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## MACROECONOMIC RISK OF INVESTMENT PORTFOLIOS AT THE WARSAW STOCK EXCHANGE

### Abstract

The essay presents the attempt to examine selected macroeconomic risk factors of portfolio investments in Polish capital market as well as to build investment portfolios sensitive to particular risk profiles. With this objective in view, quoted companies at WSE were classified in accordance to selected macroeconomic risk factor, applying the multidimensional statistic analysis. On the basis of the classification the shares portfolios of different risk profiles were built.

The principal components analysis was applied to specify the main macroeconomic risk factors. Next, for all assets individually multifactor regression models were built to describe relations between the return rates of the assets and the macroeconomic risk factors. As a result of the regression analysis the sensitivity risk measures were received.

The clustering analysis was applied in order to classify the assets in accordance to the sensitivity risk measures. The result of classification was used to build the portfolios that are sensitive to specific of macroeconomic risks. Finally the influence of the specific macroeconomic risks on total investment risk was examined.

**Key words:** Multidimensional statistic analysis; principal components analysis; cluster analysis; risk management; portfolio analysis.

### 1. Introduction

Within developing free market economies an economic grow of a given country results in a grow of a capital market efficiency. It means that the capital market and in particular the changes at the stock exchange are becoming more and more sensitive to the changes taking place in macroeconomic. Such situation is currently taking place in Polish capital market, which is defined as the so called emerging market. Therefore, the investors while taking decisions should

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include in their analyses the risk concerning the sensitivity of financial instruments to the changes of macroeconomic factors within a given economy.

In the present essay the application of multidimensional statistic analysis for the evaluation of a risk concerning the main macroeconomic factors of a portfolio investment was presented. The methods of the multidimensional statistic analysis was applied to identify the main macroeconomic risk factors as well as to build shares portfolios of different profiles of the risk.

## 2. Identification of macroeconomic risk factors

A multifactor model (Tarczyński, 1997) was applied for the identification of the risk factors. Its factors were evaluated by means of the principal components analysis (Jajuga, 1993). The multifactor model is described by the following formula:

$$R_i = a_i + b_{i1}F_1 + b_{i2}F_2 + \dots + b_{ik}F_k + e_i \quad i = 1, \dots, n \quad (1)$$

where the symbols stand for as following:

$R_i$  – return rates of  $i$ -shares;  $k$  – number of factors ( $k < n$ );  $F_j$  –  $j$  – factor of macroeconomic risk;  $a_i$  – intercept of the equation;  $b_{ij}$  – sensitivity coefficient of the return rates of  $i$ -share which is dependent of  $j$ -macroeconomic factor;  $e_i$  – equation error term;  $n$  – number of companies (Jajuga, Jajuga, 2002).

The principal components analysis was applied to specify risk factors in model (1). By means of this analysis there was made the decomposition of the variation of the multidimensional observation set (primary macroeconomic variables) into a new observation set as a linear combination of the primary variables. In this way a layout of miscorrelated factors (principal components) was obtained. Principal components were applied as variables of the multifactor model. Such composed model was used to explain the changes in stock companies return rates of shares. Only the companies sensitive to changes of the principal components were used to build the investment portfolios.

## 3. Construction of portfolios of different macroeconomic risk profiles

In order to build the portfolios of different macroeconomic risk profiles there was made the classification of selected companies by means of the cluster analysis. The classification was carried out taking into account the sensitivity



coefficient ( $b_{ij}$ ) of the principal components. Next, for each separate cluster, an investment portfolio was built and a risk analysis carried out.

#### 4. Investment portfolio risk analysis

Investment portfolio risk analysis was carried out by means of the multifactor model, which for the shares portfolio takes the following formula:

$$R_p = a_p + b_{p1}F_1 + b_{p2}F_2 + \dots + b_{pk}F_k + e_p \quad (2)$$

where the symbols stand for as following:

$$R_p = \sum_{i=1}^n w_i R_i; b_{pj} = \sum_{i=1}^n w_i b_{ij}; e_p = \sum_{i=1}^n w_i e_i$$

$w_i$  – percentage of  $i$ -shares in portfolio.

Total market risk, assuming the factors independence, might be described by means of the following formula:

$$S_p^2 = \sum_{j=1}^k b_{jp}^2 S_{jp}^2 + S_{ep}^2 \quad (3)$$

where the symbols stand for as following:

$b_{jp}$  – sensitivity coefficient of total portfolio in relative to  $j$ -factor,  $S_{jp}^2$  – variance of  $j$  – factor of portfolio,  $S_{ep}^2$  – variance of equation error term of portfolio.

When decomposing the total portfolio risk into the risk of macroeconomic factors and the specific risk (portfolio components risk) the particular components can be calculated as:

$$\text{Risk of } j\text{-macroeconomic factors} = b_{jp}^2 S_{jp}^2, \quad (4)$$

$$\text{Specific risk (portfolio components risk)} = S_{ep}^2. \quad (5)$$

#### 5. Empirical analysis – the object of the analysis

The monthly macroeconomic data and monthly return rates from Warsaw Stock Exchange companies, quoted between January 1999 and August 2005, are the object of the analysis. Macroeconomic variables were presented in Table 1.

Table 1

## Macroeconomic variables (primary risk factors)

Symbol of variable	Name of variable	Description of variable
ZRENBS	Changes of return rate of treasury note	Relative change of monthly return rate of treasury note in relation to previous month $ZRENBS_t = (RENBS_t - RENBS_{t-1}) / RENBS_{t-1}$
ZBEZROBO	Changes of unemployment rate	Relative change of monthly unemployment rate in relation to previous month $ZBEZROBO_t = (BEZROBO_t - BEZROBO_{t-1}) / BEZROBO_{t-1}$
ZEURO	Changes of currency Exchange rate EURO/PLN	Relative change of monthly average of EURO currency in relation to previous month $ZEURO_t = (EURO/PLN_t - EURO/PLN_{t-1}) / EURO/PLN_{t-1}$
ZUSD	Changes of currency Exchange rate USD/PLN	Relative change of monthly average of USD currency in relation to previous month $ZUSD_t = (USD/PLN_t - USD/PLN_{t-1}) / USD/PLN_{t-1}$
ZPPI_rr	Changes of producer price index	Relative change of average monthly value of producer price index in relation to the same month in previous year. Calculated on the basis of producer price index $ZPPI\_rr_t = (PPI\_rr_t) - 100$
ZM3_rr	Changes of money supply M3	Relative change of monthly money supply in relation to the same month in previous year. Calculated on the basis of M3 index $ZM3\_rr_t = (M3\_rr_t) - 100$
ZPLBR_rr	Changes of average gross wages	Relative change of monthly value of average gross wages in relation to the same month in previous year. Calculated as transformation average gross wages index $ZPLBR\_rr_t = (PLBR\_rr_t) - 100$
ZDEFICYT	Changes of budget deficit	Relative change of monthly value of budget deficit in relation to the previous month $ZDEFICYT_t = (DEFICYT_t - DEFICYT_{t-1}) / DEFICYT_{t-1}$
ZBILHA	Changes of foreign trade balance	Relative change of monthly value of foreign trade balance in relation to the previous month $ZBILHA_t = (BILHA_t - BILHA_{t-1}) / BILHA_{t-1}$
ZWIBOR3M	Changes of Warsaw Interbank Offer Rate	Relative change of monthly value of Warsaw Interbank Offer Rate in relation to the previous month $ZWIBOR3M_t = (WIBOR3M_t - WIBOR3M_{t-1}) / WIBOR3M_{t-1}$
ZPROP_rr	Changes of level of industry production	Relative change of monthly value of industry production level in relation to the same month in previous year. Calculated as transformation industry production index $ZPROP\_rr_t = (PROP\_rr_t) - 100$



Table 1 (contd.)

Symbol of variable	Name of variable	Description of variable
ZCPI_rr	Changes of consumer price index	Relative change of average monthly value of consumer price index in relation to the same month in previous year. Calculated as transformation consumer price index $ZCPI\_rr = (CPI\_rr_t) - 100$
RWIG	Return rate of WIG	Monthly average of daily return rates of WIG $RWIG_t = AVERAGE((WIG_{t-1} - WIG_{t-1}) / WIG_{t-1})$
RWIG20	Return rate of WIG20	Monthly average of daily return rates of WIG20 $RWIG20_t = AVERAGE((WIG20_{t-1} - WIG20_{t-1}) / WIG20_{t-1})$
RMIDWIG	Return rate of MIDWIG	Monthly average of daily return rates of MIDWIG $RMIDWIG_t = AVERAGE((MIDWIG_{t-1} - MIDWIG_{t-1}) / MIDWIG_{t-1})$

Source: own study.

## 6. Empirical analysis – macroeconomic risk identification

By means of the principal components analysis there was made the decomposition of the variation of the macroeconomic variables in Table 1. These variables were transformed into 15 principal components, out of which only those were selected, whose eigenvalues were higher than one.

In this way six components were selected which were treated as macroeconomic risk factors. It turned out the six principal components explain almost 79% of the primary macroeconomic variance. Next the factor loads of the components were calculated, which helped define the level of macroeconomic risk for each component. The components factor loads are shown in Table 2.

Absolute values of factor loads of the first principal component are the highest for such variables as: ZWIBOR3M, ZRENBS, PPI\_rr, PROPRZEM, CPI\_rr. The first main principle is called the risk of inflation influence. The factor loads of the second component are the highest for the following variables: RWIG, RWIG20, RMIDWIG. It may be defined as the risk of market condition. The factor loads of the third component are the highest for the following variables: M3\_rr, ZBEZROBO. It is defined as the risk of unemployment influence. The fourth main component is mostly defined by the changes in currencies values (ZUSD and ZEURO). It mirrors the risk of currencies. The fifth component is mainly sensitive to: PLBR\_rr and ZBILHAND. Its changes have been defined as the risk of production level. The sixth component is mainly represented by the changes in the budget deficit. It mirrors the risk of budget deficit.

The selected principal components were used as the explanatory variables for multifactor models. Within the examined period: from January 1999 to August 2005, each month, 120 companies were quoted at the Warsaw Stock Exchange. For each of them a multifactor model was evaluated, in which the six principal components were used as the explanatory variables ( $F_j$ ). For further analysis out of all 120 companies only those were selected for which the determination coefficient was higher than 25%. In this way there were 49 companies selected.

Table 2

Factor loads of principal components

Macroeconomic variables	PC.1	PC.2	PC.3	PC.4	PC.5	PC.6
ZRENBS	<b>-0.726</b>	-0.290	0.347	0.142	-0.042	-0.036
PPI_rr	<b>-0.855</b>	-0.100	0.004	-0.188	0.175	0.032
ZWIBOR3m	<b>-0.808</b>	-0.102	0.280	0.024	0.097	-0.043
PROPRZEM	<b>-0.607</b>	0.168	0.536	-0.193	-0.079	-0.085
CPI_rr	<b>-0.682</b>	-0.288	-0.554	0.067	-0.030	0.017
RWIG20	-0.201	<b>0.868</b>	-0.057	0.361	-0.043	-0.001
RWIG	-0.143	<b>0.929</b>	-0.018	0.284	-0.013	-0.050
RMIDWIG	-0.148	<b>0.856</b>	0.011	0.139	-0.121	-0.226
ZBEZROBO	-0.131	-0.001	<b>-0.587</b>	-0.198	-0.164	-0.303
M3_rr	-0.523	-0.248	<b>-0.582</b>	0.310	-0.245	-0.065
ZEURO	0.333	-0.436	0.333	<b>0.426</b>	-0.022	-0.433
ZUSD	0.026	-0.466	0.195	<b>0.689</b>	-0.253	-0.174
PLBR_rr	0.158	-0.027	-0.092	-0.136	<b>-0.800</b>	0.131
ZBILHAN	-0.154	0.065	0.415	-0.317	<b>-0.587</b>	0.058
ZDEFICYT	-0.063	-0.048	0.039	0.417	-0.021	<b>0.816</b>

Source: own study.

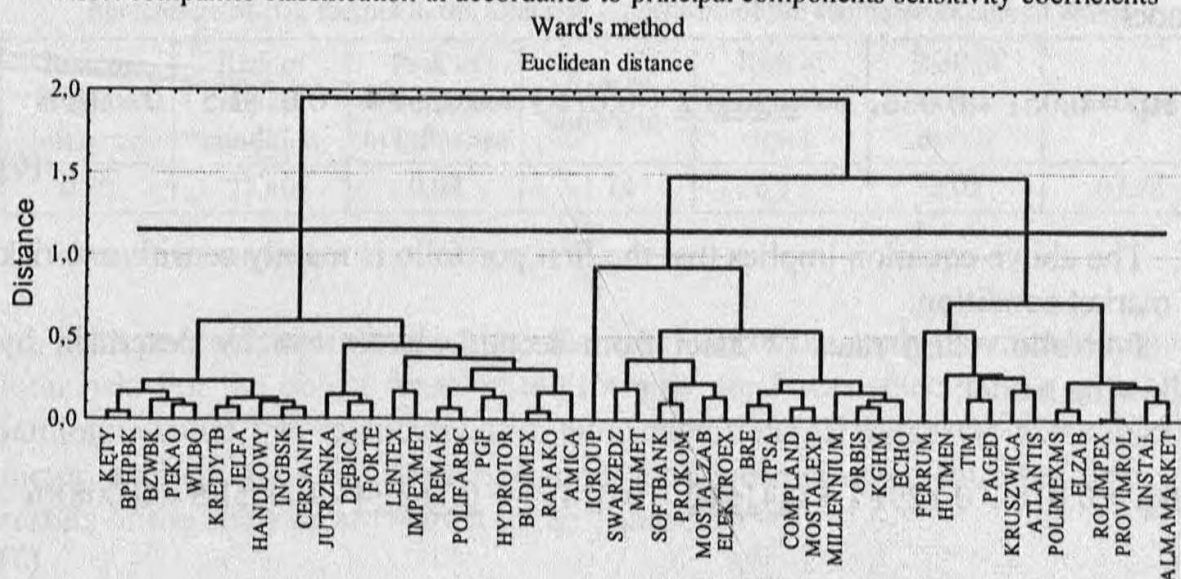
## 7. Empirical analysis – companies classification

Selected 49 companies were characterised by means of the sensitivity factor ( $b_{ij}$ ) and then classified according to the values of those parameters. The classification was carried out by means of the cluster analysis, to which the Ward's method was applied, where the Euclidean distance was chosen as the distance measure. The result of the analysis is shown in the Drawing 1.

Basing on the dendrogram as presented in Drawing 1, the companies were divided into an appropriate number of classes. The division was carried out by cutting the branches of the dendrogram on the distance level allowing the differences between the closest clusters being the biggest possible. The cutting place is marked on the Drawing 1 by a single horizontal line. In this way three clusters were obtained.



## Asset companies classification in accordance to principal components sensitivity coefficients



Drawing 1. Asset companies classification in accordance to principal components sensitivity coefficients

Source: own study.

The first cluster was created by the following companies: KĘTY, BPHPBK, BZWBK, PEKAO, WILBO, KREDYTB, JELFA, HANDLOWY, INGBSK, CERSANIT, JUTRZENKA, DĘBICA, FORTE, LENTEX, IMPEXMET, REMAK, POLIFARBC, PGF, HYDROTOR, BUDIMEX, RAFAKO and AMICA.

The second cluster was created by the following companies: IGROUP, SWARZEDZ, MILMET, SOFTBANK, PROKOM, MOSTALZAB, ELEKTROEX, BRE, TPSA, COMPLAND, MOSTALEXP, MILLENNIUM, ORBIS, KGHM and ECHO.

The third cluster was created by the following companies: FERRUM, HUTMEN, TIM, PAGED, KRUSZWICA, ATLANTIS, POLIMEXMS, ELZAB, ROLIMPEX, PROVIMROL, INSTAL and ALMAMARKET.

## 8. Empirical analysis – risk of investment portfolios

The investment portfolio was built for each separate cluster. The return rates of built portfolios were calculated by means of the multifactor model. In order to evaluate the risk profile of each portfolio there were created portfolios containing the same proportion of each asset.

Portfolio return rate of asset from first cluster can be described by following model:

$$R_p = 0.061 - 0.036F_1 + 0.268F_2 + 0.01F_3 + 0.055F_4 - 0.018F_5 - 0.089F_6 \quad (6)$$

The above equation implies that the first portfolio is mainly sensitive to risk of market condition.

Portfolio return rates of asset from second cluster can be described by following model:

$$R_p = 0.018 - 0.129F_1 + 0.416F_2 - 0.014F_3 + 0.163F_4 - 0.065F_5 - 0.008F_6 \quad (7)$$

The above equation implies that the second portfolio is more sensitive to risk of market condition than first portfolio and is sensitive to currency risk.

Portfolio return rates of asset from third cluster can be described by following model:

$$R_p = 0.067 - 0.056F_1 + 0.379F_2 + 0.177F_3 + 0.141F_4 + 0.044F_5 - 0.103F_6 \quad (8)$$

The above equation implies that the third portfolio is sensitive to risk of market condition and risk of unemployment influence.

On the basis of equation (2), (3), (4) and (5) the portfolio return rates, portfolio risk of macroeconomic factors and specific risk of portfolio were estimated. Moreover there were calculated the percentage of each risk components in total risk of investment portfolio. The result of the analysis from first portfolio is shown in the Table 3-7.

Table 3

The return rates and risk of the portfolio of the same percentage of assets

Return rate	Total risk	Macroeconomic risk	Specific risk
6.06%	0.26	0.08	0.18

Source: own study.



Table 4

Percentage of risk factors in the total risk – portfolio of the same percentage of assets

Risk of inflation influence	Risk of market condition	Risk of unemployment influence	Risk of currencies	Risk of production level	Risk of budget deficit	Specific risk
0.50	27.40	0.04	1.14	0.13	3.02	67.78

Source: own study.

The portfolio optimization was the next step of the analysis, minimising the total risk. For the object function the formula no. 3 was selected, for which the minimum value was calculated. In limited conditions all the macroeconomic risk factor, excluding the risk of market conditions, were assumed counting zero. The results of the analysis are shown in the Table 5.

Table 5

Percentage of risk factors in the total risk – optimal portfolio

Risk of inflation influence	Risk of market condition	Risk of unemployment influence	Risk of currencies	Risk of production level	Risk of budget deficit	Specific risk
<b>0.00</b>	31.21	<b>0.00</b>	2.08	<b>0.00</b>	1.56	65.15

Source: own study.

As the result of optimisation the risks of inflation influence, unemployment influence and production level have been reduced completely. However, in this portfolio the risks of changes in currencies and budget deficit cannot be reduced. The return rate of the present portfolio counts 3.93%. Next, the optimisation analysis was carried out again, assuming the specific risk being equal or below 40% of the total risk. The result of the analysis is shown in the Table 6.

Table 6

Percentage of risk factors in the total risk – optimal portfolio

Risk of inflation influence	Risk of market condition	Risk of unemployment influence	Risk of currencies	Risk of production level	Risk of budget deficit	Specific risk
<b>0.00</b>	53.00	4.38	0.48	0.04	2.10	<b>40.00</b>

Source: own study.

As the result of specific risk reduction the risk of macroeconomic factors have been increased. Otherwise the reduction of specific risk make the portfolio return rate has been increased from 3.93% to the level 4.12%.

Next the same analysis was made for second portfolio. The result of analysis is shown in Table 7–10.

Table 7

The return rates and risk of the portfolio of the same percentage of assets

Return rate	Total risk	Macroeconomic risk	Specific risk
1.82%	0.6	0.22	0.38

Source: own study.

Table 8

Percentage of risk factors in the total risk – portfolio of the same percentage of assets

Risk of inflation influence	Risk of market condition	Risk of unemployment influence	Risk of currencies	Risk of production level	Risk of budget deficit	Specific risk
2.77	28.60	0.03	4.41	0.71	0.01	63.48

Source: own study.

Result of optimizing the second portfolio is presented in Table 9 and 10.

Table 9

Percentage of risk factors in the total risk – optimal portfolio

Risk of inflation influence	Risk of market condition	Risk of unemployment influence	Risk of currencies	Risk of production level	Risk of budget deficit	Specific risk
2.47	36.98	0.00	4.92	0.00	0.00	55.63

Source: own study.

Having optimised the second portfolio, its return rate measured 2.87%. Next, the optimisation analysis was carried out again limiting the specific risk of the portfolio. In the end the portfolio of the specific risk equal or below 45% was obtained. The result of the analysis is shown in the Table 10.

Table 10

Percentage of risk factors in the total risk – optimal portfolio

Risk of inflation influence	Risk of market condition	Risk of unemployment influence	Risk of currencies	Risk of production level	Risk of budget deficit	Specific risk
2.40	48.21	0.00	4.18	0.00	0.20	45.00

Source: own study.



The limiting of the specific risk increased the budget deficit risk as well as the risk of market conditions. These changes resulted in the limit to the portfolio return rates to the level of 0.98%.

Next, the analysis of the third portfolio was carried out. The results of the analysis are shown in the chart 11–14.

Table 11

The return rates and risk of the portfolio of the same percentage of assets

Return rate	Total risk	Macroeconomic risk	Specific risk
6.69%	0.66	0.21	0.45

Source: own study.

Table 12

Percentage of risk factors in the total risk – portfolio of the same percentage of assets

Risk of inflation influence	Risk of market condition	Risk of unemployment influence	Risk of currencies	Risk of production level	Risk of budget deficit	Specific risk
0.48	21.45	4.67	2.97	0.28	1.60	68.55

Source: own study.

Table 13

Percentage of risk factors in the total risk – optimal portfolio

Risk of inflation influence	Risk of market condition	Risk of unemployment influence	Risk of currencies	Risk of production level	Risk of budget deficit	Specific risk
0.01	19.04	4.45	3.77	0.00	0.00	72.74

Source: own study.

As the results of the third portfolio optimisation its return rates decreased to the level of 1.92%. However, the optimisation allowed for total reduction of the risk of production level as well as the risk of budget deficit. Unfortunately the reduction of the total risk resulted in the increase in the specific risk to the level of 72% of the total risk.

Finally there was examined how the specific risk of portfolio can be limited. As the result of optimization the specific risk was limited to the level of 54% of the total risk portfolio and portfolio return rate was increased from the level of

1.92% to the level of 3.62%. Unfortunately the reduction of the specific risk resulted in the increase in the risk of market condition and risk of budget deficit. The results of the analysis are shown in the Table 14.

Table 14

Percentage of risk factors in the total risk – optimal portfolio

Risk of inflation influence	Risk of market condition	Risk of unemployment influence	Risk of currencies	Risk of production level	Risk of budget deficit	Specific risk
0.00	37.15	3.17	5.06	0.03	0.59	54.00

Source: own study.

## 9. Conclusion

As results from the analyses, in the case of only 49 of the companies quoted at the Warsaw Stock Exchange within the period between January 1999 and August 2005 the return rates depended in at least 25% on the changes in macroeconomic factors described by means of the principal components. Despite the fact that Polish capital market is not too effective, which is proved by the weak reactions of WSE to the changes of macroeconomic factors, it is possible to build several investment portfolios of different macroeconomic risk profiles. The constructed portfolios are mostly sensitive to specific risk as well to the risk of market conditions. Moreover, they are characterised by the sensitivity to changes in currencies values unemployment influence. The remaining macroeconomic risk factors do not take the major role. The analyses show that there is a possibility to build portfolios of different risk profiles and to reduce totally some of the macroeconomic risk factors.

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## **Ryzyko makroekonomiczne portfeli inwestycyjnych na GPW w Warszawie**

W pracy podjęto próbę oceny wybranych czynników ryzyka makroekonomicznego inwestycji portfelowej na polskim rynku kapitałowym. W tym celu przeprowadzono analizę klasyfikacji spółek ze względu na wybrane czynniki ryzyka makroekonomicznego, a następnie zbudowano portfele akcji o określonych profilach tego ryzyka.

Badanie przeprowadzono na miesięcznych danych makroekonomicznych oraz miesięcznych stopach zwrotu spółek notowanych na GPW w Warszawie w okresie od stycznia 1999 do sierpnia 2005 r.

Do specyfikacji ryzyka wykorzystano analizę głównych składowych. Wyznaczone składowe główne potraktowano jako czynniki ryzyka makroekonomicznego. Następnie oszacowano funkcje regresji opisujące stopy zwrotu akcji z wyznaczonymi czynnikami ryzyka. W wyniku analizy regresji otrzymano miary ryzyka wrażliwości stóp zwrotu spółek na poszczególne czynniki ryzyka makroekonomicznego. Następnie wykorzystano analizę skupień i dokonano klasyfikacji spółek ze względu na wyznaczone miary wrażliwości.

Na podstawie wyników klasyfikacji zbudowano portfele akcji o określonych profilach makroekonomicznego ryzyka a następnie przeprowadzono analizę dywersyfikacji ryzyka portfeli. Ostatecznie zbadano wpływ poszczególnych czynników ryzyka na całkowite ryzyko inwestycji.