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The risk–return profile of Lithuanian private pension funds

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ABSTRACT
The introduction of a private pension funds in conjunction with the public social security system is the essence of pension system reform that was implemented in Lithuania. The performance of private funds is mainly presented by fund's net asset value and few classical risk estimates. Such evaluation shows the management company's ability to profitably invest funds, but does not give the evidential risk–return evaluation. This paper refers to the overall statistical analysis of 26 private pension funds over a certain time period. The objective of the research is to determine the risk–return profile of pension funds and to answer the question whether the categories specified based on investment strategy in equities reflect fund's empirical behaviour. Research methodology includes the statistical analysis, risk measuring, performance ratio estimation, and K-means clustering. The conclusions obtained by the research allow determining whether the distinct pension funds have beaten a low risk reference and are adequately assigned to a certain risk category.

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1. Introduction

Declining birth rates and increasing life expectancy led to the pension system's reform in many countries around the world. The essence of these reforms is to improve the financial solvency of existing pension systems. Capacities, conditions, and value vary from country to country in order to implement the reform. The most popular decisions involve increasing the retirement age, stimulating or supporting the voluntary accrual for retirement, formalising the compulsory participation in private funds, and increasing the pension contribution (Chybalski, 2014; Finseraas & Jakobsson, 2014; Jaime-Castillo, 2013; Ličmane & Voronova, 2012; Mladen, 2013; Tuesta, 2014).

Lithuania has undertaken a pension reform in 2004, which was renewed in 2013. This was the reason to establish private pension funds. Currently, Lithuanian pension system provides three distinct sources of accumulation for retirement funds – so-called pension pillars (Bitinas, 2011):

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- 1st pillar – State social insurance funds. State social pension is financed from taxes paid by people currently working.
- 2nd pension pillar – quasi/mandatory funded pension operated by the private pension funds. The part of State social insurance fund is invested into assets.
- 3rd pension pillar – voluntary private funded pension scheme. Accumulation can be managed by private funds or life-insurance companies.

This paper focuses on the risk–return performance analysis of 2nd pillar private pension funds (PFs). The review by the Bank of Lithuania shows (Bank of Lithuania, 2014) that the asset value accumulated in 2nd pillar has amounted to EUR 1,867.7 million at 31 December 2014; the number of participants has reached 1.15 million. It means that a majority of workers takes part in the quasi/mandatory pillar since the assets managed in the 3rd pillar equal to EUR 47.58 million; the number of participants is 39,933. Accumulated benefits from 2nd or 3rd pillar funds are transferred to the personal account of the future retiree and reinvested in order to increase the accumulated amount of money.

Currently, 26 2nd pillar pension funds are operating in Lithuania. They are managed by 7 companies: Swedbank investicijų valdymas, SEB investicijų valdymas, AVIVA Lietuva, DNB investicijų valdymas, MP Pension Funds Baltic, INVL Asset Management, andDanske Capital investicijų valdymas. Pension funds in general invest approximately 38% of their capital (approximately EUR 750 million) in the Baltic market, while capitalisations of Baltic stock and bond markets are EUR 6.38 and 5.34 billion, respectively. Moreover, a review of Central Bank (Bank of Lithuania, 2015) reveals that only 0.69% of capital is directly (through the stock exchange) invested in stock, while 38.45% goes to government bonds, and 48.92% to other funds (mostly registered in Luxemburg). We may conclude that currently the direct impact to the stock market is very weak, while the government bonds market may be affected highly significantly. Every pension fund manager is obliged to invest in conservative pension funds while other pension funds are of different parts in equities. According to the recommendations of the Association of Financial Analysts (Association of Financial Analysts, 2004), pension funds in Lithuania are classified into several categories based on the investment strategy in equities:

- Conservative investments – no risky funds. It includes investments in securities issued by the State government or Central Bank. This strategy is recommended to preserve the accumulated value at the end of the accumulation period.
- Small allocation in equities – low risk funds. Nearly two-thirds of the funds invest in government securities, while other investments concern equities. This strategy is recommended for investors of high risk sensitivity (aversion) who expect higher yield.
- Medium allocation in equities – intermediate risk funds. Investment in stocks reaches 30–70% of allocation. This choice is most suitable for investors who follow the capital market and understand the perception of risk.
- All in equities – high risk funds with 70–100% allocation in stock market. High yield investments are recommended for investors with little sensitivity to the risk because of a strong financial position or other personal reasons.

People in Lithuania are encouraged to accumulate savings for their retirement by choosing private pension funds and not to rely only on the state pension funding. In this context, some risks arise:

- Empirical evidence strongly supports the conjecture that for the most part, participants have chosen inappropriate fund in which to participate: young members have selected pension funds with too conservative risk profile, older participants have chosen funds with major allocation in equites producing a higher risk to lose their savings due to fluctuation in markets (Buškutė & Medaiskis, 2011).
- The participants are very passive and not willing to change their choice made while entering a pension system: 5.56% (in 2013) and 2.78% (in 2014) of all those who accumulate in 2nd pillar decided to change their pension accumulation manager or pension fund (Bank of Lithuania, 2013, 2014).
- Pension fund managers give recommendations for fund's selection but rarely provide deeper statistical analysis. Moreover, if such an analysis is carried out, it is usually limited to pension funds managed by a certain company.
- Under the present regulation, benchmarks in 2nd pillar funds are obligatory, but are chosen voluntarily within the fund. It causes difficulty to compare the fund's outcomes globally in Lithuania.

The study of 2nd pillar pension funds in Lithuania is scant. Recently, some scientific publications have appeared where the performance of Lithuanian pension funds is explored from different point of views (Bartkus, 2014; Bitinas & Maccioni, 2013; Jablonskienė, 2013; Jurevičienė & Samoškaitė, 2012; Kavaliauskas & Jurkštienė, 2013; Volskis, 2012). The descriptive statistical analysis or econometric modelling is mainly applied for the research, which allows us to determine certain performance metrics or tendencies, then to compare pension funds operating in Lithuania. The motivation of those studies is usually to give the recommendations for 2nd pillar participants to choose the right fund or to describe the evolution of funds. The contribution of this paper – define groups with similar risk–return profiles and consider their riskiness from empirical data. The obtained results are compared with four categories specified by the Association of Financial Analysts (2004). The present study helps to select the concrete pension fund by measuring non-systematic risk.

To perform the research how similar or different funds behave historically, scientific approaches are applied to classify pension funds into groups. The research will end by answering the question: whether the obtained clusters of pension funds overlap with the categories specified based on investment allocation in equities? The research methods include descriptive statistical analysis, risk–return measuring, efficiency measuring, and K-means clustering. Matlab programming language is used for statistical computing.

2. Related works

Most European countries have experienced pension system reforms, where the social security scheme 'pay-as-you-go' (Siebert, 2010; Willmore, 2004) was prevailing as the main system. The reasons usually vary from country to country, but the difficulty sustaining their pension systems is at consensus. An increasing life expectancy in conjunction with low fertility rates caused switching to compulsory and/or voluntary pension schemes (Croitoru, 2015; Martín, 2010). The other significant determinants deteriorating the financial status of pension systems include the labour market, gross domestic product (GDP), income adequacy of pensions, and education (Chybalski, 2014). In certain countries, such factors like 'envelope salaries', unemployment, crisis and migration can also significantly influence the pension system (Agudo & García, 2011; Han, 2013; Mavlutova & Titova, 2014; Velculescu, 2010).

The review of studies focusing on the evaluation of the performance of mandatory and voluntary pension funds shows that funds are evaluated in a number of ways. We can distinguish two main groups within the above topic scope: modelling technique and data science methods.

Econometric modelling, asset–liability modelling, simulation, and similar modelling methodologies are implemented when it is needed to describe relations between relevant variables, forecasting not only pension fund's financial and monetary value in the future but also macroeconomic variables, social factors, demographic tendencies, political stability, globalisation, and external vulnerability as well (Heer & Irmen, 2014; Mielczarek, 2013; Thomas, Spataro, & Mathew, 2014). For the estimation of pension systems performance, the comparative study can be carried out in order to draw conclusions on a regional level and provide a basis for further analysis of certain countries situations. A good example is the Global Pension Statistics' project (OECD, 2013) launched in 2002 in order to create a valuable means to measure and monitor the retirement systems, as well as to compare those indicators, referring to wealth and investments, benefits and contributions, and operating expenses of private pension funds, across OECD and non-OECD countries. The statistical methods mainly applied to the analysis of empirical data generated by pension funds (Knill, Lee, & Mauck, 2012; Mohan & Zhang, 2014; Preciado & Recio, 2010). The risk estimation is on topic within this field of interest. Many authors (Chekhlov, Uryasev, & Zabarankin, 2005; Karagiannidis & Wilford, 2015; Lohre, Neumann, & Winterfeldt, 2008; Mielczarek, 2013) examined diverse risk measures, like skewness, standard deviation, Value at Risk (VaR), Conditional Value at Risk (CVaR), maximum drawdown, and others, to evaluate the dynamic behaviour of a managed portfolio from experience or in modelling. By combining several relevant measures, the evaluation of a fund's performance is more significant. Then, it is a question of technique, like principal component analysis, clustering, or other data science tools, to apply for adjusting those estimates that might be as principal determinants for fund's assessment.

The investment strategy of pension funds is based on the classical concept – reducing risk and volatility while at the same time providing maximum return. To implement this rule, risk-adjusted evaluations of return on investment may be induced. References in financial economics lead to an abundant choice of diverse measures to be used for comparing, ranking, or analysing the asset portfolios. Well known measures, like Sharpe, Sortino, Rachev and others (Farinelli, Ferreira, Rossello, Thoeny, & Tibiletti, 2008; Kolbadi, 2011), also known as performance ratios, pertain risk and reward in a single variable. Usage of indices and benchmarks is a beneficial way to measure market performance against a range of external influences. On the other hand, the choice of the benchmark is contentious, as it becomes complicated to distinguish between benchmark inefficiency and abnormal returns (Blake, Lehmann, & Timmerman, 2002; Grinblatt & Titman, 1994). Recent evidence (Petraki & Zalewska, 2015) suggests that benchmarks, known as Primary Prospectus Benchmark, used to assess the performance require greater scrutiny, since the indices are selected by managers that are easy to outperform and does not reflect the investment skill of pension managers. The other studies show that it is prudent to assess the performance of pension funds representing them as mutual funds (Blake, Lehmann, & Timmerman, 1999; Thomas & Tonks, 2001); but in contrast to mutual funds, the switching across providers is not so flexible due to additional costs. Some analysts (Blake et al., 1999; Coggin, Fabozzi, & Rahman, 1993) have conclusively shown that pension fund managers were rational by selecting a stock picking strategy, but were not able to time the market.

Drawing on a range of sources, the authors set out the different ways to analyse the performance of pension funds. Our research contributes to the field focusing on non-systematic risk assessment for pension funds' returns using asymmetric risk-adjusted measures.

3. Yield analysis of 2nd pillar pension funds

Empirical data supporting the research was collected for 26 pension funds over time period 5 May 2011– 30 January 2015. The period starts at 5 May 2011, because older data were available only for 18 of the 26 funds. By investment strategy, those funds are arranged into four categories:

- Pension funds with conservative investment:
  - Aviva Europensija (EURO1),
  - Konservatyvaus valdymo Danske pensija (DK1),
  - DNB pensija 1 (DNB1),
  - ERGO Konservatyvusis (ERGO1),
  - Finasta konservatyvaus investavimo (FIN1),
  - MP Stabilo II (MP1),
  - SEB pensija 1 (SB1),
  - Swedbank Pensija 1 (SW1);
- Pension funds with small equity share, investing up to 30% of funds in equity:
  - Aviva Europensija plius (EURO2),
  - DNB pensija 2 (DNB2),
  - Finasta augančio pajamingumo (FIN2),
  - Swedbank Pensija 2 (SW2);
- Pension funds with medium equity share, investing 30–70% of funds in equity:
  - Aviva Europensija ekstra (EURO3),
  - Danske pensija 50 (DK2),
  - DNB pensija 3 (DNB3),
  - ERGO Balans (ERGO2),
  - Finasta aktyvaus investavimo (FIN3),
  - MP Medio II (MP2),
  - SEB pensija 2 (SB2),
  - Swedbank Pensija 3 (SW3),
  - Swedbank Pensija 4 (SW4);
- Pension funds with equity 70–100%:
  - Danske pensija 100 (DK3),
  - Finasta racionalios rizikos (FIN4),
  - MP Extremo II (MP3),

– SEB pensija 3 (SB3)
– Swedbank Pensija 5 (SW5).

The dynamics of Net Asset Value (NAV), a conventional measure of the value of pension assets of a participant in a pension fund, is the fundamental variable that describes the evolution of pension funds. Using this measure, the equity curve over time is computed and depicted in each category of pension funds (Figures 1– 4). To conduct proper performance evaluations, the benchmark index OMX Vilnius, marked as a light solid line, is included in the analysis. Every figure includes averaged equity curve (black solid line) estimated from all 26 pension funds at each time moment.

Figures 1–4 show that by the end of 2011 the sharp drop in earnings of all pension funds is observed, as well as in benchmark value. The improvement was followed by a recurring decline in the middle of 2012 and in the middle of 2013. The averaged percentage yields of pension funds outperformed OMX Vilnius benchmark over 2012–2013 but the recovery rate was not high for each subsequent year as it can be more clearly seen in Figure 5, though resulting similar yield at the end of the period. As might be expected, the fluctuations in the percentage values of conservative pension funds and of small equity share funds were not so significant as those of pension funds with a higher risk tolerance investing a greater portion of their funds in equity. The group of conservative funds includes two funds, EURO1 and FIN1, which outperform the other conservative funds over the observed time period. The long-term performance of SW1 is stable but very low compared to others in

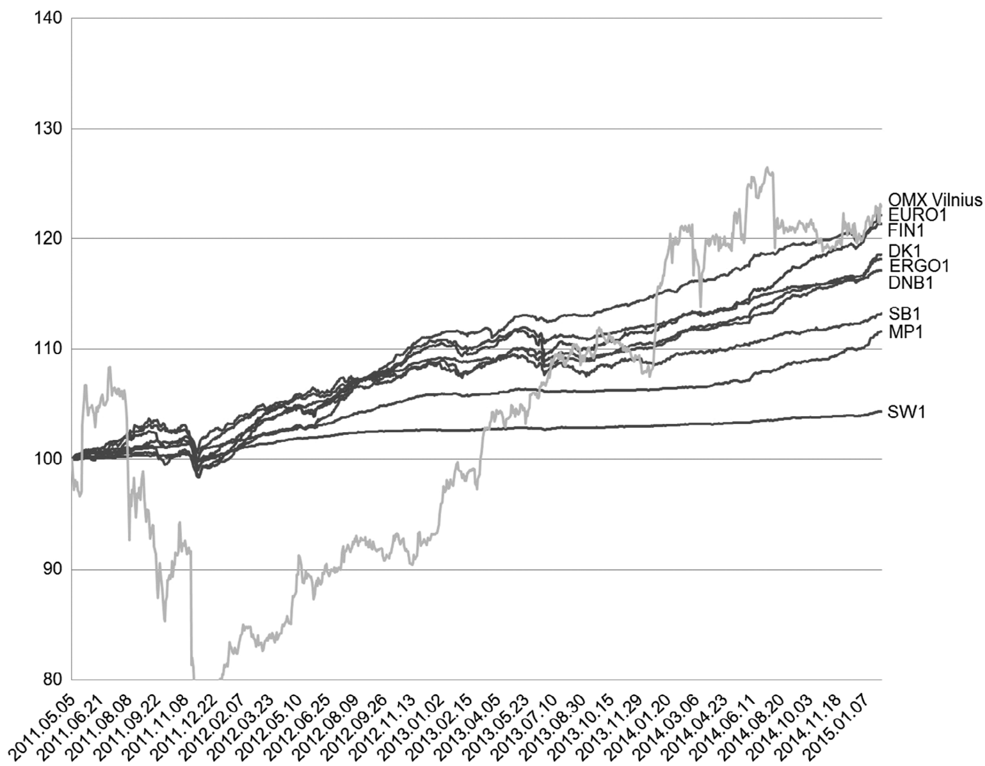

Figure 1. Long-term performance of pension funds with conservative investments. Source: Own calculations based on data retrieved from web pages of pension accumulation companies.

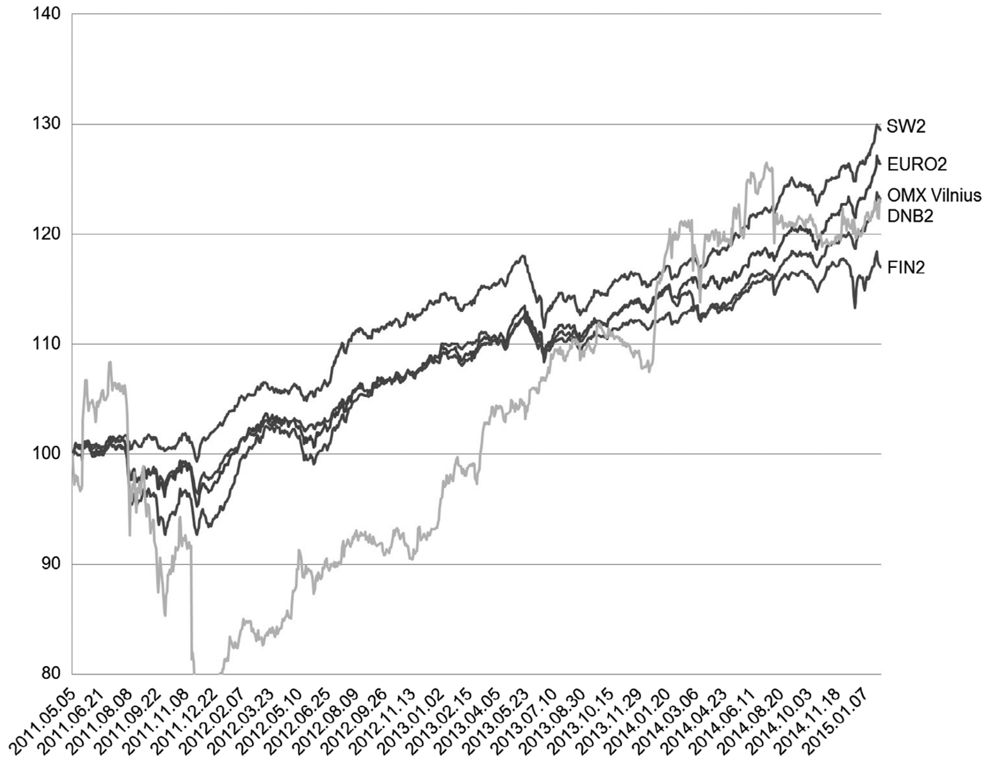

Figure 2. Long-term performance of pension funds with small equity share. Source: Own calculations based on data retrieved from web pages of pension accumulation companies.

this group. In the group of pension funds with small equity share the fund SW2 exhibits the most significant maintaining profitability over time. By the end, FIN2 has experienced the most significant decline within this group. Pension funds, displayed in Figure 3, move in relation to each other very similar. The same might be observed within risky pension funds (Figure 4), where the instability and tension are more exposed.

Table 1 shows the pension funds arranged by the percentage yield value from minimum to maximum at a given time. The positioning of funds tends to vary in time: low risk funds used to generate higher yields than risky funds at the beginning of the period, then the values of yields show the reverse trend. It probably reflects the situation in the financial market caused by undergoing economic crisis. In recent years, the value of conservative pension funds yields similar earnings, while funds with equities exhibit different dynamics and has no clear positioning in time. However, we can conclude that at the end of the almost 4-year period the highest percentage yield is reached by several most risky funds. Moreover, these funds outperform the benchmark OMX index.

4. Risk measuring and performance evaluation of 2nd pillar pension funds

4.1. Methodology

Rate of return R_i over the i-th period is estimated using formula

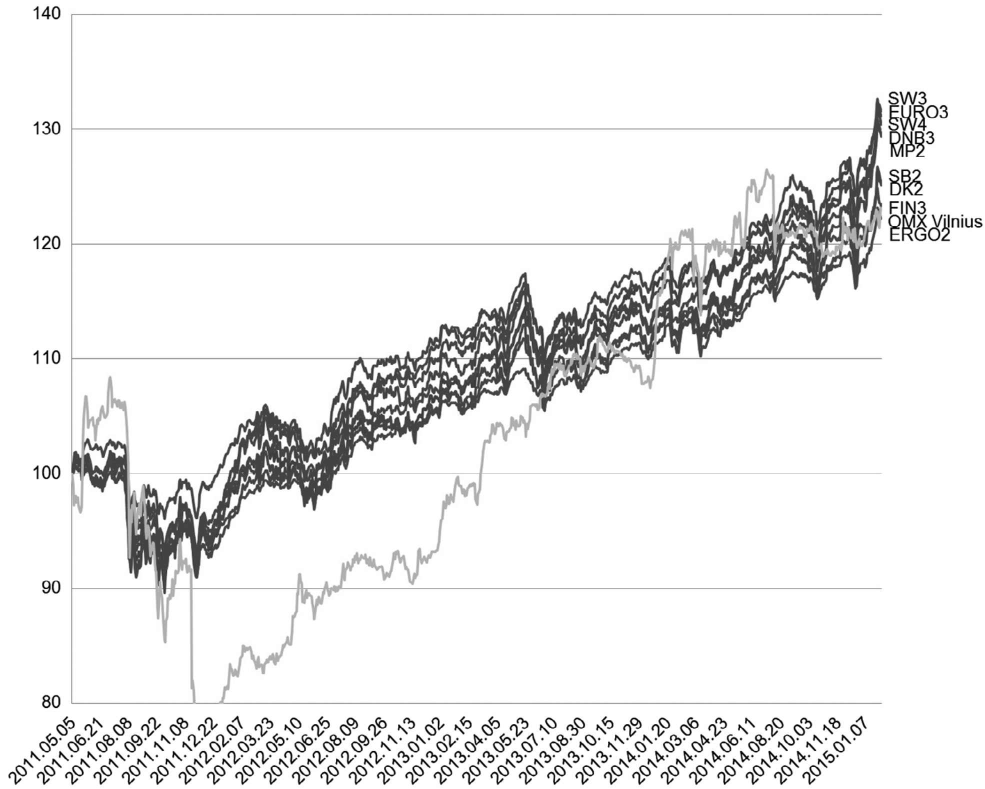

Figure 3. Long-term performance of pension funds with medium equity share. Source: Own calculations based on data retrieved from web pages of pension accumulation companies.

$$R_i = \frac{X_i - X_{i-1}}{X_{i-1}};$$

where X_i is the net asset value at the end of i-th period, while $X_{i\text{-}1}$ is the net asset value at the end of (i-1)-st period what is equal to the net asset value at the beginning of i-th period, $i = 1, 2, \ldots, n$. The period length to be specified in the analysis is one day and one month, which means daily and monthly returns.

The criterion for measuring the reward is the mean value of a fund's rate of return (mean return). Risk level is estimated in terms of semi-standard deviation (SemiDev) and conditional value-at-risk (CVaR) at different tolerance levels α. This set of measures allows concerning distinct risk features. Semi-standard deviation evaluates the fluctuations in returns below the mean. CVaR is expected value of losses exceeding their $1 - \alpha$ quantile, i.e., only the worst α *100% are taken into account.

As stated in the reference (Wiesinger, 2010), there are more than 100 risk-adjusted measures, or performance ratios, that are suggested in the scientific literature. They are designed to compare investment returns meaningfully. In this research, we have chosen five ratios for pension funds evaluations: Sharpe, Sortino, Stable Tail-Adjusted Return Ratio (STARR), Rachev, and Mean-Absolute-Deviation (MAD) ratio (Farinelli et al., 2008; Kolbadi, 2011; Konno & Yamazaki, 1991; Wiesinger, 2010):

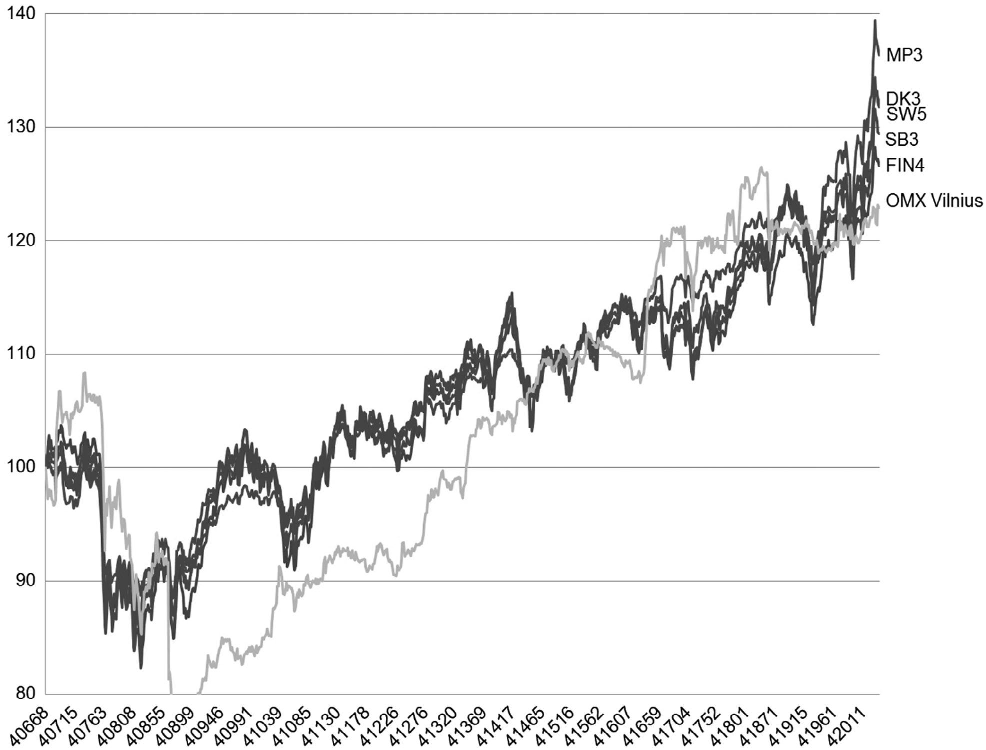

Figure 4. Long-term performance of pension funds with equity. Source: Own calculations based on data retrieved from web pages of pension accumulation companies.

- Sharpe ratio estimates the adjusted return of the portfolio relative to a target return and stands as leading risk-adjusted measure in applications. Usually, Sharpe ratio near 1 is considered acceptable as good value;
- Sortino ratio is the added return per unit of 'bad' risk rather than general risk and therefore improves on the Sharpe ratio when highly volatile portfolios are analysed. Large values of Sortino ratio indicates there is a low probability of a big loss;
- STARR, is the relation of the asset mean excess return to its conditional value-at-risk. Larger STARR values indicate better performance.
- Rachev is a gain-to-loss measure, which gives rewards for extremely big deviations upward and penalties for extreme deviations downward.
- MAD ratio assesses the relationship between expected return and Mean Absolute Deviation of returns. This ratio penalises more heavily the performance of funds whose returns strongly fluctuate negatively or positively around their mean.

The experiment is divided into four distinct cases based on input: return and risk measures of daily returns (Case 1), performance ratios of daily returns (Case 2), return and risk measures of monthly returns (Case 3), and performance ratios of monthly returns (Case 4).

4.2. Results of risk–return estimation

We present the results in Table 2. The Table shows all considered statistics (characteristics, measures) of all 26 funds computed from daily or monthly returns. Case 1 and 2 considers

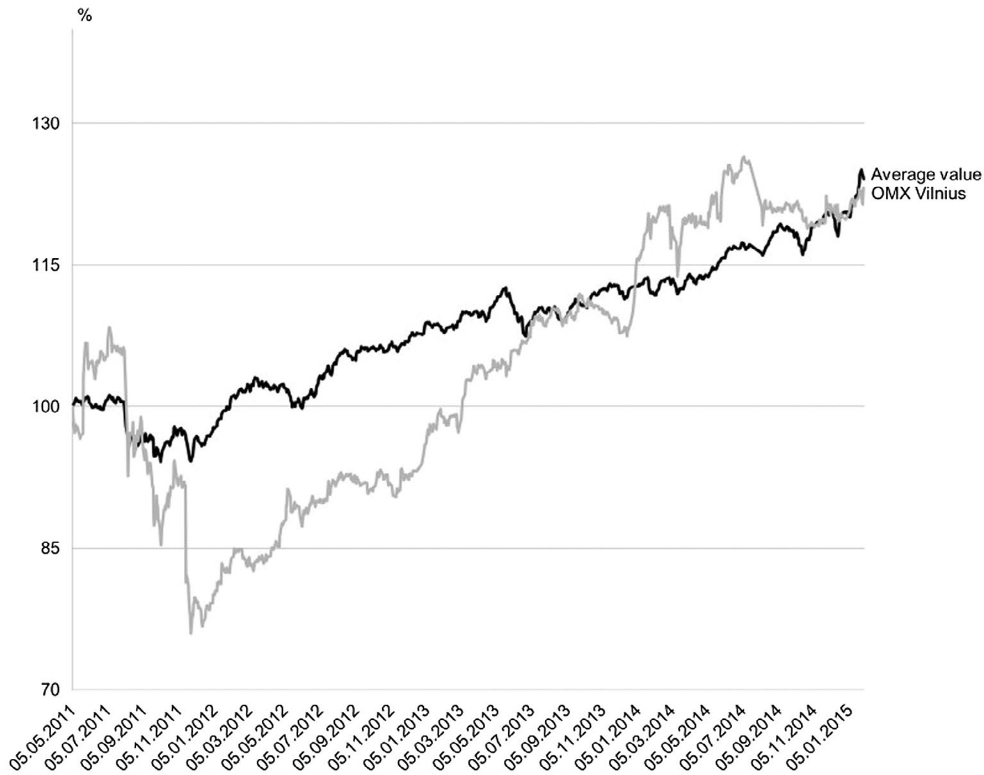

Figure 5. Long-term performance of averaged equity curve compared with OMX Vilnius index. Source: Own calculations based on data retrieved from web pages of pension accumulation companies.

daily returns while Case 3 and 4 monthly returns. In each Case and each characteristic, the best value is emphasised to easily see which fund is the best one. For the sake of simplicity, we include mean return in the group of risk measures.

Table 2 shows that fund MP3 realised the highest mean return. Perhaps surprisingly, this is not accompanied by the highest values of risk measures, which makes this fund even more attractive for investors focusing mainly on maximising the reward. On the other hand, the less risky behaviour was observed for fund SW1, no matter which measure of risk is used. Therefore, fund SW1 is recommended for the most risk-averse decision makers. When both risk and reward is taken into account, fund MP1 reaches the highest values of all considered performance rations. All these conclusions are valid for both daily and monthly data.

5. Clustering of 2nd pillar pension funds

To cluster 26 2nd pillar pension funds, two distinct ways of analysis are used in the study:

- Clustering pension funds using their time series over time period 5 May 2011–30 January 2015.
- Clustering pension funds based on risk and performance measures.

K-means algorithm is chosen for clustering. The idea of the algorithm is an iterative partitioning that minimises the sum (over all clusters) of the within-cluster sums of

Table 1. Percentage yield value at a specified date.

30 January 2012		30 January 2013		30 January 2014		30 January 2015	
DK3	94.95	SW1	102.60	SW1	103.10	SW1	104.30
FIN4	95.75	MP3	105.12	MP1	106.44	MP1	111.57
ERGO2	96.58	DK2	105.73	SB1	109.42	SB1	113.22
SW5	96.93	MP1	105.89	SB3	109.97	FIN2	116.97
DK2	96.94	FIN4	106.27	SW5	110.26	DNB1	117.12
MP3	97.13	MP2	106.36	DK1	110.84	ERGO1	118.17
SB3	97.23	DK3	106.36	FIN4	111.10	DK1	118.57
FIN2	98.15	SW5	106.56	ERGO1	111.15	FIN1	121.34
EURO3	98.29	ERGO2	106.60	DK2	111.38	EURO1	122.17
MP2	98.38	SB3	107.63	MP2	111.66	ERGO2	122.22
DNB3	99.10	SB1	107.63	MP3	111.68	FIN3	123.14
SW4	100.03	EURO3	107.76	DNB2	111.98	DNB2	123.19
EURO2	100.15	DK1	107.85	EURO1	112.35	DK2	125.13
FIN3	100.23	DNB3	108.10	SB2	112.37	SB2	125.43
DNB2	100.49	DNB2	108.64	ERGO2	112.40	EURO2	126.36
SW1	100.82	ERGO1	108.87	SW4	112.50	FIN4	126.61
SB2	100.90	SW4	109.08	DNB1	112.65	MP2	129.36
FIN1	100.96	EURO2	109.08	DNB3	113.43	SB3	129.45
DK1	101.00	EURO1	109.72	FIN2	113.80	SW2	129.49
EURO1	101.53	FIN2	109.84	DK3	113.93	DNB3	129.72
MP1	101.62	DNB1	110.33	EURO2	114.33	SW4	130.38
DNB1	102.03	SB2	110.79	SW3	115.10	EURO3	131.18
SW3	102.62	SW3	111.59	FIN1	115.15	SW3	131.55
ERGO1	103.21	FIN1	111.60	EURO3	115.89	SW5	131.77
SB1	103.63	FIN3	112.48	SW2	116.18	DK3	132.18
SW2	104.31	SW2	113.37	FIN3	116.74	MP3	136.36
OMX	82.39	OMX	99.11	OMX	119.50	OMX	122.90

no risky funds high risky funds

Source: Own calculations based on data retrieved from web pages of pension accumulation companies.

point-to-cluster-centroid distances (Lin, Vlachos, Keogh, & Gunopulos, 2004). The main steps implementing this algorithm include:

- The number of clusters, *K*, is specified before the algorithm is applied.
  - The selected range for possible *K* values involves from two until five clusters. Since pension funds are formally arranged into four risky categories, special attention is paid to the analysis with four clusters.
- Clustering is the process of grouping objects into 'clusters' according to some distance measure.
  - In the experiment, Euclidean, Cosine, Correlation, and Cityblock distance measures are considered.
- Replicating the algorithm several times because of its sensitivity to initial cluster centroid positions.
- Validation of clustering.
  - The correctness of clustering algorithm results is verified using silhouette index (Maulik & Bandyopadhyay, 2002). This measure ranges from + 1, indicating series that are very distant from other clusters, to −1, directing series that are probably assigned to the wrong cluster. Silhouette index also allows to determine the optimal number of clusters.

Table 2. Mean returns, risk measures, and performance ratios of the funds for daily returns and monthly returns.

Case 1: Daily returns, %					Case 3: Monthly returns, %			
Reward	CVaR01	CVaR05	SemiDev		Reward	CVaR01	CVaR05	SemiDev
0,0220	0,5540	0,2498	0,0922	EURO1	0,4441	3,3193	1,8771	0,7908
0,0183	0,3690	0,1656	0,0620	ERGO1	0,3763	2,3096	1,0738	0,5541
0,0212	0,4054	0,1927	0,0677	FIN1	0,4425	2,1464	1,2933	0,6179
0,0046	**0,0905**	**0,0418**	**0,0139**	SW1	0,0951	**0,5788**	**0,2062**	**0,1363**
0,0136	0,3556	0,2143	0,0687	SB1	0,2748	1,7475	1,0596	0,5203
0,0120	0,1233	0,0576	0,0209	MP1	0,2419	0,6117	0,2880	0,2550
0,0187	0,2833	0,1434	0,0485	DK1	0,3855	1,3941	0,9155	0,5295
0,0173	0,4252	0,1794	0,0707	DNB1	0,3580	2,2136	1,1260	0,5226
0,0259	1,0004	0,5677	0,1849	EURO2	0,5185	4,2476	2,8677	1,2875
0,0174	1,2555	0,6391	0,2089	FIN2	0,3669	5,7537	3,7570	1,6147
0,0285	0,6761	0,4102	0,1315	SW2	0,5698	4,4342	2,2400	1,1201
0,0230	0,6974	0,4006	0,1273	DNB2	0,4589	3,4869	2,3677	1,0119
0,0306	1,7579	1,0284	0,3232	EURO3	0,6087	8,9136	5,0574	2,0447
0,0224	1,4133	0,7823	0,2535	ERGO2	0,4490	7,1696	4,4192	1,7637
0,0234	1,5352	0,8703	0,2775	FIN3	0,4728	7,4883	4,9795	2,1285
0,0305	1,0748	0,7197	0,2191	SW3	0,6016	5,5000	3,5104	1,6807
0,0303	1,8898	1,1815	0,3598	SW4	0,5847	9,7749	5,9965	2,5168
0,0255	1,5310	0,8801	0,2792	SB2	0,4801	6,9400	4,6068	1,9835
0,0294	1,9938	1,1737	0,3691	MP2	0,5618	10,1127	5,6773	2,2740
0,0248	0,8979	0,5531	0,1719	DK2	0,4884	5,5308	3,2113	1,3934
0,0290	1,2898	0,7601	0,2366	DNB3	0,5756	6,9718	4,1877	1,7045
0,0282	3,0730	1,7233	0,5350	FIN4	0,5526	15,8400	9,5718	3,6963
0,0330	2,9752	1,7832	0,5515	SW5	0,6610	14,8715	8,7207	3,5761
0,0305	2,7732	1,6068	0,5020	SB3	0,5702	14,1651	8,4381	3,3659
0,0366	2,9163	1,7491	0,5404	MP3	**0,6956**	14,0021	8,0420	3,2740
0,0314	1,5482	0,9877	0,3001	DK3	0,6120	9,8379	5,3484	2,1812

Case 2: Daily returns						Case 4: Monthly returns				
Sharpe	Sortino	STARR	Rachev	MAD		Sharpe	Sortino	STARR	Rachev	MAD
0,2231	0,2853	0,0880	0,9008	0,3501	EURO1	0,5616	0,6880	0,2366	0,9889	0,8209
0,2529	0,3350	0,1106	1,0423	0,3845	ERGO1	0,6792	0,8992	0,3504	1,4389	1,0084
0,2804	0,3642	0,1101	0,9799	0,4539	FIN1	0,7161	0,9506	0,3421	1,3005	1,0220
0,2191	0,3190	0,1104	1,1399	0,3285	SW1	0,6978	1,0457	0,4611	2,1789	1,0718
0,1449	0,1992	0,0637	1,0191	0,1995	SB1	0,5281	0,6884	0,2593	1,2451	0,7266
0,3284	**0,5285**	**0,2081**	**1,8467**	**0,4884**	MP1	**0,9485**	**1,4251**	**0,8399**	**2,9948**	**1,2626**
0,2769	0,3944	0,1303	1,2915	0,4035	DK1	0,7281	1,0051	0,4211	1,7711	1,0073
0,2144	0,2884	0,0967	1,0457	0,3541	DNB1	0,6851	0,8764	0,3180	1,1754	0,9886

0,1077	0,1443	0,0457	0,9289	0,1483	EURO2	0,4027	0,5215	0,1808	0,9683	0,5273
0,0743	0,0954	0,0273	0,7764	0,1111	FIN2	0,2272	0,2993	0,0976	0,9642	0,3059
0,1532	0,2105	0,0694	1,0554	0,2066	SW2	0,5087	0,6733	0,2544	1,2457	0,6742
0,1374	0,1833	0,0574	0,9136	0,1862	DNB2	0,4535	0,5835	0,1938	0,9604	0,6102
0,0719	0,0969	0,0298	0,9023	0,0989	EURO3	0,2977	0,3802	0,1203	0,8241	0,4008
0,0745	0,0969	0,0287	0,8018	0,1061	ERGO2	0,2546	0,3271	0,1016	0,8232	0,3451
0,0687	0,0917	0,0269	0,8627	0,1000	FIN3	0,2221	0,2951	0,0949	0,9780	0,2995
0,0966	0,1333	0,0424	0,9930	0,1292	SW3	0,3579	0,4799	0,1714	1,0682	0,4551
0,0611	0,0839	0,0256	0,9534	0,0837	SW4	0,2323	0,3045	0,0975	0,8687	0,3042
0,0699	0,0939	0,0290	0,8979	0,0965	SB2	0,2420	0,3235	0,1042	0,9444	0,3173
0,0611	0,0823	0,0250	0,9025	0,0850	MP2	0,2471	0,3188	0,0990	0,8344	0,3345
0,1066	0,1459	0,0449	0,9702	0,1474	DK2	0,3505	0,4587	0,1521	0,9692	0,4754
0,0935	0,1243	0,0381	0,8666	0,1259	DNB3	0,3377	0,4340	0,1375	0,8694	0,4558
0,0414	0,0556	0,0163	0,8456	0,0587	FIN4	0,1495	0,1934	0,0577	0,7647	0,2023
0,0445	0,0612	0,0185	0,9550	0,0626	SW5	0,1848	0,2410	0,0758	0,8337	0,2433
0,0462	0,0620	0,0190	0,8694	0,0634	SB3	0,1694	0,2204	0,0676	0,7924	0,2238
0,0507	0,0688	0,0209	0,9160	0,0699	MP3	0,2125	0,2781	0,0865	0,8680	0,2833
0,0771	0,1052	0,0318	0,9246	0,1059	DK3	0,2806	0,3621	0,1144	0,8746	0,3894

*Figures in bold emphasise the maximum performance ratio.
Source: Own calculations based on data retrieved from web pages of pension accumulation companies.

Table 3. Values of silhouette index / distance metrics (as time series).

	Number of clusters			
Silhouette index / distance metrics	$K = 2$	$K = 3$	$K = 4$	$K = 5$
Equity curves	**0,72** Correlation	0,55 Correlation	0,57 Correlation	0,52 Euclidean
Time series of daily returns	**0,64** Euclidean	0,58 Correlation	0,56 Correlation	0,59 Correlation
Time series of monthly returns	**0,74** Correlation	0,67 Euclidean	0,64 Cityblock	0,54 Euclidean

*Value of silhouette index marked in bold determines the recommended number of clusters.
Source: Own calculations based on data retrieved from web pages of pension accumulation companies.

5.1. Clustering of 2nd pillar pension funds using their time series

In the experiment, there are three time series to be analysed: yields, daily returns, and monthly returns. While performing the clustering algorithm, the value of silhouette index is maximised for four metrics to be considered. The clustering results for the parameters listed above are summarised in Table 3.

The recommended number of clusters is $K = 2$ for each time series because of the highest value of silhouette index achieved. The pension funds assigned to each cluster are given in Table 4 when $K = 2$. The assignment of pension funds to four clusters is relevant in order to compare with four formally specified categories.

Table 4 shows that clustering equity curves and series of daily returns in two clusters forms one cluster with less risky funds and another cluster with more risky funds. However, this is not true in the case of clustering of series of monthly returns. When four clusters are considered, we can see that the results substantially differ from the official categories. The less risky funds are divided in two or three clusters, while the other three categories are merged in one or two clusters.

5.2. Clustering of 2nd pillar pension funds: risk measures and performance ratios

The clustering analysis is carried out upon for four case studies specified in Section 4.1. Silhouette index is used as the main argument to set the recommend number of clusters. The clustering results are summarised in the Table 5.

Table 6 shows similar results of clustering to those presented in Table 4, however with some remarkable differences:

- When two clusters are considered, daily return results show one cluster with less risky funds and another one with more risky funds. Contrary to the results in Table 4, now the first cluster contains all conservative funds expect of SB1 (no matter if risk measures or performance ratios are used) while in Table 4 (equity curves) the only exception was FIN1. The larger difference is evident when compared to clustering of series of daily returns.
- When two clusters and monthly returns are considered, the clustering now gives more reasonable results (in terms of risk profile) than in Table 4 but still less in hand with the risk categories than in the case of daily returns.
- When four clusters and daily returns are considered, the resulting clusters in Case 1 are very similar to official categories. However, this is not observed in the other three cases.

Summarising, we think that the clustering according to risk measures using daily returns is the most similar to the official categories, while the clustering using monthly returns allows

Table 4. The assignment of pension funds to *K* clusters (as time series).

	K	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Equity curves	2	EURO1, ERGO1, SW1, SB1, MP1, DK1, DNB1	FIN1, EURO2, FIN2, SW2, DNB2, EURO3, ERGO2, FIN3, SW3, SW4, SB2, MP2, DK2, DNB3, FIN4, SW5, SB3, MP3, DK3		
	4	EURO1, ERGO1, FIN1, DK1, DNB1, DNB2	SW1, SB1, MP1	EURO2, FIN2, SW2, ERGO2, FIN3, SW3, SW4, SB2, MP2, DK2, DNB3	EURO3, FIN4, SW5, SB3, MP3, DK3
Time series of daily returns	2	EURO1, ERGO1, FIN1, SW1, SB1, MP1, DK1, DNB1, EURO2, FIN2, SW2, DNB2, ERGO2, FIN3, SW3, SB2, DK2, DNB3	SW4, MP2, EURO3, FIN4, SW5, SB3, MP3, DK3		
	4	EURO1, FIN1, SW1, DK1	ERGO1, SB1	MP1, DNB1	EURO2, FIN2, SW2, DNB2, ERGO2, FIN3, SW3, SW4, SB2, MP2, DK2, DNB3, EURO3, FIN4, SW5, SB3, MP3, DK3
Time series of monthly returns	2	EURO1, ERGO1, FIN1, EURO2, FIN2, EURO3, ERGO2, FIN3	SW1, SB1, MP1, DK1, DNB1, SW2, DNB2, SW3, SB2, DK2, DNB3, SW4, MP2, FIN4, SW5, SB3, MP3, DK3		
	4	EURO1, ERGO1, EURO3, FIN3	FIN1, FIN2	EURO2, ERGO2	SW1, SB1, MP1, DK1, DNB1, SW2, DNB2, SW3, SW4, SB2, MP2, DK2, DNB3, FIN4, SW5, SB3, MP3, DK3

no risk funds	low risk funds	intermediate risk funds	High risk funds

Source: Own calculations based on data retrieved from web pages of pension accumulation companies.

Table 5. Values of silhouette index / distance metrics (for risk measures and performance ratios).

Silhouette index / distance metrics	Number of clusters			
	$K = 2$	$K = 3$	$K = 4$	$K = 5$
Case 1	**0,90** Correlation	0,81 Euclidean	0,76 Euclidean	0,77 Euclidean
Case 2	**0,88** Correlation	0,86 Euclidean	0,75 Euclidean	0,74 Correlation
Case 3	**0,83** Correlation	0,79 Euclidean	0,77 Euclidean	0,77 Euclidean
Case 4	**0,82** Euclidean	0,78 Euclidean	0,75 Euclidean	0,76 Euclidean

*Value of silhouette index marked in bold determines the recommended number of clusters.
Source: Own calculations based on data retrieved from web pages of pension accumulation companies.

for dividing the most risky funds in different clusters. ANOVA for each clustering outcome is skipped because it will not give us any useful information to this research.

6. Conclusion

Demographic, micro- and macroeconomics trends, and social factors in countries have necessitated reform of the public pension system. The introduction of a private, usually mandatory, second pillar pension funds in conjunction with the public social security system is the essence of reforms to be implemented. The risk–return analysis of 26 2nd pillar pension funds was carried out using empirical data over time period 5 May 2011–30 January 2015. The following conclusions are obtained:

(1) Referencing the long-term performance of 2nd pillar pension funds in terms of averaged equity curve (over all funds) to benchmark index (OMX Vilnius index), the overall performance of pension funds is more stable, has increasing trend and has experienced the decline that is inevitable in financial markets. Moreover, the most profitable funds reached slightly higher yield than the benchmark with significantly smaller volatility over the period.
(2) The reward–risk analysis found three interesting funds: MP3 realised the highest mean daily (monthly) return; SW1 minimises all considered risk measures; and finally, MP1 reaches the highest values of all analysed performance rations.
(3) Applying clustering analysis to daily data, the funds are divided optimally in two groups, the first one contains almost all conservative funds (no other funds), while the second one all the other funds. Perhaps surprisingly, the clustering analysis of monthly data gives completely different results. Finally, it can be inferred that clustering of pension funds does not match to the assignment of pensions funds to clusters if pension funds are clustered into four groups according to the recommendations of the Association of Financial Analysts (2004).

The presented results highly depend on the selected time period. Enlarging the period by years 2008–2010 may lead to different conclusions. Unfortunately, including these years would require the limitation to only 18 funds. The analysis may be enriched by some other risk measures or performance ratios; however, we expect the same (or similar) results.

The most unanticipated finding shows a reasonable likelihood that few conservative funds behave historically risky and fall into cluster with rather risky funds. It means that it is not rational to choose a concrete pension fund in accordance with the established categories based on the investment strategy in equities. It could be only a primary decision; then a continuous risk assessment should be performed regarding the historical pension fund

Table 6. The assignment of pension funds to *K* clusters (for risk measures and performance ratios).

K																													
K															Case 1														
2	EURO1	ERGO1	FIN1	SW1	MP1	DK1	DNB1				SB1	EURO2	FIN2	SW2	DNB2	EURO3	ERGO2	FIN3	SW3	SW4	SB2	MP2	DK2	DNB3	FIN4	SW5	SB3	MP3	DK3
4	EURO1	ERGO1	FIN1	SW1	SB1	MP1	DK1	DNB1	SW2	DNB2		EURO2	FIN2	ERGO2	SW3	DK2	DNB3		EURO3	FIN3	SW4	SB2	MP2	DK3		FIN4	SW5	SB3	MP3
K															Case 2														
2	EURO1	ERGO1	FIN1	SW1	MP1	DK1	DNB1				SB1	EURO2	FIN2	SW2	DNB2	EURO3	ERGO2	FIN3	SW3	SW4	SB2	MP2	DK2	DNB3	FIN4	SW5	SB3	MP3	DK3
4	EURO1	ERGO1	FIN1	SW1	DK1	DNB1		MP1	EURO2		SB1	SW2	DNB2	SW3	DK2		FIN2	EURO3	ERGO2	FIN3	SW4	SB2	MP2	DNB3	FIN4	SW5	SB3	MP3	DK3
K															Case 3														
2	ERGO1	FIN1	EURO2	FIN3				EURO1	SW1	SB1	MP1	DK1	DNB1	FIN2	SW2	DNB2	EURO3	ERGO2	SW3	SW4	SB2	MP2	DK2	DNB3	FIN4	SW5	SB3	MP3	DK3
4	ERGO1	FIN1	EURO2	FIN2	EURO3	ERGO2	FIN3		DNB1	DNB2	DK2	DK3		EURO1	SW1	SW2	SW3	SB2	DNB3	MP3		SB1	MP1	DK1	MP2	SW4	FIN4	SW5	SB3
K															Case 4														
2	ERGO1	FIN1	EURO2	FIN2	EURO3	FIN3				EURO1	SW1	SB1	MP1	DK1	DNB1	SW2	DNB2	ERGO2	SW3	SW4	SB2	MP2	DK2	DNB3	FIN4	SW5	SB3	MP3	DK3
4	ERGO1	FIN1		EURO1	SW2	SW3	DNB3	ERGO2		EURO2	FIN2	EURO3	FIN3		SW1	SB1	MP1	DK1	DNB1	DNB2	SW4	SB2	MP2	DK2	FIN4	SW5	SB3	MP3	DK3

no risk funds | low risk funds | intermediate risk funds | high risk funds

Source: Own calculations based on data retrieved from web pages of pension accumulation companies.

behaviour. This assessment could be carried out by independent experts or supervisors of financial markets, since pension funds' managers tend to publish their experience analysis in attractive ways for participants.

Despite these promising results, further study with more focus on systematic risk is therefore suggested. To develop a full picture of pension funds market in Lithuania, additional studies will be needed with focus on pension fund characteristics (size, age, fees and so on), especially by exploring the application of factor or regression analysis models to the emerging and relatively small Lithuanian market.

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