	0,54	0,44	0,26	0,31
HU	0,62	0,60	0,17	1,00	0,50	0,54	0,62	0,62	0,69	0,64	0,61	0,55	0,29	0,45	0,77	0,45	0,77
D	0,80	0,57	0,40	0,50	1,00	0,84	0,74	0,72	0,51	0,82	0,73	0,73	0,32	0,54	0,78	0,21	0,53
A	0,77	0,59	0,62	0,54	0,84	1,00	0,85	0,78	0,65	0,91	0,80	0,88	0,58	0,68	0,79	0,25	0,67
BE	0,70	0,58	0,60	0,62	0,74	0,85	1,00	0,85	0,77	0,91	0,85	0,84	0,65	0,78	0,86	0,47	0,70
DK	0,62	0,61	0,48	0,62	0,72	0,78	0,85	1,00	0,70	0,85	0,85	0,80	0,76	0,64	0,80	0,49	0,81
E	0,53	0,60	0,41	0,69	0,51	0,65	0,77	0,70	1,00	0,79	0,87	0,83	0,55	0,85	0,75	0,69	0,73
F	0,75	0,53	0,47	0,64	0,82	0,91	0,91	0,85	0,79	1,00	0,89	0,88	0,58	0,77	0,88	0,45	0,74
I	0,59	0,68	0,49	0,61	0,73	0,80	0,85	0,85	0,87	0,89	1,00	0,85	0,66	0,81	0,82	0,58	0,78
NL	0,74	0,58	0,68	0,55	0,73	0,88	0,84	0,80	0,83	0,88	0,85	1,00	0,64	0,84	0,75	0,48	0,70
N	0,32	0,39	0,52	0,29	0,32	0,58	0,65	0,76	0,55	0,58	0,66	0,64	1,00	0,54	0,40	0,41	0,68
P	0,53	0,45	0,54	0,45	0,54	0,68	0,78	0,64	0,85	0,77	0,81	0,84	0,54	1,00	0,71	0,60	0,53
S	0,73	0,68	0,44	0,77	0,78	0,79	0,86	0,80	0,75	0,88	0,82	0,75	0,40	0,71	1,00	0,53	0,75
IRL	0,12	0,39	0,26	0,45	0,21	0,25	0,47	0,49	0,69	0,45	0,58	0,48	0,41	0,60	0,53	1,00	0,53
UK	0,53	0,57	0,31	0,77	0,53	0,67	0,70	0,81	0,73	0,74	0,78	0,70	0,68	0,53	0,75	0,53	1,00

Figure 17: Correlation Matrix of GDP growths

In Figure 17, the correlation matrix of countries and their GDP growth is depicted. The colouring legend is the same as we used for returns, red are high correlations and green no correlations. From this figure bundles of countries which economies are clearly

dependent on each other can be identified. The middle of the table with countries like Germany, Austria, Belgium, Sweden, and a few others are very much dependent on each other. Interestingly, the Eastern European countries do not correlate with any of the other countries and not even in the CEE region. The only exception is Hungary with its stronger correlation to Sweden and the United Kingdom. Reasons for this are unknown. It shows how much economies of Western and Eastern part of Europe are interconnected.

4.3.2 Correlation of GDP and real estate returns

In this subsection, ten years real estate returns in particular countries are grouped with the GDP growth of that same country. It is noteworthy to see the extent to which overall economic growth influences real estate returns. It provides valuable information whether there is a possibility to forecast future expected returns in a pursued country based on the overall economic outlook.

	σ(GDP)	σ(Return)	COV	CORR
Switzerland	1,70%	0,83%	0,000062	0,439037
Czechia	2,98%	5,77%	0,001416	0,824128
Poland	1,68%	4,90%	0,000592	0,717730
Hungary	3,00%	7,31%	0,001613	0,735623
Germany	2,69%	1,95%	0,000211	0,401808
Austria	2,00%	1,08%	0,000071	0,326366
Belgium	1,56%	2,14%	0,000248	0,738661
Denmark	2,01%	2,51%	0,000240	0,477102
Spain	2,55%	8,51%	0,002056	0,947465
France	1,51%	5,62%	0,000689	0,813615
Italy	2,38%	2,66%	0,000366	0,578835
Netherlands	2,10%	4,30%	0,000736	0,812690
Norway	1,33%	5,54%	0,000429	0,581034
Portugal	2,20%	4,86%	0,000884	0,826851
Sweden	3,05%	5,91%	0,001341	0,742539
Ireland	9,06%	21,09%	0,013917	0,728671
U. Kingdom	2,13%	11,34%	0,001046	0,433830

Table 8: Correlation of real estate returns and GDP growth

Table 8 reveals the extreme correlation of real estate returns and GDP growth in Spain. Very high correlation is also observed in Portugal, Netherlands, France, and in CEE countries. One of the reasons could lie in the sectorial distribution of investments in index portfolios. Summation of the retail and office sectors of the index portfolio in Spain, Portugal and France results to over 80 percent. Remarkably, the Dutch index portfolio is strongly invested in residential.

Real estate returns of CEE countries are in general well correlated with GDP growth. It is important to know that the percentage of the retail together with the office sector in the index portfolio is also quite high as well, whereas residential real estate investments are in these countries rare[4]. However this is also slowly changing and residential real estate investments are gaining on importance.

4.4 Hypothesis verification

The quantitative and qualitative analyses of the former sections provide an initial impression. In this section, the results will be reviewed and the hypothesis will be either verified or negated.

Prior to discussing the final conclusion concerning the performance of CEE countries, it should be mentioned that the umbrella term of CEE countries does not represent the uniqueness of the countries included. This is not only from a statistical point of view, but also politically, socio-economically and demographically. Baltic countries are quite different to Balkan countries; these also have little in common with the so-called Visegrad countries in Central Europe. Due to data availability issues, this thesis has focused on the latter. Nevertheless, this group of countries has shown as well very different results due to the differences of real estate market maturity analysed in the referenced research papers (Haran, et al., 2016, p. 38). Consequently, one significant conclusion is that despite its small size, the real estate sector in Central and Eastern Europe cannot be treated as a homogeneous market.

4.4.1 Results of qualitative analysis

The qualitative analysis of the economic and business environment in section 4.1 has shown that in general, the CEE region has made significant progress in terms of transparency and investment related issues. Despite this positive feature, the gap of GDP per capita levels between Western and Eastern Europe is still substantial and will not be closed in the immediate future. As a result of this gap, CEE countries have historically benefited and continue to benefit from wage competitiveness in the office and industrial spheres, thus contributing to attractive rent levels for support and shared service operators and warehouses supplying both the region and Western Europe. However, the net wage growth itself is eroding this advantage over time.

[4] see home ownership rates in the Appendix I.

4.4.2 Quantitative comparisons

The quantitative analysis has shown that countries of CEE region are not the game-changers. The return performance is relatively good, but they do not offer higher returns than in Western European countries. Only Poland offers very competitive performance and thus seems to be very attractive market. Nevertheless, including CEE countries into pan European portfolio might be an appealing alternative for investments when looking at minimizing risk. CEE markets are showing less pronounced levels of volatility than many Western countries. They offer good risk/return ratio and thus very stable performance.

Cross-correlation statistics of real estate returns amongst European countries show us that the performance of CEE countries is closely associated with the majority of European countries. Comparing this data, another noteworthy effect was determined. In each index, the boom-bust cycle model was identified; however, there are two different elements playing a role. Firstly, it is the magnitude, which results in higher standard deviations. Secondly, it is the timing. As explained in subsection 4.2.1 some countries such as the United Kingdom and Ireland are ahead with their cycle and others are lagged.

Other statistical other statistical/numerical factors, which influence real estate returns were investigated. Apart from low interest rates as a result of low inflation there is the GDP growth. Interest rates are strongly harmonised within the European region as this is regulated by the European Central Bank (ECB), and most of countries outside of Eurozone are converging to its decisions, although with some time lags. The second value which differs between countries is the productivity of the country. As demonstrated in some examples, this could possibly be the key to forecast future growth of total returns in certain countries with high correlations between GDP growth and real estate returns.

But firstly, there was the comparison of the GDP growth index, which highlighted the fact that some countries are economically dependent on each other. The majority of the continental Europe is economically linked and the correlation between them is high. Interestingly, the CEE region together with Ireland and Norway seem relatively independent form the Western countries.

The cross-correlation between GDP growth and real estate total returns has brought some meaningful side results. Notably, the magnitude of this relationship differs from

country to country. From the analysis of the boom-bust model in section 3.1 it is apparent the discrepancy in results. A simplistic approach would consider GDP growth as the economic cycle and real estate returns as the real estate market cycle. Taking the aforementioned into consideration, it is evident that the relationship between real estate and economic cycle should not be simplified or generalised in a model.

Consequently, the question for further research is following. Does this boom-bust model relationship exist in each country as the theory states, though simply with disparate timing in each country? If this were the case, there would be evidence of a lagged high correlation for both curves. On the other hand, should it be considered that this boom-bust model is purely a theoretical model, which can be applied for some but not for all countries? The reason for this assumption could be the structure of an economy or the exogenous factors influencing the economy or the real estate sector separately. In first case, if the high correlation of real estate returns and GDP growth[5] in Spain is taken as an example, this significant value could be explained by the considerable importance of the real estate sector on the Spanish economy.

For more comprehensive analysis, a lagged correlation table[6] has been calculated; nevertheless, there was no evidence of any higher correlation. In fact, the correlations lose their magnitude when analysed within a more extensive lag period.

[5] The reference here relates to Table 8
[6] See the Appendix X.

5. Conclusions

Since 2007, the European real estate sector has been characterised by a distinct focus on prime tier established markets after a protracted period of instability. The variance in post-crisis recovery periods offers promising opportunities for the diversification of risk among countries. However, the lack of suitable investment possibilities in traditional markets has widened the investment horizons of investors. Hence, since 2013 CEE real estate markets have witnessed a positive change in investor sentiment towards them. This recent shift of capital from Western to Eastern Europe was analysed, in an attempt to ascertain whether there is a reliable basis for this movement and whether the CEE countries indeed have more to offer.

In the course of this research, both qualitative and quantitative analysis have been performed with all relevant available data. From this analysis, it would appear that in general there are potential benefits, which can be achieved by including CEE countries into the European portfolio; though a closer examination at the individual country level is required in order to identify their potential role in this portfolio. Out of the three countries analysed, Poland leads with its competitive performance and relatively low volatility. Over the last ten years, Czechia has not performed as well as Poland; however it is still offers solid performance with higher volatility. Disappointingly, the analysis showed Hungary's low total return and relatively high volatility. Qualitative analysis and investor's survey showed that Hungary could be the next upswing candidate within CEE region in coming years. The one condition being that internal political situation stabilises.

5.1 Discussion

During this research several themes identified, which would now require more in-depth examination. Firstly in the subsection 4.2.1, the phenomenon of lagged correlation between countries is described. If additional returns data were available, particularly longer time-series data, it would have been beneficial to determine whether there is a lagged correlation among countries, which depend on each other. For instance, this would have been helpful for an analysis of this effect on Czechia in relation to Germany, by virtue of the interconnectedness of these two economies.

Furthermore, according to this research the boom-bust model may function differently in some countries. The relationship between real estate and economic cycles in CEE countries behaves differently compared to Spain or the United Kingdom. Hence, it would be necessary to perform lagged cross-correlation between GDP growth and real

estate returns over longer periods (approximately 15 years or more). This would show particular cycle movements within investigated period of ten years. The goal would be to find a higher lagged correlation than in non-lagged situation and show movement relationships between real estate market cycle and economic cycle, as depicted in Figure 2.

For more detailed and wider analysis, it would be necessary to standardise the data survey and publicize this data, particularly for academic purposes. Indeed, it would be desirable to have accessible sectorial data with standardised frequency of data points for all investigated countries.

5.2 Prospects

The volume of the CEE markets is still quite limited compared to their Western European counterparts; regardless the current growth trend for CEE markets is positive and it is expected that they will benefit from new sources of capital in the coming years. Moreover, the region's occupational and economic prospects are some of the most robust in Europe and yields are not yet fully compressed to reflect this. Likewise, income growth is possibly to be one of the drivers of overall investment returns in the medium term.

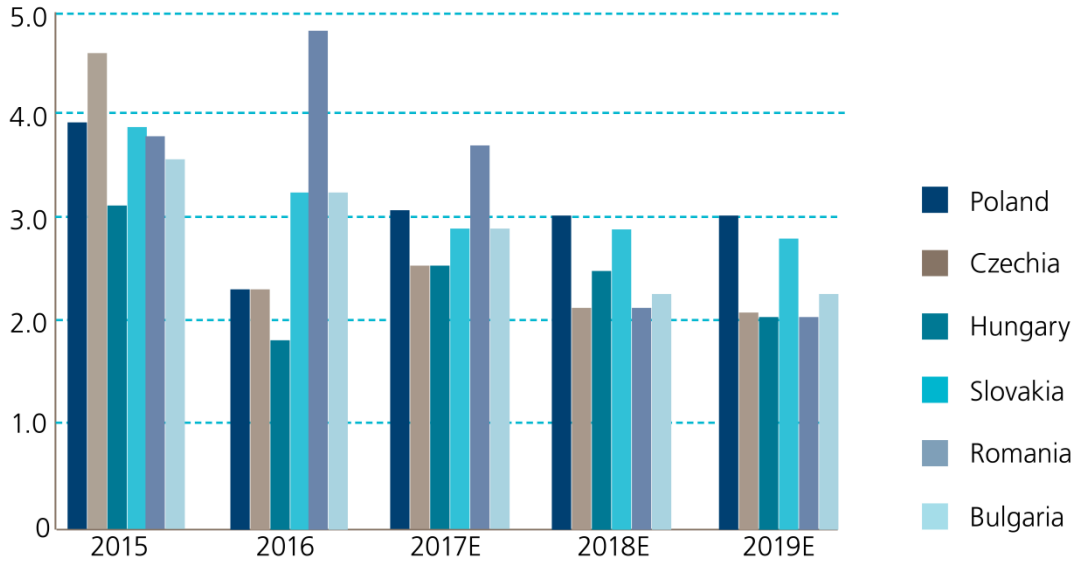


Figure 18: Recent and forecast GDP growth (yoy, %) in the CEE-6 countries (Robinson, 2016, p. 7)

Figure 18 illustrates the perspective that in the long-run there is a stable and relatively high GDP growth forecast for CEE countries for the next years compared to the EU average of about 1%. This region is also experiencing the lowest level of its unemployment rates. In 2017, Czechia boasts of a 3% rate mark. Poland with 4.3% and

Hungary with 5.1% are among the countries with lowest unemployment rates in Europe[7]. This economic environment has a very constructive effect on wage growth and accordingly on consumer spending. This in turn boosts the retail sector and the overall good economic situation is beneficial also for the office sector.

The forecast for the three investigated countries is certainly promising for the future. However, in consideration of the analysis of returns and the application of the boom-bust model it seems probable that in the short-run the real estate economic cycle is currently at its peak, mainly in CBDs of the capital cities of these countries. An alternative to CBD could be regional diversification and investment in lower-tiered cities. Furthermore investment in the CEE region is nevertheless not without the risks, to which Hungary is exposed in the form of geopolitical instability and legislative changes or the political insecurity experienced by Poland.

[7] Czechia shows in 2017 the lowest unemployment rate in the whole Europe, see Appendix VII

Bibliography

Anderson, J., & Gonzales, A. (2012, October 23). *Does Doing Business matter for foreign direct investment?* Retrieved from Doing Business: http://www.doingbusiness.org/reports/thematic-reports/does-doing-business-matter-for-foreign-direct-investment

Andonov, A., Kok, N., & Eichholtz, P. (2013). A Global Perspective on Pension Fund Investment in Real Estate. *The Journal of Portfolio Management*, pp. 32 - 42.

Blake, N., Goodwin, A., McIntosh, A., & Simmons, C. (2011). *Property and inflation.* London: Investment Property Forum.

BNP Paribas Real Estate. (2017). *OFFICE INITIAL YIELDS WILL RECORD NEW COMPRESSIONS IN MOST MARKETS OF CONTINENTAL EUROPE.* Issy-les-Moulineaux: BNP Paribas Real Estate.

Boppart, S., Fries, D., Hasenmaile, F., Hürzeler, F., Kaufmann, P., Lüthi, M., . . . Dr. Waltert, F. (2016). *Schweizer Immobilienmarkt 2016: Vertreibung aus dem Paradies.* Credit Suisse Economic Research. Zürich: gdz AG.

Craddock, P. (2014). *Implications for Property Yields of Rising Bond Yields.* London: Investment Property Forum.

Curran, R. (2016). *REAL ESTATE MARKET OUTLOOK: Czech Republic.* Prague: CBRE Research.

Cwiklinski, M., & Wojtczak, W. (2017). *Briefing European Investment.* London: Savills plc.

DiPasquale, D., & Wheaton, W. (1992). The markets for real estate assets and space: A conceptual framework. *Real Estate Economics (formerly AREUEA Journal), 20*(2), 181-198.

Doing Business. (2016, October 25). *Doing Business 2017: Equal Opportunity for All.* Retrieved from http://www.doingbusiness.org/reports/global-reports/doing-business-2017

Fraboul, A. (2017). *EUROPEAN OFFICE MARKET REPORT.* Paris: BNP Paribas Real Estate.

Garcia, D., & Kaufmann, P. (2014). *Global Investor 1.14.* Zürich: Giles Keating, Credit Suisse AG.

Geltner, D. M., Miller, N. G., Clayton, J., & Eichholtz, P. (2013). *Commercial Real Estate Analysis and Investments* (3 ed.). Mason: OnCourse Learning.

Global Real Estate Transparency Index Team. (2016). *Taking Real Estate Transparency to the Next Level.* Retrieved from Global Real Estate Transparency Index 2016: http://www.jll.com/greti/rankings

Gralin, M. V. (2016). *Property yields keep falling – where are the opportunities in Europe? European Fair Value Index™.* London: Cushman & Wakefield.

Hallett, J. (2016, March 1). *Investment In the CEE Property Market More Stable Than In Western Europe.* Retrieved from Emerging Europe: http://emerging-europe.com/special-reports/ee-at-mipim-2016/investment-in-the-cee-property-market-more-stable-than-in-western-europe/

Haran, M., McCord, M., Davis, P., McCord, J., Lauder, C., & Newell, G. (2016). European emerging real estate markets: Re-examining investment attributes and framing opportunities. *Journal of Property Investment & Finance, 34*(1), pp. 27-50.

Inman, P. (2016, July 12). Irish economy surges 26% as revised figures take in foreign investment. *The Guardian.*

Kapp, J.-P. (2016, May 30.). *Das sind die wettbewerbsfähigsten Länder der Welt.* Retrieved from NZZ Online: https://www.nzz.ch/wirtschaft/imd-ranking-politische-ungewissheit-beeintraechtigt-die-wettbewerbsfaehigkei/

Lizieri, C. (2013). After the Fall: Real Estate in the Mixed-Asset Portfolio in the Aftermath of the Global Financial Crisis. *The Journal of Portfolio Managment: Special Real Estate Issue, 39*(5), pp. 43 - 59.

Lizieri, C., & Pain, K. (2014). International Office Investment in Global Cities: The Production of Financial Space and Systemic Risk. *Regional Studies, 48*(3), pp. 439-455.

MSCI. (2014, June). *IPD Indexes and Benchmark Methodology Guide.* Retrieved from https://www.msci.com/index-methodology

MSCI. (2016, 04 20). *IPD® ANNUAL PROPERTY INDEX*. Retrieved from www.msci.org: https://www.msci.com/real-estate-fact-sheet-search

MSCI. (2017, March 27). *IPD® Czech Republic Annual Property Index (EUR).* Retrieved from https://www.msci.com/real-estate-fact-sheet-search?p_p_id=extendedlister_WAR_extendedlister_INSTANCE_yWFoRWV7pc2w&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-factsheet-search&p_p_col_count=1&_extendedlister_WAR_extendedlister_INSTANCE

Organisation for Economic Co-Operation and Development. (2017a, July 1). *OECD Data.* Retrieved from https://data.oecd.org/unemp/unemployment-rate.htm

Organisation for Economic Co-Operation and Development. (2017b, May). *OECD.Stat*. Retrieved from http://stats.oecd.org/

Organisation for Economic Co-Operation and Development. (2017c, July 1). *OECD Data.* Retrieved from https://data.oecd.org/price/inflation-cpi.htm

Robinson, M. (2016). *CEE Real Estate Investemnt Compass 2017.* Colliers. London: Colliers International Group Inc.

Schulte, K.-W. (2008). *Immobilienökonomie* (Vol. I). München: Oldenbourg.

Statista. (2017, July 12). *Das Statistik-Portal.* Retrieved from https://www.statista.com/statistics/246355/home-ownership-rate-in-europe/

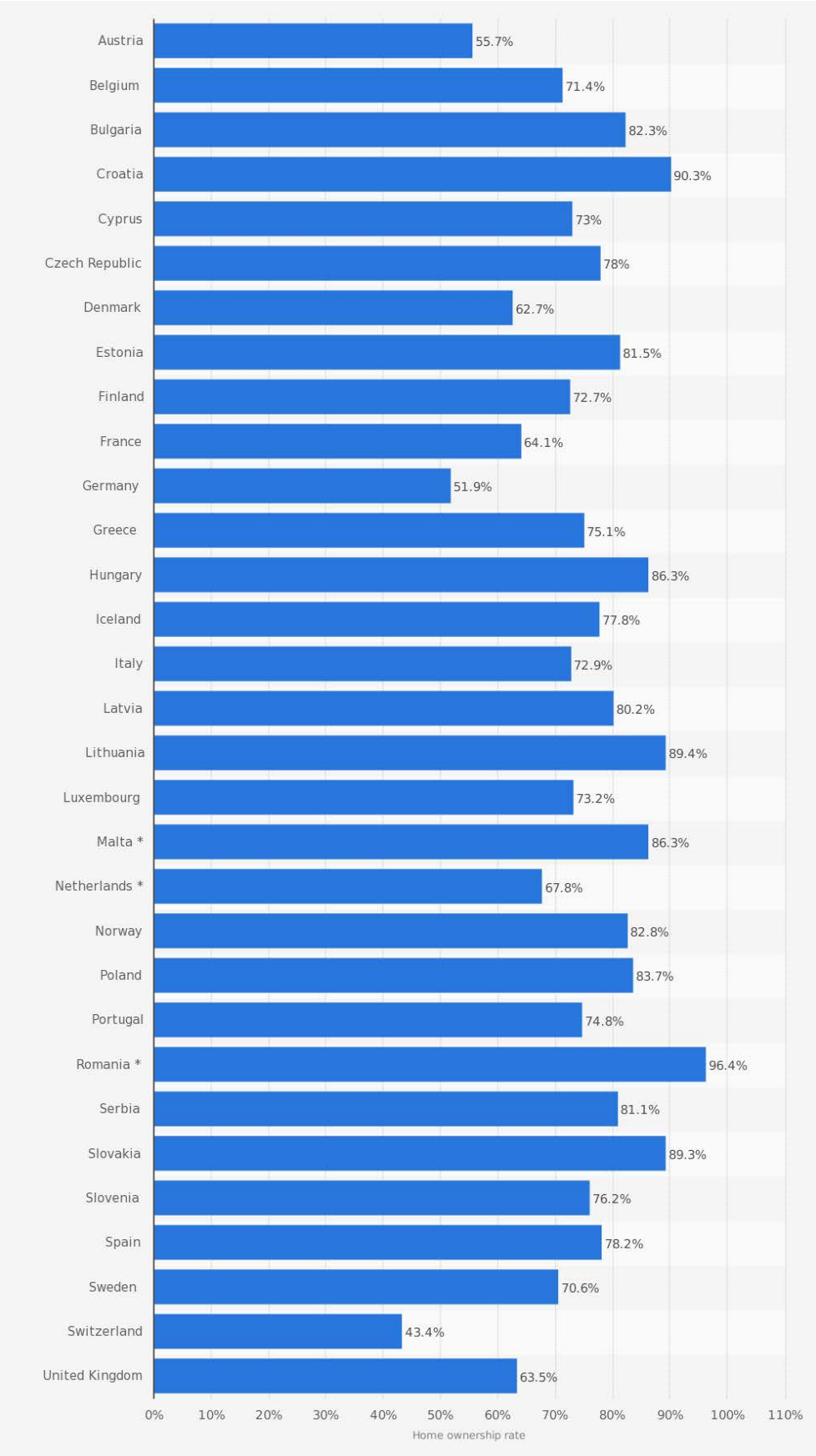
Trübestein, M. (2015). *Real Estate Asset Management: Studienergebnisse zu direkten und indirekten Immobilieninvestitionen in der Schweiz, Deutschland und Österreich.* Luzern: Springer Gabler.

Vacha, A., & Mikulka, M. (2017, April 4). *As long as interest rates are low, we are experiencing a golden age, says head of CPI.* Retrieved from Hospodarske Noviny: http://byznys.ihned.cz/c1-65683890-dokud-jsou-urokove-sazby-nizko-zazivame-zlate-...05.04.2017

Wakefield, C. &. (2017). *The Great Wall of Money.*

Wüest Partner. (2016). *Global Property Market.* Zürich: Wüest Partner.

Appendix I.: Homeownership rate in selected European countries in 2015 (Statista, 2017)

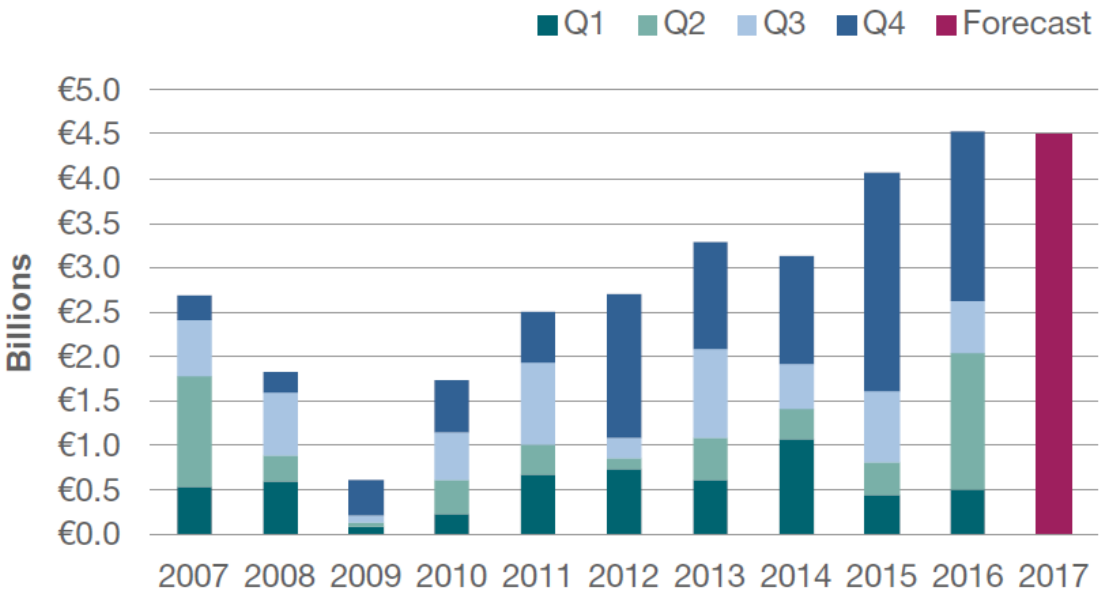


Source (Statista, 2017)

Appendix II.: Covariance matrix

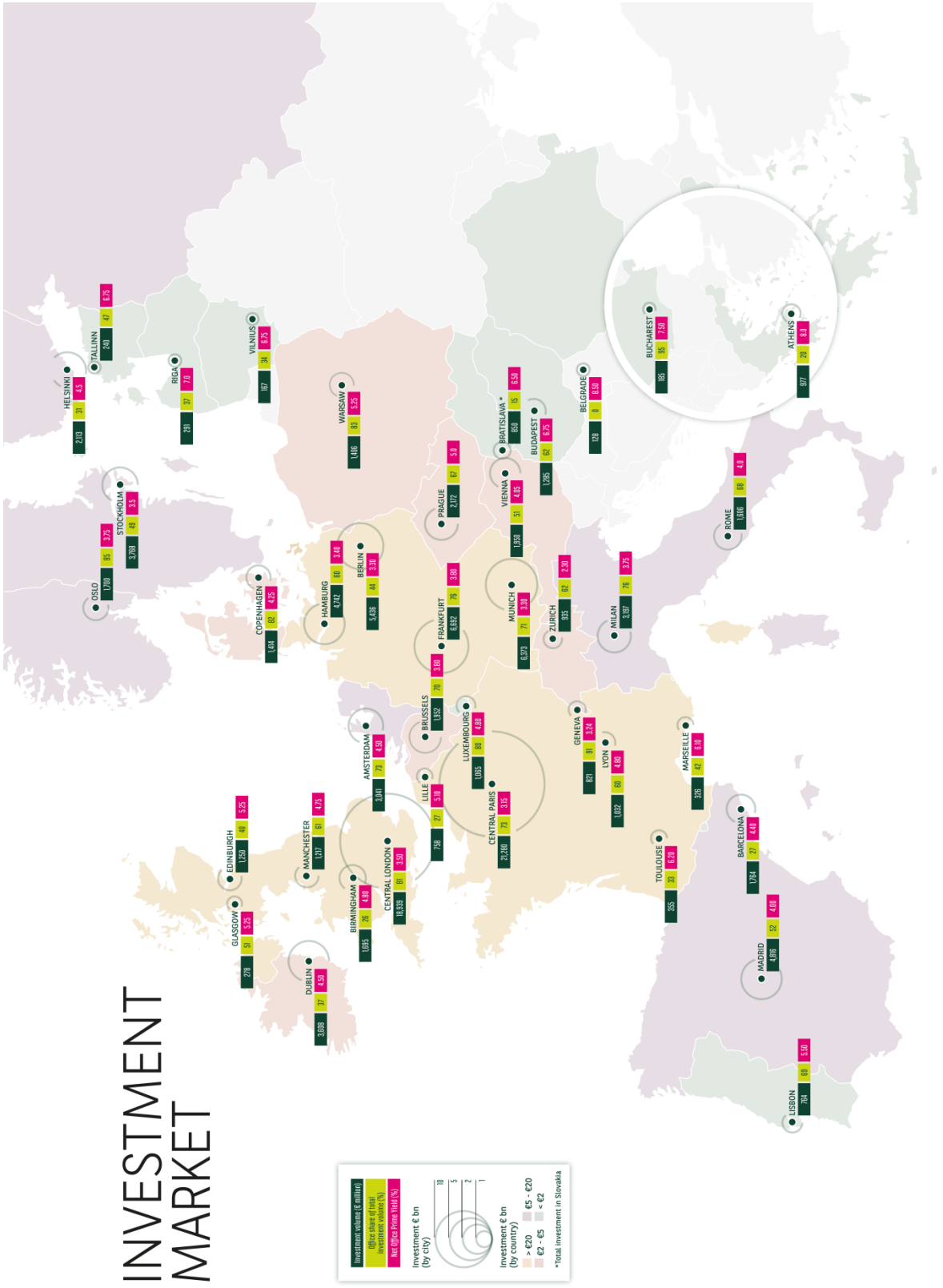
Kovarianz	Switzerland	Czechia	Poland	Hungary	Germany	Austria	Belgium	Denmark	Spain	France	Italy	Netherland:	Norway	Portugal	Sweden	Ireland	UK
	0,000069	0,000243	0,000276	0,000270	0,000036	0,000039	0,000053	0,000071	0,000114	0,000241	0,000080	0,000108	0,000137	-0,000008	0,000169	-0,000192	-0,000207
	0,000243	0,003333	0,002472	0,004057	0,000897	0,000313	0,001062	0,001304	0,004200	0,003010	0,001125	0,002018	0,002745	0,001989	0,002946	0,007897	0,001435
	0,000276	0,002472	0,002403	0,003108	0,000474	0,000229	0,000756	0,000888	0,002514	0,002442	0,001047	0,001356	0,001747	0,001053	0,001841	0,003432	0,000059
	0,000270	0,004057	0,003108	0,005340	0,001193	0,000343	0,001300	0,001599	0,005575	0,003629	0,001357	0,002594	0,003086	0,002553	0,003570	0,009788	0,001610
	0,000036	0,000897	0,000474	0,001193	0,000381	0,000089	0,000309	0,000381	0,001568	0,000705	0,000165	0,000638	0,000744	0,000706	0,000962	0,003255	0,000854
	0,000039	0,000313	0,000229	0,000343	0,000089	0,000118	0,000038	0,000073	0,000308	0,000392	0,000025	0,000067	0,000338	0,000020	0,000455	0,001268	0,000848
	0,000053	0,001062	0,000756	0,001300	0,000309	0,000038	0,000460	0,000496	0,001534	0,000919	0,000440	0,000751	0,000954	0,000862	0,000903	0,002562	0,000287
	0,000071	0,001304	0,000888	0,001599	0,000381	0,000073	0,000496	0,000629	0,001922	0,001197	0,000540	0,001027	0,001219	0,001122	0,001232	0,002740	0,000240
	0,000114	0,004200	0,002514	0,005575	0,001568	0,000308	0,001534	0,001922	0,007238	0,003588	0,001266	0,003263	0,003664	0,003679	0,004337	0,013238	0,003048
	0,000241	0,003010	0,002442	0,003629	0,000705	0,000392	0,000919	0,001197	0,003588	0,003160	0,001171	0,001783	0,002749	0,001726	0,002920	0,006592	0,001851
	0,000080	0,001125	0,001047	0,001357	0,000165	0,000025	0,000440	0,000540	0,001266	0,001171	0,000707	0,000845	0,001052	0,000874	0,000852	0,000835	-0,000420
	0,000108	0,002018	0,001356	0,002594	0,000638	0,000067	0,000751	0,001027	0,003263	0,001783	0,000845	0,001852	0,001747	0,001938	0,001900	0,003563	-0,000269
	0,000137	0,002745	0,001747	0,003086	0,000744	0,000338	0,000954	0,001219	0,003664	0,002749	0,001052	0,001747	0,003073	0,002030	0,003034	0,007575	0,002782
	-0,000008	0,001989	0,001053	0,002553	0,000706	0,000020	0,000862	0,001122	0,003679	0,001726	0,000874	0,001938	0,002030	0,002367	0,002039	0,005227	0,000452
	0,000169	0,002946	0,001841	0,003570	0,000962	0,000455	0,000903	0,001232	0,004337	0,002920	0,000852	0,001900	0,003034	0,002039	0,003495	0,009155	0,003687
	-0,000192	0,007897	0,003432	0,009788	0,003255	0,001268	0,002562	0,002740	0,013238	0,006592	0,000835	0,003563	0,007575	0,005227	0,009155	0,044465	0,017824
	-0,000207	0,001435	0,000059	0,001610	0,000854	0,000848	0,000287	0,000240	0,003048	0,001851	-0,000420	-0,000269	0,002782	0,000452	0,003687	0,017824	0,012864

Appendix III.: Poland investment volume 2007 – 2017 (Cwiklinski & Wojtczak, 2017, p. 19)



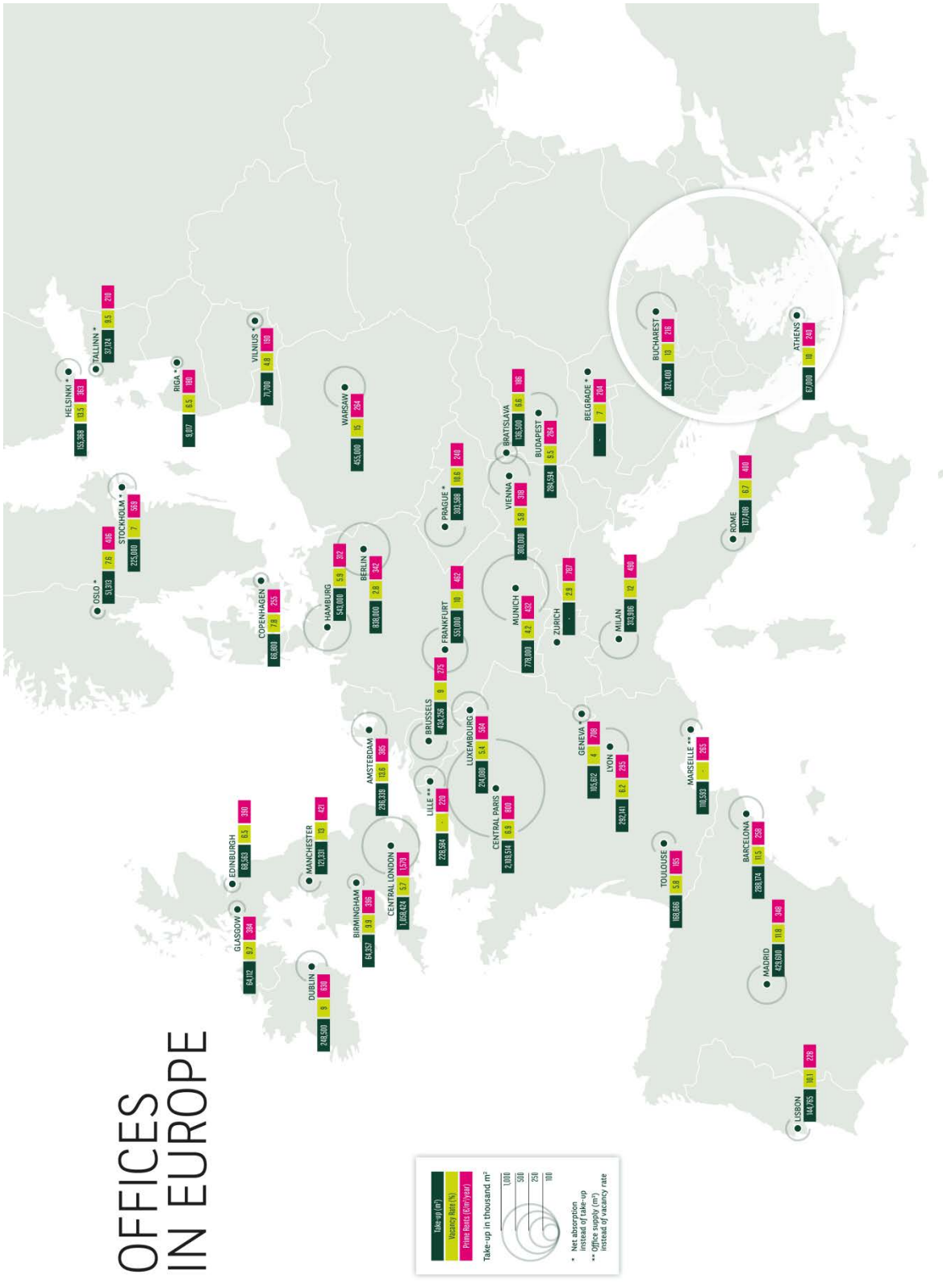
Source: (Cwiklinski & Wojtczak, 2017, p. 19)

Appendix IV.: Investment volumes in Europe in 2016 (Fraboul, 2017, p. 4)



Source: (Fraboul, 2017, p. 4)

Appendix V.: Offices in Europe in 2016 (Fraboul, 2017, p. 2)



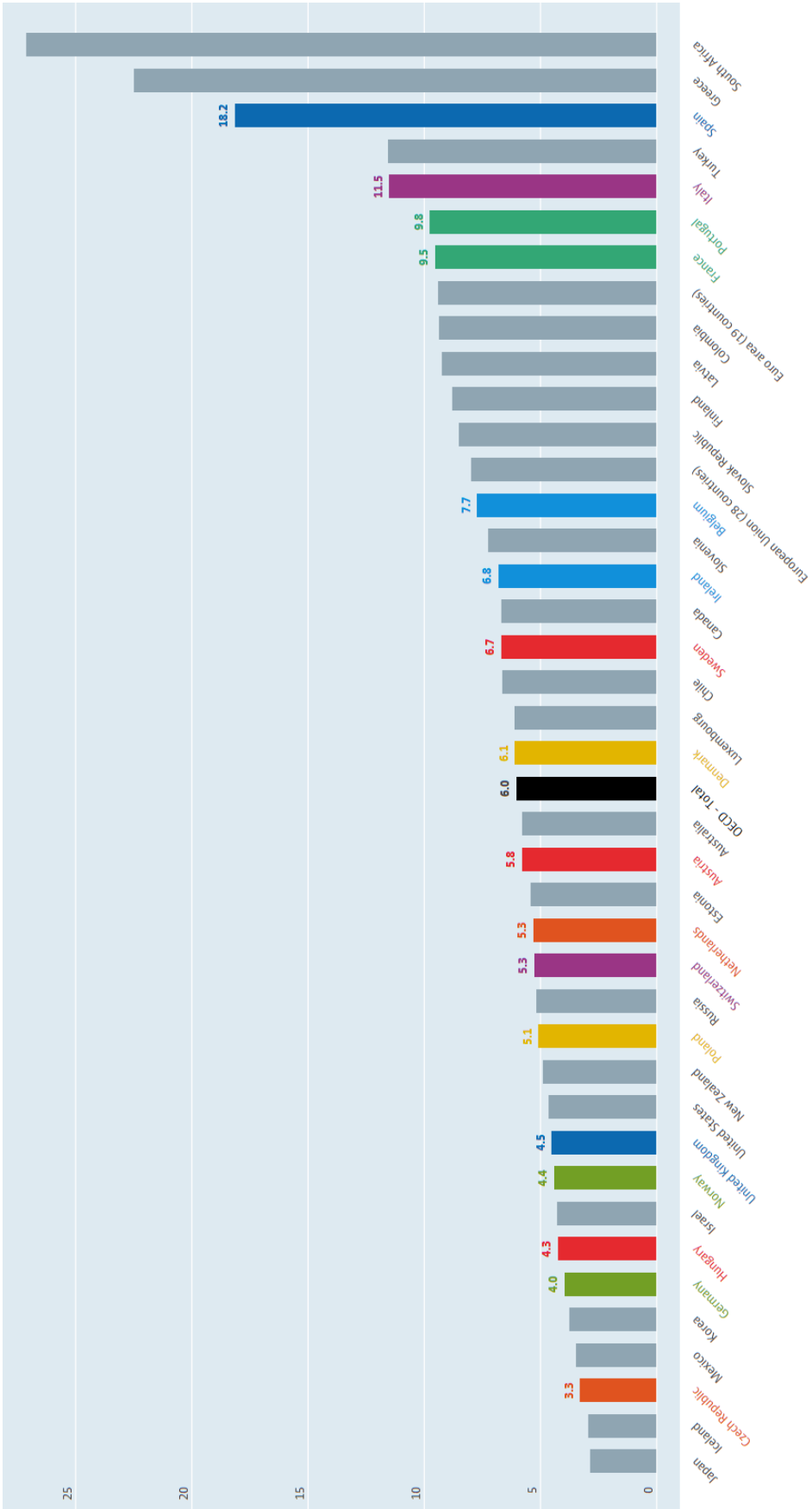
Source: (Fraboul, 2017, p. 2)

Appendix VI.: Returns - IPD data (MSCI, 2016)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CH	7,3%	6,3%	5,5%	6,1%	7,9%	7,1%	5,9%	5,2%	6,5%	6,2%
CZ	16,3%	-0,9%	-4,7%	3,2%	8,1%	3,9%	3,5%	7,1%	8,6%	8,3%
PL	16,0%	4,7%	-3,3%	7,5%	10,6%	5,5%	4,4%	5,9%	6,8%	4,6%
HU	14,0%	-2,8%	-13,1%	1,2%	5,0%	-2,1%	1,9%	3,9%	8,2%	6,2%
D	6,2%	3,0%	1,9%	4,0%	5,3%	4,4%	4,8%	5,9%	8,3%	7,5%
A	5,8%	3,1%	4,4%	6,4%	6,5%	6,6%	6,1%	5,2%	5,7%	5,7%
BE	9,6%	4,2%	3,1%	4,6%	5,1%	4,3%	3,3%	6,7%	8,4%	5,6%
DK	10,5%	3,4%	2,5%	5,0%	4,8%	3,9%	3,3%	5,4%	7,8%	7,7%
E	13,3%	-3,8%	-9,9%	3,2%	2,2%	-2,5%	0,1%	8,5%	15,1%	14,3%
F	18,0%	-0,8%	-2,3%	9,7%	8,2%	6,6%	5,2%	6,1%	8,6%	8,1%
I	11,0%	3,7%	2,1%	5,3%	4,0%	1,6%	2,1%	3,8%	4,1%	3,8%
NL	11,7%	3,2%	-1,0%	4,2%	3,6%	1,1%	0,3%	3,9%	7,7%	11,0%
N	18,2%	-3,2%	4,3%	8,1%	7,9%	5,1%	5,2%	8,3%	11,6%	10,4%
P	12,8%	2,4%	1,5%	4,6%	0,5%	0,1%	1,4%	6,7%	10,2%	11,8%
S	15,5%	-3,3%	1,1%	10,3%	10,3%	6,4%	6,9%	8,4%	13,8%	14,0%
IRL	9,7%	-35,3%	-22,9%	-2,4%	-2,4%	3,2%	12,3%	36,1%	25,1%	12,7%
UK	-2,4%	-21,8%	3,1%	15,0%	8,2%	3,8%	11,2%	17,7%	13,3%	3,9%

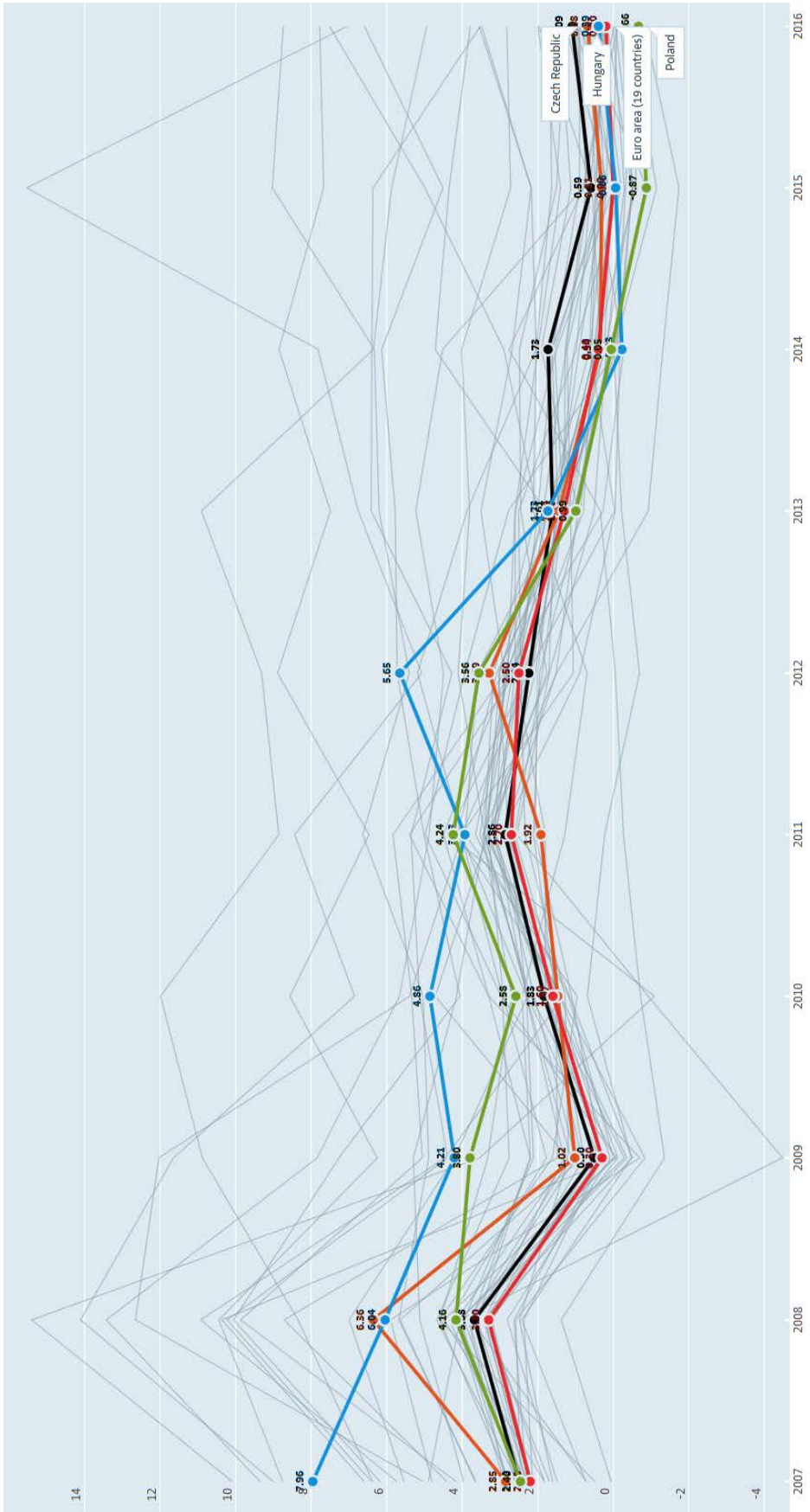
Source: (MSCI, 2016)

Appendix VII.: Unemployment rate in Europe in the 1st quarter of 2017 (Organisation for Economic Co-Operation and Development, 2017a)



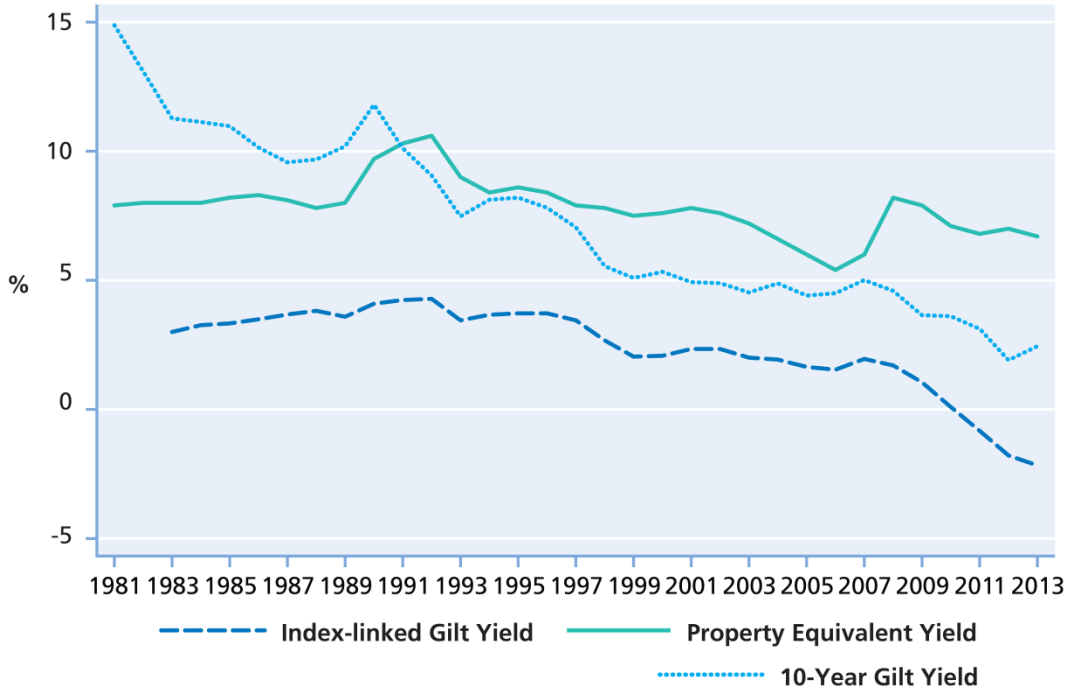
Source: (Organisation for Economic Co-Operation and Development, 2017a)

Appendix VIII.: Inflation, annual growth rate in %, 2007 – 2016 (Organisation for Economic Co-Operation and Development, 2017c)



Source: (Organisation for Economic Co-Operation and Development, 2017c)

Appendix IX.: UK IPD property equivalent yields, 10-year and index-linked gilt yields compared on an annual basis, 1981–2013 (Craddock, 2014, p. 8)



Source: (Craddock, 2014, p. 8)

Appendix X.: Lagged cross-correlation of real estate return and GDP growth

10yrs	2007-2016 σ(GDP)	2007-2016 σ(Return)	COV	CORR	1-year LAG 2006-2015 σ(GDP)	2007-2016 σ(Return)	COV	CORR	2-years LAG 2005-2014 σ(GDP)	2007-2016 σ(Return)	COV	CORR
Switzerland	1,70%	0,83%	0,000062	0,439037	1,92%	0,83%	0,000064	0,403693	1,93%	0,83%	-0,000063	-0,392819
Czechia	2,98%	5,77%	0,001416	0,824128	3,40%	5,77%	0,000669	0,340470	3,60%	5,77%	-0,000490	-0,235820
Poland	1,68%	4,90%	0,000592	0,717730	1,87%	4,90%	0,000130	0,141887	1,87%	4,90%	-0,000476	-0,518078
Hungary	3,00%	7,31%	0,001613	0,735623	3,14%	7,31%	0,000800	0,348846	3,25%	7,31%	0,000341	0,143376
Germany	2,69%	1,95%	0,000211	0,401808	2,83%	1,95%	0,000024	0,043131	2,83%	1,95%	-0,000242	-0,438396
Austria	2,00%	1,08%	0,000071	0,326366	2,13%	1,08%	-0,000085	-0,369342	2,12%	1,08%	-0,000113	-0,490982
Belgium	1,56%	2,14%	0,000248	0,738661	1,63%	2,14%	0,000103	0,294506	1,65%	2,14%	-0,000081	-0,228894
Denmark	2,01%	2,51%	0,000240	0,477102	2,32%	2,51%	0,000283	0,485999	2,38%	2,51%	0,000058	0,097747
Spain	2,55%	8,51%	0,002056	0,947465	2,48%	8,51%	0,000986	0,468113	2,28%	8,51%	-0,000244	-0,125934
France	1,51%	5,62%	0,000689	0,813615	1,56%	5,62%	0,000032	0,036592	1,56%	5,62%	-0,000293	-0,332989
Italy	2,38%	2,66%	0,000366	0,578835	2,43%	2,66%	0,000153	0,237225	2,40%	2,66%	-0,000039	-0,062000
Netherlands	2,10%	4,30%	0,000736	0,812690	2,28%	4,30%	0,000312	0,318020	2,30%	4,30%	-0,000095	-0,096462
Norway	1,33%	5,54%	0,000429	0,581034	1,42%	5,54%	-0,000006	-0,007211	1,53%	5,54%	0,000010	0,012108
Portugal	2,20%	4,86%	0,000884	0,826851	2,17%	4,86%	0,000433	0,409333	2,07%	4,86%	0,000051	0,050213
Sweden	3,05%	5,91%	0,001341	0,742539	3,21%	5,91%	0,000332	0,175045	3,18%	5,91%	-0,000728	-0,387407
Ireland	9,06%	21,09%	0,013917	0,728671	9,04%	21,09%	0,006749	0,353906	4,26%	21,09%	-0,000069	-0,007687
UK	2,13%	11,34%	0,001046	0,433830	2,16%	11,34%	-0,000751	-0,305801	2,22%	11,34%	-0,000891	-0,354450

Declaration of honour

I hereby confirm on my honour that I personally prepared the present academic work on the topic of public research HPC data centres and personally carried out the activities directly involved with it. I also confirm that I have used no resources other than the ones declared. All formulations and concepts adopted literally or in their essential content from printed, unprinted or Internet sources have been cited according to the rules for academic work and identified by means of footnotes or other precise indications of source.

The support provided during the work, including significant assistance from my supervisor has been indicated in full.

The academic work has not been submitted to any other examination authority. The work is submitted in printed and electronic form. I confirm that the content of the digital version is completely identical to that of the printed version.

I am aware that a false declaration will have legal consequences

Zürich, 28. August 2017

_____

Marek Dobias