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SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS

“CONSTRUCTION AND VERIFICATION OF QUANTILE-BASED MARKET RISK MEASUREMENT MODELS”

Summary of scientific achievements, supplemented with information on teaching, popularizing and organizational contributions

Annex No. 2

Wroclaw, November 2014

INTRODUCTION

In the summary my scientific and teaching achievements from the years 1998–2013 are reported, with particular focus on the period after 2003, that is – after I had been granted a doctoral degree.

After a piece of biographical information on the course of my education and professional career, a **general characteristic of my scientific interests** and research areas is presented here. The aim of this part of the summary is outlining a broader context of detailed subjects that are discussed in the main part. The main part of the summary of accomplishments presents a **series of thematically related publications** accompanied with the motivation of the subject-matter choice and discussion of achievements that, in my opinion, constitute a substantial contribution to the development of **the scientific discipline of finance**.

In the further part there are briefly presented achievements and contributions that are not part of the series of thematically related publications and finally - teaching, popularizing and organizational contributions.

A short report in a tabular form, containing a list of my publications and conference speeches together with the information on citations is presented in the last part of the summary.

1. EDUCATION AND CAREER

In 1998, after a five-year full-time study course at Wroclaw University of Technology (WUT), Faculty of Electronics and Telecommunication, I defended with the grade A (excellent) a **master thesis** with the title “Correlation Analysis of Biomedical Signals in MATLAB Computing Environment”. My thesis supervisor was dr. hab. Andrzej Muciek, professor at WUT. I graduated from the WUT with master of science and engineering degrees, and **was awarded the prize of the President of University** for the best graduate of the year 1998.

In the years 1994-1998, parallel with my study at Wroclaw University of Technology, I was a part-time student at (the then) Wroclaw Academy of Economics, Faculty of Management and Computer Science. I graduated from Wroclaw Academy of Economics with a **bachelor degree**. The subject of my bachelor thesis was “Initial Multiobjective Selection of Stocks to an Investment Portfolio”. I defended the thesis with the grade A (excellent). The thesis supervisor was prof. dr. hab. Krzysztof Jajuga.

From Oct. 1998 till 2001 I was a full-time doctoral student at the Faculty of Management and Computer Science of Wroclaw Academy of Economics in the Department of Financial Investments and Insurance.

From Oct. 1 2001 I was employed as an assistant (tutor) in the Department of Financial Investments and Insurance.

In Feb. 2003 I defended my **doctoral thesis** under the title "Modelling and Forecasting Volatility of Financial Instruments". My doctoral thesis supervisor was prof. dr. hab. Krzysztof Jajuga, and reviewers were prof. dr. hab. Józef Stawicki from Nicolaus Copernicus University in Torun and dr. hab. Mariusz Czekała from Wroclaw University of Economics. The doctoral thesis was prepared as **part of a grant financed by the State Committee for Scientific Research** (GRANT 5 H02B 019 21). Both the thesis and its defence were highly evaluated by the Reviewers and the Board. The Board put forward a motion directed to the Faculty Council **to award a prize for the thesis**.

Since Oct.1 2004 I am employed as an **assistant professor** in the Department of Financial Investments and Insurance, now I work in the Department of Financial Investments and Risk Management, that was established on Feb. 15, 2006 as a result of division of the Department of Financial Investments and Insurance.

2. GENERAL CHARACTERISTIC OF SCIENTIFIC INTERESTS AND RESEARCH AREAS

Before some more detailed discussion of the main contributions of the series of thematically related publications "**CONSTRUCTION AND VERIFICATION OF QUANTILE-BASED MARKET RISK MEASUREMENT MODELS**", I would like to present a general description of my research activity.

Modern finance, and particularly theory and practice of financial instruments and financial markets, are strictly connected with quantitative methods and mathematical models [e.g. 8, 11, 20, 22, 23, 24][1]. During the last 30 years, in response to challenges faced by practitioners, as well as a result of verification of various theoretical hypotheses, many mathematical models of this type were developed. These models are widely used and their performance is verified in different areas and in many ways. The fast popularization of the models, their multitude and diversity are caused by a set of mutually connected reasons, such as: the development of quantitative methods, particularly theory of stochastic processes, the increase in computing power available to researchers and practitioners, availability of IT tools, including professional software, as well as easier access to historical and current data from different financial markets. Practical needs stimulated development of theoretical tools and methods. As an example may serve pricing of complex derivatives or measuring and integrating different types of risk [e.g. 8, 22, 23, 26]. The development of theoretical tools, in turn, facilitated introduction of more and more advanced financial instruments or new risk management methods.

[1] According to the reference list – page 50.

My main research is concentrated on broadly understood modelling of financial time series, particularly modelling volatility of prices of financial instruments, and thus on market risk and concomitant model risk, which is usually treated as a particular sub-type of operational risk. **I have focused on the models of: dynamics of prices (for single financial instruments and their portfolios), pricing of derivative and debt instruments, as well as market risk management in a broad sense (i.e. construction and verification of risk measurement models).**

The main emphasis was put on financial instrument models, but theoretical concepts and research results of these works may also find applications in the group of models describing so-called "market participants" (e.g. in portfolio theory – when verifying classical Markowitz model and creating and verifying its modifications; particularly – my discussion of and empirical research on correlation matrix forecasting and distribution asymmetry verification), or in some elements of market equilibrium theory (e.g. in CAPM model – discussion of and empirical research on multivariate GARCH models and forecasting volatility and correlation in time series of returns). This was not, however, the main area of interest in my research.

Both my doctoral thesis and publications after gaining a doctorate reflect my conviction that **current challenge is not proposing new modifications of models for single instruments or portfolios but rather verification of their performance and applicability as tools for solving particular real-life problems** in financial markets. The quality of time series models should be verified not only in the teaching sample on the basis of econometric measures of model performance but also and especially in the test sample on the basis of the indicators taking into account the financial effect of the applied approach.

The vast **majority of my publications focuses on model risk analysis** in wider sense. The model risk arises when a mathematical model is used in real world and it is inherent in the very idea of model, which is always just an approximation of reality. My works are concentrated on the issue of model risk identification and evaluation of model performance, paying particular attention to financial effects of model application.

My interests in the area of model risk may be divided into two domains:

1) **Model risk of risk measurement models,**
2) **Model risk of financial instrument pricing models.**

Both risk measurement and pricing models are often based on some underlying models of financial time series. When applying financial time series models one should be, in my opinion, aware of the following two questions:

1) **What knowledge about the nature of the analysed phenomenon may be implied from the fact that a given model was "accepted" (was not rejected in the process of its verification)**

2) **How to use the model to solve practical problems?**

The answer to the second question is part of my main area of interest and research, which is reflected in most of my post-doctorate publications.

Before the defence of my doctoral thesis my research interests concentrated on applications of taxonomic methods in portfolio selection using the data available in financial reports. It was a continuation of my research on market efficiency in my bachelor thesis. The area of investigation that dominated, however, my interests in later time and then determined the choice of the subject-matter of my doctoral thesis was modelling and forecasting of volatility. The main aim of this group of publications was presentation and discussion of properties of univariate AR-GARCH models and their verification as underlying models of Value at Risk measurement for a single financial instrument. These works belonged to the first ones in which usefulness of classical AR-GARCH models was verified for Polish market data with some elements of model risk discussion.

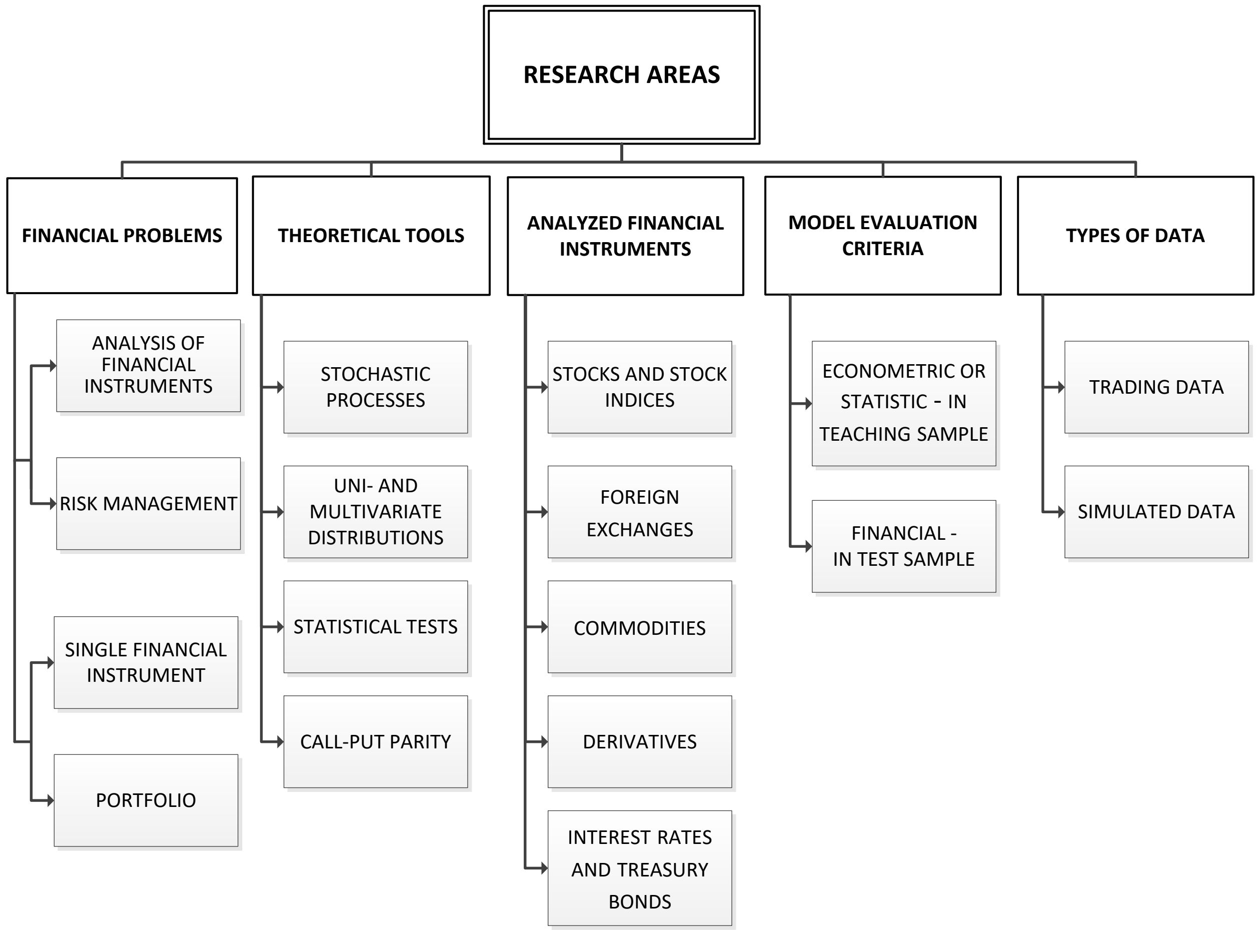
Doctoral thesis "Modelling and Forecasting Volatility of Financial Instruments" summed up the first stage of research with main emphasis on volatility of financial instruments. The aim of the thesis was review and comparison of methods used to model volatility of returns and forecast volatility parameter of financial instruments, as well as using these methods in market risk measurement. The following detailed auxiliary aims were set:

1) critical review and comparison of conditional expected value models,
2) critical review and comparison of conditional variance models,
3) review of distributions of standardized residuals,
4) critical review and comparison of volatility parameter forecasting methods based on time series models,
5) critical review and comparison of volatility parameter forecasting methods based on market expectations,
6) presentation of empirical research results in the area of volatility modelling and forecasting for real-life time series of returns on some chosen financial instruments.

Here I would like to present my **post-doctorate** research achievements in division according to different criteria which are not always disjunctive.

Details concerning particular publications, suggestions, pieces of research and conclusions are presented in the part referring to the discussed series of thematically related publications (Chapter 3, pp. 13–40) and in the part presenting other achievements (Chapter 4, pp. 40–45).

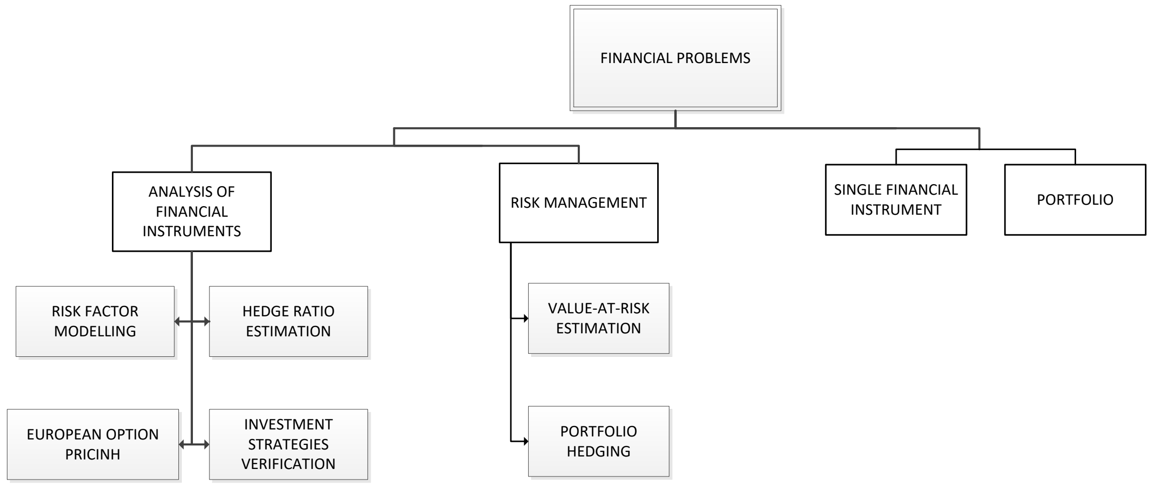
Areas of my research are divided into more detailed problems:



DIVISION IN RESPECT OF FINANCIAL PROBLEMS

My publications may be divided into two general groups as far as financial subjects are concerned: **analysis of financial instruments** and **risk management**. Some works may be counted among representatives of both groups (e.g. delta coefficient determination on the basis of theoretical option pricing models).

Moreover, the discussion on financial time series modelling and application of mathematical models in finance may refer to a single financial instrument or portfolio. Corresponding models may be thus divided into univariate and multivariate (portfolio) models.



In the area of **analysis of financial instruments** my research activity addressed such issues as **risk factor modelling**, **an analysis of European option pricing models** and an analysis of **investment strategies including performance evaluation (arbitrage, quasi-arbitrage, speculation and hedging)**.

In the area of analysis of financial instruments the following subfields may be distinguished:

a) identification (mainly of skewness) and modelling of financial time series properties for risk factors (rates of return on stocks, foreign exchange, market indices, commodities and interest rates);

This is the broadest field of my research. The results are presented in **publications P3**[2], **P4**, **P5**, **P6**, **P8**, **P9**, **P10**, **P12**, **P14**, **P15**, **P16**, **P17**, **P21** and were discussed during **conference speeches WP19**[3], **WP21** (proceedings of these conference are currently in preparation). Details mainly on pp. 25–27 (identification) and pp. 27–31 (modelling).

b) European option pricing;

My research consisted in systematization of theoretical knowledge and analysis of properties of pricing models for European put and call options. The results are presented in **publications P1**, **P7** and were discussed during **conference speeches WP17** and **WZ8,** on the basis of which a publication is now prepared. Details on pp. 41–42.

[2] **Symbols** conform the ones used in tabular list of publications and conference speeches at the end of this summary (p. 53). **P** – publication, **WP** – conference speech in a local conference in Poland, **WZ**- conference speech in an international conference.

[3] **Conference speeches are listed here only if the research results have not been published in a form of journal articles nor conference proceedings yet.**

c) investment strategy verification;

This area may be divided according to a widely accepted classification of investment strategies, that is: speculative, arbitrage and hedging strategies. The last group are presented below in the part devoted to "risk management".

As far as speculative strategies are concerned, I dealt with the issues related to the market of Treasury fixed income debt instruments. Partial results regarding yield curve modelling with Nelson-Siegel and Svensson models were presented in the conference speech **WP16** and research on investment strategies in the publication **P20**. Details on p. 44.

Investment strategies using derivatives were investigated in 3 publications (**P11**, **P13** and **P19** – details on p. 40).

As far as **risk management** is concerned my work is concentrated on the following fields:

a) Value at Risk as market risk measure;

My research in this area is concentrated on the following fields:

- Value at Risk estimation methods for some chosen classes of financial instruments and portfolios, with the use of risk factor models developed as part of research on financial time series properties (details on pp. 31–34)

and

- Verification of effects obtained by application of these methods by means of a comparison between Value at Risk forecasts and portfolio losses realized indeed in corresponding periods (historical data). Details on pp. 34–38.

In the works **P9** and **P21** there are discussed ways in which multivariate generalizations of ARMA-GARCH models may be used in Value at Risk estimation (details on pp. 32–33).

Another issue thoroughly analysed in this area is verification of Value at Risk forecast quality on the basis of historical data (**backtesting**). The results are presented in the publication series **P18**, **P22**, **P23**, **P24** and in conference speeches **WP23**, **WP25**. The results (especially those concerning the power of the specific tests) are of a key importance for evaluation of Value at Risk measurement methods, including evaluation of usefulness of broadly understood risk factor models. Details on pp. 34–38.

b) hedging of a portfolio against risk of price changes;

As part of my research in model risk issues I analysed also sensitivity of option values to changes of the underlying instrument price. I showed the difference in values of delta coefficient determined on the basis of Black-Scholes-Merton model and a model using AR-GARCH process. I identified conditions under which model risk is insignificant and conditions when deviations are particularly large. The results are published in **P7**. Details on pp. 41–42.

As part of my research in multivariate time series modelling I analysed usefulness of methods showing different level of model intricacy for determining hedge ratio for a stock portfolio hedged with futures on a market index. The results were presented in **WP19** and **WP22** (details on p. 39).

The issues (indirectly) connected with the portfolio construction and hedging are presented in publications **P2** and **P14**, which have been subjected to empirical evaluation techniques of volatility and correlation matrix forecasting. Details on p. 40.

Works: **P1**, **P2**, **P3**, **P4**, **P5**, **P6**, **P7**, **P8**, **P10**, **P12**, **P17**, **P18**, **P22**, **P23**, **P23** and conference speeches: **WP15**,**WP17**, **WZ1**, **WZ3**, **WZ3**, **WZ5**, **WZ8**, **WZ9**, **WZ10**, **WZ11** addressed time series modelling for separate **single financial instruments** (if portfolio data were used, they were treated jointly as if the portfolio was a single financial instrument – a synthetic instrument).

The issues related to time series modelling for **portfolio of financial instruments** are, in turn, presented in the following articles: **P9**, **P11**, **P13**, **P14**, **P15**, **P16**, **P19**, **P20**, **P21** and were discussed in a number of conference speeches, like: **WP16**, **WP19**, **WP22**, **WP23**, **WP24**, **WP25**. Results presented there will be published in a form of journal articles and conference proceedings during the next year.

DIVISION IN RESPECT OF THEORETICAL TOOLS

My research activity may be also divided in respect of underlying theoretical concepts (models of stochastic processes, random variable distributions, parity equations), but the border between pieces of research belonging to these categories is sometimes vogue.

The first area is an analysis of issues connected with **stochastic processes**. The following publications are devoted to this subject: **P1**, **P2**, **P3**, **P4**, **P5**, **P6**, **P7**, **P8**, **P9**, **P10**, **P12**, **P14**, **P15**, **P16**, **P21**. This area is associated with risk factor modelling issues. Details mainly on pp. 27–31 and 41–43.

The second is **an analysis of univariate and multivariate distributions of random variables**. Conclusions from **skewness tests** for return distributions are presented in **P8**, **P10**, **P12**, **P17** (details on pp. 25–27 and p. 27–30). Also **dependence structure in multivariate distributions** of returns was analysed. The concept of copula functions was used in this research. This area of my research is reflected in **P16** and **P21 (details on p. 32)**. The results of statistical tests verifying some Value at Risk estimation techniques are presented in **P9**, **P18**, **P21, P22**, **P23** and **P24** (details on pp. 34–38).

Another field was an analysis of **put-call parity** that, if holds, makes arbitrage impossible. These issues were discussed in **P11**, **P13**, **P19**. Details on pp. 40–41.

DIVISION IN RESPECT OF ANALYZED FINANCIAL INSTRUMENTS

As far as empirical research is concerned my works entailed analyses connected with the market of the following classes of financial instruments:

a) **stocks and stock indices of Polish market** (details mainly on pp. 25–34 and pp. 43–44) – publications: **P2**, **P3**, **P4**, **P5**, **P7**, **P8**, **P9**,**P10**, **P11**, **P12**, **P14**, **P15**, **P16**, **P17**, **P21**, conference speeches: **WZ1**, **WZ9**, **WP19**, **WP22**,

b) **foreign exchanges** (details mainly on pp. 25–34 and pp. 43–44): **P2**, **P9**, **P12**, **P14**, **P15**, **P16**,

c) **derivatives** (details on pp. 40–43): options: **P1**, **P7**, **P12**, **WZ8**, **WP17**, futures: **P11**, **P12**, **WP19**, **WP22**, MiniWIG20 unit: **P19**,

d) **interest rates and treasury bonds** (details on p. 44): **P6**, **P20**, **WP16**,

e) **commodities** (details on p. 43–44): **P2**,

f) **indices of foreign markets** (details mainly on pp. 25–34): **P9**, **P12**, **P15**, **P16**.

DIVISION IN RESPECT OF MODEL EVALUATION CRITERIA

A part of my research activity was connected with the issues of data fitting **in teaching sample**. I was searched for best fitted models according to a given econometric criterion. Works: **P1**, **P3**, **P4**, **P5**, **P6**, **P7**, **P8**, **P10**, **P12**, **P15**, **P16** concentrated on model evaluation only on the basis of the goodness of fit. Details mainly on pp. 25-34.

The aim of some other part of research was, however, examining performance of models as forecasting tools in the **test sample**. Regardless of their in-teaching-sample goodness of fit the models were compared in respect of their forecasting ability. This is definitely the approach I prefer over the bare goodness-of-fit analysis. Evaluation of the quality of forecasts better suits the goal of financial model verification, which is answering the question if the model is likely to perform well as a tool for real-life financial problem solving. Questions of this kind are discussed in the following positions: **P2**, **P14**, **P21**. Details on pp. 43–44 and p. 32. Some part of my research, that is: **P9**, **P20**, contains a combination of the two aforementioned approaches. Selected aspects on p. 44.

DIVISION IN RESPECT OF DATA USED

Only one article in my academic career (**P18**) did not contain any section with empirical results. In all other publications empirical research constituted important part of the contribution. It was usually verification of some hypotheses set in preceding sections or an element supplementing theoretical discussion or illustrating its subject. Calculations were performed by myself with the use of procedures developed by me in MATLAB programming environment. This gained recognition by reviewers of my articles and other authors, which is also indicated by the number of citations. My works may be divided into such in which the data used came from market quotations (**P2**, **P3**, **P4**, **P5**, **P6**, **P8**, **P9**, **P10**, **P11**, **P12**, **P13**, **P14**, **P15**, **P16**, **P17**, **P19**, **P20**, **P21**, **WZ1**, **WZ8**, **WZ9**, **WP16**, **WP17**, **WP19**, **WP22** – mainly on pp. 25–34 and pp. 41–45) and those in which conclusions were drawn from simulations (**P22, P23, P24, WZ10, WP23, WP24, WP25** – details on pp. 34–38). In the second approach I exercised due diligence to make sure that all necessary assumptions (about shapes of distributions, model parameters, etc.) do not stand in contradiction to commonly observed properties of real data. Some works combine the two approaches (**P1**, **P7** – pp. 41–42).

The effect of my research is 40 positions published before the end of October 2014. 24 paper positions out of 40 were published in post-doctorate period of my academic career.

As part of my research activity I took **an active part in a number of scientific conferences** presenting the results of my research (for a detailed list of conferences with titles see pp. 56-60). **The total number of my speeches is 54, in which 40 was in the post-doctoral period of my research**. After my doctorate I gave **36 individual conference speeches** (22 in Polish and 14 in English). **At international conferences I delivered 17 speeches**[4] (of which 14 independently in English). **Two of my speeches were awarded (details on page 49).**

Moreover, I am also an author of 2 chapters in a monograph which was prepared and published as part of a grant by the State Committee for Scientific Research, titled "Zastosowanie metod ekonometryczno-statystycznych w zarządzaniu finansami zakładów ubezpieczeń – 5 H02B 018 21" ("The use of econometric-statistic methods in insurance company management – 5 H02B 018 21").

[4] For detailed summary see on p. 53.

These are the following chapters: "Metody budowy portfeli inwestycyjnych" ("Methods of constructing investment portfolios"), section 7.1, pp. 335-358, and "Klasyfikacja I porządkowanie zakładów ubezpieczeń – przegląd metod i badania empiryczne", subsection 8.4.1., pp. 420-446 ("Classification and ranking of insurance companies – a review of methods and empirical research"). The head of the grant was Prof. dr. hab. Wanda Ronka-Chmielowiec.

Finally, I would like to mention some **current directions of my research** that fit within the areas of interest that have just been discussed in this summary. These directions of further development are treated by me as a natural continuation of the research I have been doing so far. Main area of my current investigations is an analysis of some kind of risk - the **model risk which arises from parameter estimation errors** in models used for pricing financial instruments and in risk management (**WP24**, **WP25**, **WP26**). It is obvious that for a finite sample of data parameter estimators based on this sample bear the risk of estimation error and this error then causes error of the output from the model. The aim is to determine minimum size of a sample needed to guarantee that if model parameters are estimated from the sample then the confidence interval of the final output from the model (e.g. Value at Risk, option price, hedge ratio, etc.) for a given confidence level is of a given, acceptable width. The last area of research is particularly important because ignorance of limitations of methods may result in erroneous interpretations and conclusions. This, in turn, may cause wrong decisions in practice.

The second area of my current research is the **analysis of the statistical power of the backtests for value-at-risk and expected shortfall estimations**. I would like to determine (for the typical length of the sample series), the minimal significance level of the test (value of the I type error – rejection of the correct model), which must be accepted in order to obtain satisfactory power of backtests (to reject incorrect model) for the assumed deviations from the correct model. It is also specifically understood model risk analysis (**WP23**).

3. SERIES OF THEMATICALLY RELATED PUBLICATIONS AND RESEARCH ACHIEVEMENTS CONSTITUTING SUBSTANTIAL CONTRIBUTION TO THE DEVELOPMENT OF THE DISCIPLINE OF FINANCE

Here I would like to present my series of thematically related publications "**CONSTRUCTION AND VERIFICATION OF QUANTILE-BASED MARKET RISK MEASUREMENT MODELS**" and discuss the achievements I find my substantial contribution to the development of economic science in the discipline of finance (according to the article 16, section 2 of the Act of March 14, 2003 on degrees in science, title in science and degrees and title in arts (Dz.U. 2003, no. 65, pos. 595, with amendments)).

3.1. COMPOSITION OF THE SERIES OF THEMATICALLY RELATED PUBLICATIONS

As the thematically related series of publications "**CONSTRUCTION AND VERIFICATION OF QUANTILE-BASED MARKET RISK MODELS**" being a presentation of my achievements I indicate **my 11 major publications** from the area of time series modelling and model risk in market risk modelling. The publications are presented here in chronological order[5]:

- **P3 Modelling of the "long memory" in volatility series** (in Polish), in: Preference Modelling and Risk '03, Trzaskalik T. (ed.), published by Academy of Economics in Katowice, Katowice, 2003, ISBN 83-7246-363-8, pp. 491-504, (Modelowanie „długiej pamięci" szeregów zmienności stóp zwrotu, in: Modelowanie Preferencji a Ryzyko '03),
- **P8 Modelling of Skewness and Excess Kurtosis in Stock Returns Using Conditional Pearson Type IV Distribution** (in Polish), in: Taxonomy nr 12, Jajuga K., Walesiak M. (scientific editors), Research Papers of Wroclaw University of Economics, Nr 1076, Wrocław, 2005, PL ISSN 0324-8445, pp. 434-443, (Wykorzystanie warunkowego rozkładu Pearsona typu IV w modelowaniu skośności i leptokurtozy rozkładów stóp zwrotu, in: Taksonomia nr 12),
- **P9 Application of Multivariate AR-GARCH Models in Value-at-Risk Measuring**, in: Financial Investments and Insurance – World Tendencies and Polish Market, Jajuga K., Ronka-Chmielowiec W. (editors), Research Papers of Wrocław University of Economics, Nr 1088, Wrocław, 2005, PL ISSN 0324-8445, pp. 126-138, **my contribution 70%**, (**co-author: Daniel Papla[6]**, Department of Financial Investments and Risk Management, Wroclaw University of Economics, **co-author contribution 30%)** (Wykorzystanie wielorównaniowych modeli AR-GARCH w pomiarze ryzyka metodą VaR, in: Inwestycje finansowe i ubezpieczenia – tendencje światowe a rynek polski),

[5] **Abbreviations in accordance with the tabular summary on p. 53.**

[6] In the work **P9** the contribution of the co-author (Daniel Papla, PhD) was 30%. He was the co-author of the research concept and final conclusions. My contribution was the rest of the work, particularly details of using multivariate GARCH models in Value-at-Risk measuring, backtesting procedures and all calculations in empirical part of our research (with my original procedures in MATLAB).

P12 Modelling of conditional kurtosis and skewness in financial time series (in Polish), in **Dynamic Econometric Models** (in Polish), Published by Nicolaus Copernicus University, Toruń, 2005, ISBN 8323118647, pp. 111-120, (Modelowanie warunkowej kurtozy oraz skośności w finansowych szeregach czasowych, in: Dynamiczne Modele Ekonometryczne),

P15 Some Practical Challenges in Multivariate GARCH Modelling (in Polish), in: Taxonomy nr 13, Jajuga K., Walesiak M. (scientific editors), Research Papers of Wroclaw University of Economics, Nr 1126, Wrocław, 2006, PL ISSN 0324-8445, pp. 194-205, (Niektóre praktyczne wyzwania w modelowaniu wielowymiarowych procesów GARCH, in: Taksonomia 13),

P17 Measuring and Testing of Skewness for Financial Return Distributions (in Polish), in: Taxonomy nr 14, Jajuga K., Walesiak M. (scientific editors), Research Papers of Wroclaw University of Economics, Nr 1169, PL ISSN 0324-8445, pp. 122-130, (Pomiar i testowanie skośności rozkładów stóp zwrotu instrumentów finansowych, in: Taksonomia 14),

P18 Survey and Comparison of Backtesting Procedures (in Polish), in: Mathematical and econometric methods in financial risk assessment, Chrzan P. (ed.), Research Papers of Academy of Economics in Katowice, Katowice, 2007, ISBN 978-83-7246-822-2, pp. 113-124, (Przegląd i porównanie metod oceny modeli VaR, in: Matematyczne i ekonometryczne metody oceny ryzyka finansowego),

P21 Application of alpha-stable distributions and the copula functions in Value-at-Risk measuring (in Polish), in: Modern Finance Challenges, Jajuga K. (ed.), published by Wroclaw University of Economics, Wrocław, 2009, ISBN 978-83-7011-947-8, pp. 123-131, **my contribution 70%**, (**co-author: Daniel Papla**[7], Department of Financial Investments and Risk Management, Wroclaw University of Economics, **co-author contribution 30%)**, (Zastosowanie rozkładów alfa-stabilnych i funkcji powiązań (copula) w obliczaniu wartości zagrożonej (VaR), in: Wyzwania współczesnych finansów),

P22 Analysis of Power for Some Chosen VaR Backtesting Procedures: Simulation Approach (in English), in: Advances in Data Analysis, Data Handling and Business Intelligence, Studies in Classification, Data Analysis and Knowledge Organization, A. Fink, B. Lausen, W. Seidel, A. Ultsch (ed.), Springer, Heidelberg, 2010, ISBN 978-3-642-01043-9, pp. 481-490,

P23 Comparison of Some Chosen Tests of Independence of Value-at-Risk Violations (in English), in: Algorithms from and for Nature and Life, Studies in Classification, Data analysis, and Knowledge Organization, B. Lausen, D. Van den Poel, A. Ultsch (ed.), Springer, Heidelberg, 2013, ISBN 978-3-319-00034-3, pp. 407-416,

[7] In the **P21** work the contribution by the co-author (Daniel Papla, PhD) was 30%. He was the co-author of the research concept and final conclusions. He was an author of the discussion on using copula functions in dependence structure description. My contribution was the rest of the work, in particular details of Value-at-Risk measuring, Monte Carlo procedure, backtesting model evaluation and all calculations in empirical part of our research (with my original procedures in MATLAB).

P24 Value-at-Risk Backtesting Procedures Based on the Loss Functions - Simulation Analysis of the Power of Tests (in English), in: Data Analysis, Machine Learning and Knowledge Discovery, M. Spiliopoulou, L. Schidt-Thieme, R. Janning (ed.), Springer, Heidelberg, 2014, ISBN 978-3-319-01594-1, pp. 273-281.

3.2. MOTIVATION FOR SUBJECT CHOICE

A serious increase of general level of broadly understood risk, particularly after beginning of the crisis in 2007, made risk one of the most important categories in finance. Efficient management of risk (identification, measurement, steering, effect verification) has become not only an element of economic performance improvement strategy but even the crucial task of economic entity management, critical to its survival. During this time advanced quantitative methods have become part and parcel of risk management [e.g. 8, 15 ,20 ,22 ,23 ,26 and **P1**–**P24**][8].

A part of daily routine become usage of stochastic process models to describe financial data. Very popular assumption that subsequent rates of return are independent and follow the same distribution (usually Gaussian) with constant parameters is also an assumption about a stochastic process. For example these assumptions are used in a simple (usually too simple) but very popular model of geometric Brownian motion. As it has already been said, the fast increase of the number, diversity and popularity of mathematical models in finance is caused by a number of interconnected reasons: the development of quantitative methods, particularly stochastic processes, the increase of available computing power and IT solutions, including professional software for scientific calculations and modelling, and also access to data sets from different markets. The models are widely applied and their performance is verified in various fields and in many different ways.

Each model is, however, only an attempt to reproduce in a simplified form the reality. This simplification is necessary to be able to construct the model and then use it. On the other hand, the simplification is itself a source of risk, namely – model risk [e.g. 8, 11, 20, 26]. **Model risk is an inevitable phenomenon** and is connected first of all with:

1) adopting an incorrect form of the model (e.g. the model does not take into account all important risk factors, risk factor distributions are wrongly specified, inappropriate dependence structure assumed – for example, a model based on linear dependence measures used for modelling data with some other type of dependence structure),

2) parameter estimation errors (because of a wrong method of estimation or arising just as a result of a finite length of sample),

3) using a model that is inappropriate for a given task (e.g. when a pricing model that requires assumption of market efficiency and unlimited liquidity is used on a market with low liquidity or during a crisis).

[8] References – list on p. 50, My papers – list on p. 53.

Potential threat lies in ignorance of the risk and magnitude of its potential consequences. **Model risk should be identified, measured and mitigated**. In many cases ignorance of existence or magnitude of this kind of risk caused serious financial problems. One of the best-known cases in which model risk played the main role was the collapse of Long Term Capital Management (LTCM) mutual fund in 1998. This case is particularly illustrative not only because the size of loss and systemic importance of the fund but also for the fact that the fund used advanced mathematical models and its founders, operators and users were renowned authorities in the discipline of finance. Losses incurred as a result of realization of a scenario that was far from the model assumptions (amongst others – Russian crisis of 1998) show how great caution should be exercised when applying theoretical models in practice. First of all one needs to be aware of assumptions underlying the model. Even if the assumptions are fulfilled at a given moment, there should be done an analysis answering the question under what circumstances the assumptions may become invalid.

A positive aspect of financial crisis that started in 2007 was bringing the problem to attention of practitioners and theoreticians of finance. Particularly they were made aware of the need to evaluate models not only in respect of goodness of fit to historical data but also model robustness, understood as resistance to changes of market conditions. The models should be also understandable for their users [22, 26].

There is still lack of general standards of modelling particular risk factors and financial instrument pricing on this basis, neither is there unanimity about risk measurement methods [4, 5, 9, 10, 15, 16, 17, 26, 28, 29, 30, 31, 32, 33, 34, 35, 39 and **P1**–**P10**, **P12**, **P14**–**P16**]. **Current challenges, however, in my opinion, is not proposing new modifications of models (for single instruments or portfolios) but rather verification of their performance and applicability as tools for solving particular real-life problems** [e.g. 15, 25, 26, 34, and e.g. P2, P9, P14, P20, WZ12, WZ13].

The quality of time series models should be verified not only in the teaching sample on the basis of econometric measures of model performance but also and especially in the test sample on the basis of the indicators taking into account the financial effect of the applied approach. The key criterion that should be used when evaluating an econometric model in finance is not how well the model describes the current and the past reality but rather how powerful it is in forecasting the future evolution of the phenomenon it describes, which may be verified not earlier than ex post. A model that is worked on should be verified for different time series and different periods. Models that are resistant to market condition changes and understandable for potential users should be preferred.

The main area of my research is subordinated to the aim of identification of models and solutions showing minimal level of intricacy and giving at the same time acceptable and intended effects from the point of view the tasks that are set in the area of finance. By models to be identified or developed, there are understood models of time series of returns (on single instruments or portfolios). By solutions, there are understood mainly various tests, like statistical tests of skewness of distributions or tests verifying performance of risk measurement models. By tasks in the domain of finance, mainly risk measurement or financial instrument pricing is understood.

For econometric models this approach boils down to a two-step procedure: first take to further analysis only the models that have not been rejected on the basis of goodness of fit tests in the teaching sample and then select from amongst of them the models that best perform in financial sense for the test sample data. Models that best fit the data in the teaching sample are not always (and hardly ever, indeed) the best ones if broadly understood effects of their application to financial problems is concerned.

Theoretical discussions and empirical research presented in the thematically related series of publications "**CONSTRUCTION AND VERIFICATION OF QUANTILE-BASED MARKET RISK MEASUREMENT MODELS**" was intended to broaden the knowledge about the use of models in finance (especially in market risk measuring) and to search for solutions that offer a reasonable trade-off between minimization of the level of model intricacy and maximization of performance in the sense of measures considering quality of final outcome (accomplishment of tasks in the domain of real-life economic problems).

A **quantile-based model of market risk measurement** is understood here: as a parametric or semi-parametric model whose result is such estimation of market risk of a single financial instrument or a portfolio of financial instruments that uses information about a (conditional or unconditional) quantile (or quantiles) of a usually unknown (conditional or unconditional) distribution of value change within a certain time interval.

The most typical approach is based on lower quantiles of value change distributions. The negative concept of risk is adopted then. This gives as a result the so called downside risk measures [e.g. 1, 8, 15, 20, 21, 22, 24, 26, 34].

In my research I focused on the **Value at Risk** ($VaR_t(q)$) and **Expected Shortfall** ($ES_t(q)$) at some chosen tolerance level which is denoted with *q*. These two risk measures are defined in the following way:

$$P\left(W_{t+1} \le W_t - VaR_t(q)\right) = P\left(\Delta W_{t+1} \le -VaR_t(q)\right) = q$$

$$ES_t(q) = E\left[-\Delta W_{t+1} \mid \Delta W_{t+1} \le -VaR_t(q)\right],$$

where:

ΔW_{t+1} – change of value in a given time interval, *q* – VaR tolerance level (usually 1% or 5%).

These are two complementary downside risk measures that are most popular in practical applications. They are particular cases of "**spectral risk measure**", introduced by Acerbi in

2002 [1]. A spectral risk measure is a weighted average (an integral with a weighting function) of quantiles of portfolio value change distribution.

Within the area of construction and verification of quantile-based market risk measurement models I concentrated mainly on the most popular [e.g. 5, 20, 21, 22, 24, 26, 34] downside risk measure, that is – **Value at Risk**. The definition of Value at Risk that has been presented above (as such loss on a portfolio that probability of incurring this or higher loss during a predefined period is low and equal to some assumed significance level, known as VaR tolerance level) is very intuitive but pretty general at the same time. It does not specify the way in which the value should be estimated and verified. **This generates several theoretical and practical challenges which constitute an important subject of my investigations**.

In practice models of quantile-based risk measures are constructed with the use of stochastic models describing dynamics of returns. The initial value of the analysed portfolio is needed, which is no problem, and unconditional or, more often, conditional quantiles of the future distributions of returns need to be estimated.

In the case of Value at Risk only one quantile of return distribution is needed. This is a quantile corresponding to VaR tolerance level ($VaR_{T+1}^{R}\left(q\right)$).

For Expected Shortfall there is to be estimated expected value of quantiles corresponding to lower probabilities than VaR tolerance level ($ES_{T+1}^{R}\left(q\right)$).

These values may be estimated using models based on conditional expected value of returns, conditional variance and conditional shape of the future distribution of returns:

$$VaR_{T+1}^{R}\left(q\right)=\hat{\mu}_{T+1}+\sqrt{\hat{h}_{T+1}}\hat{Q}_{z}^{q}$$

$$ES_{T+1}^{R}\left(q\right)=\hat{\mu}_{T+1}+\sqrt{\hat{h}_{T+1}}E\left[\hat{z}_{t}\mid\hat{z}_{t}\leq\hat{Q}_{z}^{q}\right],$$

where:

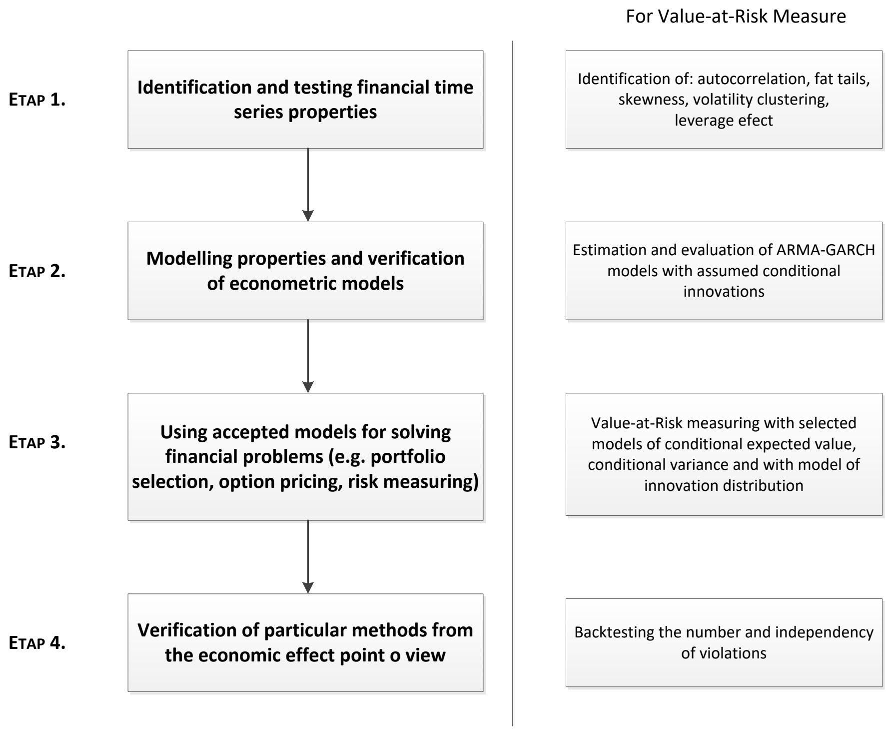
$\hat{\mu}_{T+1}$ – estimator of expected value of conditional distribution of returns for the [T, T+1] period,

$\hat{h}_{T+1}$ – estimator of conditional variance for the [T, T+1],

$\hat{Q}_{z}^{q}$ – estimator of the quantile corresponding to probability *q* of a random variable *z*, where *z* is standardized conditional error of the model; distribution of the random variable *z* introduces to the model information about the shape of conditional distribution.

When solving a financial problem with the use of time series models, proposition of an integrated scheme of conduct, verification of its effects and, finally, accepting or rejecting it, requires a set of actions. This, of course, refers also to the situation of **applying time series models to risk measuring**.

The following tasks may be distinguished. They are also subsequent steps of the general procedure:



Such approach is also presented in the detailed discussion of the series of thematically related publications, in which the tasks listed above are associated with corresponding steps of the procedure of constructing and using quantile-based risk management models.

The steps of the procedure may be associated with the following publications (thematically related series):
Step 1 – **P17**,
Step 2 – **P3**, **P8**, **P12**, **P15**,
Step 3 – **P9**, **P21**,
Step 4 – **P18**, **P22**, **P23**, **P24**.

This is not, however, a disjunctive classification. The areas of research interpenetrate in the articles.

The thematically related series of publications do not exhaust the subject, but it addresses the main issues of financial time series modelling (identification of time series properties, modelling, application of the model, performance verification) by the example of one, very important both from theoretical and practical point of view [e.g. 7, 14, 19, 20, 21, 22, 32], problem of value at risk measuring.

Currently **I continue my research in the fields discussed in the thematically related series** of publications. My interests concentrate on model risk. At present I investigate the problem of the size of confidence interval for risk measures (Value at Risk and Expected Ehortfall) resulting from parameter estimation error in ARMA-GARCH models for a finite sample (**WZ13, WP26**). It seems obvious that **interval estimation should supplement point estimation of risk measures, at least on the stage of verification. If, for instance, two models (say, showing different level of intricacy) return identical point estimates of Value at Risk – let the value is 2 million zloty – but 90% confidence intervals differ much, for instance one is [2 – 0.05, 2 + 0.05] million, that is: the width of 100 thousand, and the second is [2 – 0.5, 2 + 0.5] million, that is: the width of 1 million, then the methods should not be treated as equivalent. In the case of Value at Risk measure the size of the confidence interval is determined not only by estimation error of conditional expected value and conditional variance model parameters but also estimation error of conditional quantile of standardized residuals. The level of model intricacy and the length of sample used for estimation should be chosen on the basis of acceptable (assumed) size of confidence interval. Moreover, parameter estimation error has its impact on the procedure of backtesting of the risk measurement model.**

Parallel to the above topics I do the research in the field of test power analysis for Value at Risk and Expected Shortfall (WP23), as well as some aspects of model risk in this area.

3.3. KEY ACHIEVEMENTS IN THE THEMATICALLY RELATED SERIES OF PUBLICATIONS

The aim of the series of works is presenting the process of constructing and verifying a quantile-based risk measurement model, and particularly a Value at Risk measurement model involving econometric concepts to describe financial time series, as well as broadening knowledge in some chosen areas. As far as Value at Risk estimation is concerned, market risk of stocks, stock indices, foreign exchange rates and commodities is analysed. As far as Value at Risk model verification is concerned, the discussion is more general and entirely universal. Its conclusions may be applied to any financial instruments and any type of risk if aggregated in the form of one measure, namely – Value at Risk (that is, it may be market, credit or even operational risk). The rules end elements of the process of Value at Risk implementation may be applied, generally speaking, also to all other quantile-based risk measures (e.g. Expected Shortfall).

Moreover, conclusions derived from the empirical research presented in the series may be directly used in procedures of constructing and verifying internal Value at Risk models implemented in financial institutions.

The scheme of actions intended to implement risk measurement model based on quantile measures of risk (like Value at Risk) has already been outlined earlier in this summary. It contains the following steps:

a) **identification and testing financial time series properties,**
b) **modelling properties and verification of econometric models,**
c) **using accepted models for Value at Risk estimation,**
d) **verification of particular methods from the point economic effect of view (backtesting).**

In accordance with the aim of the thematically related series of publications the following questions were answered:

1) What properties are characteristic for financial time series (rates of return)?

In my research both the properties that are usually tested (autocorrelation in return time series, fat tails of return distribution, volatility clustering, autocorrelation of squared returns) [for Polish market data, e.g. 9, 10, 16, 28, 29, 30, 32 and e.g. **P4**] and less popular ones (long-time memory in processes of volatility, leverage effect, skewness of return distributions, changing conditional kurtosis, big number of zeros in historical samples of returns) [e.g. 3, 5, 6, 33 and for Polish market data 9, 10, 11, 16, 17, 30, 31 and **P3**, **P5**, **P8**, **P10**, **P17**] were analysed. In publication series, **particular emphasis was put on skewness of rate of return distribution measuring and testing**, which is relatively rarely analysed in literature [e.g. 3, 6, 33 and **P8**, **P17**]. This is particularly important because for distributions of higher kurtosis (as compared to normal distribution) classical Jarque-Bera test (reached under the Gaussian distribution assumption) rejects the hypothesis about asymmetry too often [6, 13]. I proved (**P17**) that asymmetry of return distributions is so popular in practice that there may be a need of considering some modifications of many methods used in risk management and financial instrument pricing. This refers of course to the methods that (in their classical versions) assume symmetric distributions of returns. For more details see p. 25. The need of taking fat tails of distributions into account when testing for skewness, for example when using generalized Jarque-Bera test, was confirmed by Prof. Domański [13, 14]. The issues of power analysis for these tests are addressed in the works [13, 14] and **WZ10**.

2) What models should be used to describe time series of returns for single instruments when treated separately and for portfolios of instruments to make the models well suited to empirical data?

I concentrated on the analysis of **goodness of fit** and on the **challenges resulting from the level of intricacy of models** (using classic, based on the frequentist statistic, approach[9]). The level of intricacy may be sometimes regarded as being identical with complexity, but in the sense used here the notion of intricacy means rather that a model depends on many parameters, is difficult to be calibrated and implemented, or, for example, some of the multitude of parameters are not directly observable in the economy, etc. The higher level of intricacy the harder implementation of the model in practice. Generalizations of classical tools of risk management or pricing, usually intended to make them take into account more properties of the analysed phenomenon, may in fact give only spurious advantage over the classical ones. This is the case if the number of parameters that need to be estimated increases inadequately to the potential improvement of model precision. The estimation error should be also considered. For more details see [e.g. 4, 5, 8, 17, 22, 25, 26 and **WP17**, **WP19**, **WP26**, **WZ13**]. The works in this area concentrated on univariate (sometimes also multivariate) models of conditional expected value and conditional variance (conditional covariance matrix). For Polish market data modelling see [e.g. 9, 10, 11, 12, 16, 17, 19, 29, 30, 35, 36]. **As for univariate models I regard particularly important the works concerning long memory in volatility time series (FIGARCH model – P3), skewness of unconditional distributions of returns (Pearson type IV distribution – P8, P17) and modelling varying-in-time kurtosis of distribution (extension of classical ARMA-GARCH models – P12). In the area of multivariate models my research concentrated mainly on multivariate GARCH models (P9) and investigated (together with doctor Daniel Papla) applicability of copula functions with alpha-stable margins to describing multivariate distributions of returns (portfolio returns – P21).** My research showed that some models (like general forms of multivariate GARCH models) applied to multi-component portfolios do not outperform indeed much simpler and better known solutions (like exponential smoothing models). We have also demonstrated that a method using on Monte Carlo simulation, with a model assuming alpha-stable one-dimensional marginal distributions of a multidimensional joint distribution and copula functions as the model of dependence structure may give better risk measuring results for two-element portfolios than classical approaches (like historical simulation and variance-covariance approach). For more details see pp. 31–34.

3) Do dynamic approaches to Value at Risk estimation based on models of conditional distributions outperform approaches based on unconditional distribution models?

[9] For Bayesian econometric study see e.g. [28, 32].

I presented a survey and an discussion of using univariate and multivariate models of conditional mean, conditional variance or covariance matrix and different models of standard error distribution in measuring risk using Value at Risk. Unlike unconditional approach, in which parameters of return distribution (or multidimensional distribution of returns) are constant in time, in the approaches using conditional models it is assumed that particular characteristics of the distribution may change in time and that it is possible to successfully model these changes by means of dynamic relationships and then use the estimates (forecasts) of future values of distribution parameters to estimate risk [e.g. 4, 10, 12, 15, 20, 30, 34]. Main emphasize was put on using different versions of multivariate GARCH models (VECH and diagonal GARCH – **P9**, **P15**). I analysed (together with doctor Daniel Papla) also less popular solutions, like alpha-stable distributions and copula functions (**P21**). We demonstrated that for two-component portfolios models with conditional expected value vectors and conditional covariance matrices (diagonal versions of the models) gave for all analysed pairs of time series (8 pairs) better results of Value at Risk estimation than unconditional models. We have, moreover, shown that in the analysed data set higher improvement of performance was obtained thanks to introducing time-varying conditional covariance matrix (diagonal VECH) than time-varying conditional expected values (AR models).

Usage of conditional covariance matrix is sufficiently easy to be recommended for practical use for two-component portfolios. For multi-component portfolios (more than 2 instruments) should be used such models that allow to describe at least some part of dynamic dependence and guarantee positive definiteness of the covariance matrix. Such condition is fulfilled, for example, by constant conditional covariance models (CCC) and models with covariances estimated using exponentially weighted moving average (in RiskMetrics standard). These models are also particular cases of general multivariate GARCH (VECH-GARCH) model. For more details see pp. 31–32.

We have also demonstrated that alpha-stable distributions and copula functions may be useful in portfolio risk measurement, particularly if marginal distributions are of different types. Due to limited scope of the research, the results cannot be treated as a ground for a general conclusion and require further confirmation using more data sets. For more details see pp. 32–34.

In all cases the discussion was backed by empirical research on the effects of application of the analysed models to Value-at-Risk-based market risk measuring. Usefulness of the models was verified on the basis of historical data and backtesting procedure. The results we obtained were confirmed in a number of works in the areas of modelling Polish market data and risk measurement [e.g. 9, other references are presented in the Appendix 5].

4) How to test Value at Risk models to identify really good solutions?

As far as I know, in Poland[10] I was the first who took up the task of systematization of knowledge about Value at Risk model verification, taking into consideration three main groups of methods:

- methods based only on time series of exceedances (hit sequences), like Kupiec test, Christoffersen test, mixed test of unconditional coverage and independence, Haas test [7, 15, 18, 20, 24, 27, 37 and **P22**, **P23**],
- methods based on the comparison of entire distributions or just their tails between empirical distribution and the theoretical one assumed in the Value at Risk model; here belong e.g. Crnkovic-Drachman test and Berkowitz test [7, 15, 27, 38 and **P22**],
- methods based on the concept of loss functions, like tests using Lopez, Caporin or Sarma, Thomas, Shah functions [2, 7, 15, 32 and **P24**].

I showed that the conclusions often drawn in practice may be fallacious because of the way the test is constructed or due to incomprehension of the nature of the problem (**P22**, **P23**, **P24**). **The analysis of test power is often utterly neglected [e.g. 7, 8, 16, 24, 34]**. I performed simulations allowing to evaluate power of chosen tests and proved unsuitability or very limited usefulness of some most popular solutions (Kupiec test of unconditional number of exceedances, Christoffersen test of independence of exceedances) for the lengths of data sets that are usually available in practice of finance.

The obtained results (P22, P23, P24 – details on pp. 34–38) were concluded by me in a form of recommendations about procedures of evaluation of internal models of risk measurement in financial institutions (recommendation concerning the for two-stage procedure of model testing).

The **description of research areas may be also presented as a coherent and logical series of actions necessary to specify and verify a Value at Risk estimation procedure**, for instance for a stock portfolio. The task may be also set in a different way, namely – the aim may be to choose the simplest model from amongst the ones that not only have not been rejected in the previous step, but are acceptable in the sense that they are not rejected by tests of a given power (the choice of the simplest Value at Risk model which for a set of data sets is rejected by a backtesting procedure with an assumed probability, guaranteeing that the power of the test – power to detect a wrong model – is of a given predetermined level).
Beneath there are presented in more details my achievements in the outlined areas.

[10] Also in the international literature little work has been done to compare the power of backtests for all three groups of approaches and on the basis of the same deviation from the null hypothesis.

TESTING SKEWNESS OF RETURN DISTRIBUTIONS

As it was mentioned, basic properties of financial time series (autocorrelation of returns, fat tails of distributions, volatility clustering) were pretty thoroughly identified and analysed in many works [for Polish market data, e.g. 9, 10, 16, 28, 29, 30, 32, 32], also in my publications from the period before doctorate and in my doctoral thesis. There are relatively few publications addressing the issue of skewness, its measuring and testing of significance, in analysis of financial time series. Fat tails (fatter than Gaussian) and numerous outliers are characteristic of financial time series. For this reason typical measures and tests may be insufficient. These properties make also any potential skewness of distribution carry more weight than if the distribution was thin tailed [3, 6, 13, 13, 33]. **Proper identification of skewness that is potentially present in distributions of returns may be essential for option pricing, portfolio construction and risk measurement.** Classical models, assuming symmetry of underlying instrument return distribution, underprice call and overprice put option if the distribution is indeed positively skewed (which is true in most cases of asymmetric distribution of returns). When a portfolio is constructed, in a model that takes asymmetry into account weights of instruments with rightwards asymmetric distributions are higher than it would be in a symmetric model. In risk measurement, in turn, it is important to choose a measure that takes into account properties of return distribution. For example using symmetric measures of volatility, like variance, is inappropriate if the true distributions are asymmetric. In such case also classical Value at Risk estimation methods give faulty results (for rightwards asymmetric distributions they overestimate risk) [22, 34].

According to my knowledge, the problem of testing skewness of financial return distribution in cases of high kurtosis has never been taken up earlier (at least not in an appropriate way) in any works concerning Polish market.

In the publication **P17** I analysed the issue of skewness testing for return distributions. In classical Jarque-Bera test (of normality) there may be distinguished elements connected with testing skewness and kurtosis. It is a mixed test, from which a skewness testing component may be isolated. Unfortunately, **using this test directly in the analysis of rates of return is usually not justified**, due to departures from normal distribution, on which the concept of Jarque-Bera test is founded [e.g. 6, 13, 14]. The differences between distributions of returns and normal distribution are well substantiated with many empirical works [e.g. 9, 10, 11, 30, 31]. In the case of symmetric distributions with tails fatter than normal the null hypothesis about symmetry is rejected too often (as compared with assumed significance of the test), which **leads to unnecessary complication of return time series models**, and thus – also models of risk measurement.

In the work **P17,** in its theoretical part, I introduced three solutions enabling skewness testing for fat-tailed distributions. Each of the solutions is based on a different construction, which enables in addition analysis of test result divergence. The following tests were analysed:

a) adjusted Jarque-Bera test, augmented as compared with the classical one by the possibility of its application to fat-tailed distributions (if it has finite three first even moments) [e.g. 6, 13, 14],
b) test of the parameter responsible for skewness modelling in the time series analysis methodology using skewed conditional Pearson type IV distribution (an approach based on log-likelihood test and comparison of a model without restrictions to the restricted one) [e.g. 6, 10, 16, 32, 33],
c) conformance test for distributions of sub-samples (conformance of distribution functions of two subsample) [e.g. 3].

In each case there were provided conditions of application of these tests with regard to the observed leptokurtosis of distributions. In the empirical part **I analysed together 150 time series of returns on stocks and indexes of Polish market**. In the theoretical part I proposed and substantiated a correction of sub-sample distribution conformance test, taking into account the fact that in empirical time series from Polish market there are many returns of value zero. This feature is characteristic of Polish market, but analysts usually neglected it. There are even 30-40% of zeros in time series of daily returns and it is not the result of no trade on these days but of equal close prices on subsequent days. In the proposed modification symmetry of distribution is analysed not around mean, which is close to zero, but exactly around zero. Classical sub-sample conformance test (which is very simple, popular, intuitive, and appropriate for fat-tailed distributions) rejected hypothesis about symmetry for virtually all analysed distributions of stock returns. After modification the test may be applied to analysis of stock returns on Polish market. Depending on the choice of test I obtained results indicating that about 30%-50% of return distributions in Polish stock market show significant skewness that should be taken into account in models and methods of portfolio construction, risk management or derivative instrument pricing. **An advantage of the research is also comparison of results given by different tests based on the same data set**, which was a starting point of my further research on power of these tests. A discussion on power of the tests may be found in [13, 14] and **WZ10**.

The work **P17** still remains one of very few pieces of research in which tests using moments of distribution are applied to verification of distribution symmetry hypothesis. In most cases the hypothesis about symmetry of return distribution is tested by analysis of significance of a parameter that in a time series model is responsible for skewness [e.g. 9, 10, 11, 16, 30, 32], which limits the scope of applications of this classical approach only to the models with a skewness parameter explicitly present in the density function formulas describing conditional or unconditional distribution.

MODELLING OF FINANCIAL TIME SERIES

Here my accomplishments in the area of econometric model construction and goodness of fit evaluation (in teaching sample) are presented.

Construction of a univariate model of return time series may be naturally divided into 4 parts:

- **modelling conditional expected value of the process,**
- **modelling conditional variance of the process,**
- **choice of the form of density function for standardized residuals of the model,**
- **modelling of higher-order conditional moments of return distributions.**

All these tasks should be considered jointly, since they influence one another and determine together properties and quality of the final model [e.g. 11, 16, 30]. In modelling of return time series there are usually used classical AR-GARCH models with Gaussian or Student-t conditional innovations. These models do not allow, however, to take into account such properties as long memory, skewness of distributions, and varying-in-time conditional higher-order moments. Basic solutions in the first three areas were analysed and verified for Polish market data in my doctoral thesis. In my works of the post-doctoral period I concentrated on gaining a broader insight into modelling long memory in GARCH-class models, taking into account conditional distributions allowing for skewness of unconditional distribution, as well as describing varying-in-time skewness and kurtosis of return distributions. These issues were addressed in the works: **P3**, **P8** and **P12**.

The aim of this research was answering the question if **further complicating of univariate time series models gives improvement of their goodness of fit to an empirical data**.

I demonstrated that:

In time series of volatility long memory is often observed, which is characterized by hyperbolic decay of squared return autocorrelation function.

The subject of analysis in publication **P3** is FIGARCH model (fractionally integrated GARCH) which is a generalization of GARCH [5] model and allows for a different decaying shape of squared return autocorrelation function. This model allows to describe not only volatility clustering but also the specific shape of squared residual autocorrelation function. Information on FIGARCH model was collected, arranged and compared with properties of basic non-fractional models (GARCH and IGARCH). **I also indicated the difference between the two ways of understanding the term "long-memory volatility model"**, which is the source of often misunderstandings. The first one is strictly related to the shape of autocorrelation function of squared rates of return. The second one refers to the influence of a disturbance at any time on forecasts of conditional variance in subsequent moments. I discussed the two indicating possible misinterpretations. I always showed that intuition based on classical model properties may be misleading. Treating FIGARCH as a model being in between GARCH and IGARCH is incorrect. Both GARCH and IGARCH are “short-memory” models, whereas FIGARCH is a “long-memory” model, if the shape of squared residual autocorrelation function is taken as a criterion. According to the results obtained in the empirical part of the research, **FIGARCH model was best fitted to the data** (time series of returns on the WIG index) in the sense of Akaike criterion, and the value of fractional exponent in autoregressive component (in the expression with unit root) is 0.14 and is statistically significant. For FIGARCH model the autocorrelation function shows the properties that are observed indeed in real-market data, that is – fast decreasing for low lag orders and then slowly for high orders. Despite interesting properties, FIGARCH models are not popular in financial practice and are very rarely discussed in research works (this refers also to research using Polish market data) [e.g. 9, 11, 16, 30, 32]. This is mainly the result of really more advanced theoretical concepts underlying these models, as well as (still at the moment) the lack of commonly available calculation packages supporting the model.

Pearson type IV distribution is successful in improving performance of models (conditional or unconditional) by allowing for both fat tails and skewness.

In the work **P8** I presented properties of Pearson type IV distribution and necessary standardizations, to construct an AR-GJR-GARCH model with conditional Pearson type IV distribution, comparable with classical solutions. I pointed out aspects related to estimation and testing of the model (possibility of log-likelihood ratio tests thanks to the fact that both Student-t and normal distributions are special cases of Pearson type IV distribution). In the empirical part **I demonstrated an advantage of a model with conditional Pearson type IV distribution over solutions with symmetric conditional distributions (normal and Student-t)**. I analysed 93 return Polish market time series. For the analysed time series the model with Pearson type IV was in 29 cases better than model with conditional Student-t distribution, which indicates that there is a need to pay more attention to the possibility of asymmetric conditional distributions in real-life data. Asymmetric distributions make it necessary to modify risk measurement techniques. As it has already been mentioned, volatility (variance) based risk measures overestimate risk of losses if the true distribution is rightwards asymmetric, which the case in majority of situations. This is one of manifestations of model risk. **I have never come across any earlier research in which conditional models with this type of distribution were used for Polish market data.** In the works of Polish authors skewed Student-t distribution [9, 11, 30, 32], rarely Johnson [10] or alpha-stable distributions [32] have been usually used.

The extension of the classical approach, in which only two first moments of distribution are modelled, by modelling time-varying skewness and kurtosis parameters significantly improves goodness of fit of the models, also for the Polish market data.

The aim of **P12** publication is presentation of possible solutions in the area of time-varying skewness modelling and kurtosis modelling for conditional distribution of returns (in a similar way conditional expected value and conditional variance are modelled), as well as answering the question: if introducing a time-varying kurtosis parameter significantly improves the quality of time series description for rates of return in Polish market. In the research Pearson type IV distribution was used as a conditional distribution, to which a time-varying parameter was introduced. Parallel to this, similar research, using Johnson distribution with time-varying shape parameters, was presented in the position [10]. **In the work P12 I analysed usefulness of AR-GARCH models with changing conditional kurtosis of Pearson type IV distribution allowed, and verified its ability to improve the quality of description of some chosen time series from Polish market**. The sample used in the research was composed of time series of simple rates of return on some chosen financial instruments (stocks, indices, foreign exchange rates). 4 models with time-varying conditional distribution kurtosis parameter were verified. The results obtained confirmed in each case significant improvement of the quality of model. Neither of the time-varying kurtosis model used in the research dominated explicitly over other models of this kind. In each case (10 time series), however, allowing for time-varying of conditional distribution improved the quality of the model (according to Akaike criterion) as compared with models without this augmentation. **Researches in the area of higher-order conditional moment modelling are very rare both in the international and in domestic literature on the subject.** In the work [10] there was analysed conditional distribution dynamics for two indices of Polish market (WIG20 and WIRR). The distribution model used there was conditional Johnson distribution with varying parameters of shape. The results confirm what there is called “existence of non-trivial dynamics of shape parameters in conditional distributions” [10] and usefulness of these models.

For a portfolio of financial instruments the task of modelling is much more complicated. Natural extensions of univariate models to a multivariate case (conditional vectors of expected values, conditional covariance matrices and models of conditional multidimensional distributions) are well known for a long time [e.g. 4, 16, 25, 26, 29, 30, 39]. The extent to which general models of this kind are complicated and the difficulty of their practical implementation are the reasons for which in this field, unlike one-dimensional case, the direction of discussion and research is reduction of the level of complexity/intricacy of the models in order to find applicable solutions [e.g. 4, 16, 29, 30].

In this area of my research I took up **practical challenges in multivariate GARCH process modelling**. This led me to the conclusion that:

Diagonal VECH model, at least for two-component portfolios, often is the best one from amongst models being special cases of multivariate GARCH to describe observed data.

In the work **P15** I presented (not very popular and rarely taken into account in studies on Polish market data in 2006) some chosen basic multivariate GARCH models being special cases of the general VECH model [4, 16, 39]. I indicated the reasons for which these models are (and, no doubt, will remain in the future) an interesting theoretical concept with limited practical applications, particularly if portfolios of financial instruments with the number of components higher than two are concerned. The practical problems are not only caused by a big number of parameters of the models. **I categorized information about general VECH model and its simplifications** (diagonal VECH, BEKK, diagonal BEKK and scalar BEKK), taking into regard number of parameters and also conditions of positive definiteness and finite values of covariance matrix. I also indicated problems in the area of parameter estimation. In empirical research I adjusted 4 multivariate models with properties that allow to use them in practice (diagonal VECH, BEKK, diagonal BEKK and scalar BEKK) to data from different markets. U**sing a sample of 105 pairs of time series of 15 financial instruments (in total 420 estimated models) I demonstrated that diagonal VECH was optimal from the point of view of the goodness of fit (Akaike criterion) in the majority of cases (76 of 105**). This result is positive in the sense that diagonal VECH model is the least problematic in practical use. This is a good news in this sense that models of this kind are least problematic in practice. The results of two-component portfolio analysis may be, for example, used in hedge ratio determining for hedging portfolios with futures contracts, because this is a bi-dimensional task by its nature (**WP19**).

Analysis of properties of multivariate GARCH models, discussion on challenges of their implementation and description of their applications for Polish market data may be found in the positions [16] and [11]. Interesting research in Bayesian comparison of multidimensional

GARCH models, including models used for data from Polish market, are conducted by a team from Cracow University of Economics, Osiewalski, Pajor, Pipień.

APPLICATION OF TIME SERIES MODELS IN VALUE AT RISK MEASUREMENT

The definition of Value at Risk does not specify how to determine this measure [comp. e.g. 20, 21, 22, 24]. A number of methods of Value at Risk estimation have been proposed, out of which big popularity gained various parametric approaches of different levels of complexity [e.g. 8, 15, 24, 35]. In parametric approaches Value at Risk is estimated using models of multivariate (unconditional) distribution of returns (i.e., a given multidimensional dependence structure) or models of (conditional) dynamics of multidimensional time series. **Both groups of methods were the subject of my research done in cooperation with dr. Daniel Papla (works P9 and P21)**.

Because of the multitude of Value at Risk approaches (and thus also the possibility that different results will be obtained) it is necessary to determine which method gives best estimates. This is the next step of Value at Risk estimation procedure. This issue is discussed in the paragraph about testing of Value at Risk models (p. 34). The verification of obtained Value at Risk estimates for test sample of historical data is necessary to evaluate usefulness of particular approaches.

In parametric approaches value at risk is estimated either with the use of unconditional multivariate distribution models (a given multidimensional dependence structure) or conditional dynamics of multivariate time series. **Both groups of models were analysed in the research carried out by me in cooperation with dr. Daniel Papla (P9 and P21).**

In both articles there is considered a two-asset portfolio. An important part of our research was identification of problems connected with implementation of the analysed models also for multi-asset portfolios. Estimation of Value at Risk using models ARMA-GARCH class of models with different conditional distributions was a subject of my own individual research before doctorate, like for example the article "Heteroskedastyczność szeregu stóp zwrotu a koncepcja pomiaru ryzyka metodą VaR" (Heteroscedasticity of return time series and the concept of risk measurement with Value at Risk measure (in Polish)) and "Pomiar ryzyka metodą VaR a modele AR-GARCH ze składnikiem losowym o warunkowym rozkładzie z grubymi ogonami" (VaR estimation and AR-GARCH Models with Fat-tailed Conditional Innovations (in Polish)).

The works **P9** and **P21** are a natural continuation of my research in risk measurement for single instruments treated separately and are can be compared to other research on risk measuring on Polish market [11, 12, 16, 32, 34, 35, 36]. **The results of our research supported the hypothesis that conditional models of time series dynamics outperform classical static (unconditional)**

approach. As part of our research in portfolio risk measurement with Value at Risk we demonstrated that:

Using models of conditional vectors of expected values and conditional covariance matrices may help improve performance of Value at Risk estimation methods.

Classical approach [e.g. 8, 24, 35] uses multivariate normal distribution (or less frequently Student-t) with constant parameters (unconditional distribution). In the work **P9** we analysed an example of conditional multivariate normal model with vectors of means and variance matrices following some relationships (VAR-GARCH) [4, 16, 29, 30, 39], applied to Value at Risk estimation for two-asset, equally weighted portfolios. We indicated limitations of time-varying conditional covariance matrix modelling and pointed out **the model risk associated both with the choice of the form of the model and with parameter estimation**. In an empirical research for equally weighted pairs of some chosen instruments we demonstrated that in all analysed cases (8 pairs of time series) diagonal VECH models gave better Value at Risk estimates, at least in the sense of the number of exceedances (number of the violations closer to the expected number), than the unconditional approach. As far as independence of exceedances is concerned, the results are not so unambiguous. In my later research I showed, however, that the reason may be low power of Christoffersen tests (**P22** and **P23**). We demonstrated also that much higher improvement of Value at Risk model performance may be obtained thanks to allowing for time-varying conditional covariance matrix (diagonal VECH models) than time-varying conditional expected values (VAR models). Because of practical limitations of application for the case with more than 2 portfolio components the **MGARCH models – except some very simplified versions, like constant correlation or exponential weighting models – are hardly ever considered as tools supporting Value at Risk estimation for portfolios of instruments** [15,2 4]. This is also confirmed by the research in the Polish market, presented in positions [11] and [16].

Copula functions may be useful in portfolio risk management, particularly when marginal distributions are different.

In P21 publication we presented **different approaches to Value at Risk measurement**. In the research two-component portfolios were taken into analysis. Marginal distributions and dependence structure were modelled separately [12, 39]. Univariate distributions of returns on particular components were modelled with alpha-stable distributions [12, 39]. This enabled taking into consideration such properties as fat tails and skewness. To describe dependence structure, copula functions were used in turn [e.g. 12, 19, 26]. Using a copula allows to, at least to some extent, solve the main problem (for dependent variables) connected with practical use of multidimensional distributions, that is – missing information about analytical form of joint distribution of returns if marginal distributions for particular components of a portfolio are of different types or even belong to different families of distributions[11]. This solution may be used as an competitive alternative to VAR-MGARCH models. It may also complement the last. Because of practical problems these approaches are hardly ever combined yet. In the work **P21** we presented a procedure of Value at Risk estimation with Monte Carlo simulation where the models used in the simulations assumed alpha-stable marginal distributions and some chosen copula functions.

In the empirical part we presented an example of an application of such approach and compared obtained results for a chosen pair of financial instruments with the methods recognized as classical (historical simulation and variance-covariance). We used three copula functions belonging to Archimedean family – Gumbel, Frank and Ali-Mikhail-Haq copulas. The Monte Carlo simulation with copula functions allows to analyse such cases in which marginal distributions are different, and thus – joint distribution does not belong to one of simple well known multivariate distributions, like multivariate Gaussian or multivariate t-distribution. The research presented there indicated an advantage of the copula-based approach with alpha-stable marginal distributions.

The work was submitted for publication in 2007 and was one of the first pieces of research in which copula functions were used in market risk measurement for data from Polish market. This work was cited at least 12 times (Appendix no. 6). In the next years copula functions became more and more popular as tools of dependence structure modelling [19, 26] – also for data from Polish market [e.g. 12, 36]. In the position [19] there were presented basics of copula theory with connection to risk modelling in Value-at-Risk framework. In the work [26] a concept of copula-based integrated measurement of enterprise risk was presented. In the position [36] copula functions were used in a model of international diversification. The broadest and most advanced research on applications of copula functions (classical approach, conditional models, regime-switching models, models with stochastic dynamics of parameters and cascade models), including risk factor modelling for Polish market data and Value-at-Risk estimation is presented in the position [12].

In the publication P9 contribution of the co-author, Daniel Papla, was evaluated as 30% and it referred to co-development of research methodology and drawing up conclusions from the research results. The remaining part of works was my individual contribution, and particularly identification of challenges and a more detailed concept of multivariate GARCH model application, as well as of back-testing, and performing calculations in empirical part of the research (using original procedures, developed by me in Matlab environment). **In the publication P21 contribution of the co-author, also dr. Daniel Papla, was evaluated**

[11] Because of the lack of the independency of the random variables it is impossible to use the convolution of the density functions. For more details, e.g. in insurance practice, see [37].

to be at the level of 30% and referred to his co-authorship of a general research methodology and discussion on possible ways of copula function application. My task concentrated on the components of the research that were connected with Value at Risk measurement, Monte Carlo simulation, model verification using back-testing procedures, and also doing all the empirical research planned in this work.

POWER ANALYSIS OF VALUE AT RISK MODEL PERFORMANCE TESTS

In practice there are used various methods of Value at Risk measurement which may give different estimates. This implies a need of performance evaluation of these methods, for which **backtesting procedures** [e.g. 2, 7, 18, 24, 27, 32, 37] are meant. This field is what I currently explore most intensely, from theoretical (**P18**) and empirical (**P22**, **P23**, **P24, WP23, WP25**) side, as well as in my popularizing activity (**WZ3**, **WZ5**, **WZ11**, **WP21**).

The main area of my research I focused on is simulation-based analysis of power of particular tests, depending on the magnitude of simulated deviation from the null hypothesis (correct model) - improper frequency of VaR exceedances, lack of exceedance independence - and on size of the sample.

The theoretical discussion and empirical research concentrated on the most popular groups of methods that are based on:

- time series of exceedances (hit sequences) – for example: Kupiec test, Christoffersen test, mixed test, Haas test [7, 15, 18, 20, 24, 27, 38 and **P22**, **P23**],
- comparison of whole distributions or tails of distributions – of empirical and theoretical distribution, where the theoretical distribution is the one assumed in Value at Risk model (Crnkovic-Drachman test, Berkowitz test) [7, 15, 27, 38 and **P22**],
- los function concept (Lopez, Caporin, Sarma-Thomas-Shah) [2, 7, 15, 32 and **P24**].

The aim of the research is to answer the question: which of the Value-at-Risk performance tests should be used to minimize type II error (acceptance of an incorrect model as a correct one). Among the advantages of the research may be counted not only estimation of power of the analysed tests for assumed departures from the correct model, but also creating a possibility of comparing results for different methods and drawing some more general conclusions (P22, P23, P24). In all analyses referring to tests of number and independence of exceedances, the power of the tests was compared for the same data sets. I am not familiar with any analogous studies on tests of all three groups of methods.

In the risk measurement, the type II error (not rejecting an incorrect model) may of course have much more serious consequences for any financial institution, or, put it more generally, for any financial decision maker, than type I error (rejecting a correct model). **An analysis of test power is often utterly neglected and reduced to general statements "greater", "less", "small" [e.g. 7,**

8, 16, 24, 34]. Despite the importance of the problem, there are no test power comparisons in the literature in this field, or the existing comparisons are very fragmentary. On the ground of such comparisons, the choice of Value-at-Risk performance evaluation method would be much easier and better substantiated. **In Poland, as far as I know, works on this area are conducted systematically only by Marta Małecka from the University of Łódź (PhD thesis in preparation [27]).** A lot of texts on some concepts of many different Value-at-Risk performance tests have been published all over the world [2, 7, 15, 27, 38], but there is still missing, in my opinion, research on comparison of properties of these tests, particularly from the point of view of their power for typical sample lengths and typical departures from the correct model. **The aim of my work partially is filling in this gap.**

As part of the work **P18** I made **a broad review and comparison of Value at Risk methods, pointing out advantages and disadvantages of particular solutions**. In Poland (before 2007) I have not come across any earlier works of this kind that would be so broad in scope. I explained the concept of classical tests, based on hit sequences (for verification of hypotheses about frequency and independence of failures, as well as mixed ones: Kupiec, Christoffersen, mixed Christoffersen test). I showed an example of a spurious Value-at-Risk "estimation technique", for which the tests fail completely (to be more precise – they do not reject the "model" that is absurd indeed). I also introduced the concept of regression tests. I discussed the idea of loss-function based tests. I made a review of various loss functions (like Lopez or Sharma-Thomas-Shah), pointing out that it is possible to treat separately the number and magnitude of exceedances (Blanco and Ihle). I indicated usefulness of loss-function based tests in the tasks of both model verification and model ranking (for instance, to select the best one in respect of a chosen criterion, from amongst those models that have not been rejected at the verification stage). This second approach is a used in a two-step procedure of Value-at-Risk model evaluation, recommenced in the publication **P24**. I systematized knowledge about tests based on quantiles of distributions and Rosenblatt transformation (Crnkovic-Drachman and Berkowitz approach). **I analysed advantages and disadvantages of these solutions and indicated threats arising from drawing conclusions from the tests if one does not understand their construction or assumptions.** The work **P18** is my only publication after doctorate that does not contain an empirical part. I find it, after all, an important component of my achievements because I identified there a cognitive gap and proposed a direction of further research, pointing out that **to determine whether these tests may be treated as useful tools of Value-at-Risk model verification, their formal evaluation should be performed, part of which should be both analysis of type I and type II errors**. As it has already been mentioned before, in Poland the only researcher who deals with this issues on a systematic basis is mgr. Małecka [27].

In the publication **P22** I concentrated my research on **power analysis of frequency-of-exceedance tests** (Kupiec tests and one of variants of Berkowitz test [7, 15]) and **independence-of-exceedance tests** (Christoffersen and another variant of Berkowitz [7, 15, 18]). I demonstrated using a simulation-based research that using critical values from χ^2 distribution leads to erroneous decisions. They may be also associated with model risk, because Kupiec test statistics have a discrete distribution that is just asymptotically convergent to χ^2 distribution. For typical lengths of time series used in the tests there may be a considerable difference between the actual and limit distribution. **I indicated that a better solution is using critical values obtained from simulated distribution of the test statistic under the assumption that the model is correct.** I presented differences between these approaches for typical VaR tolerance levels (5% and 1%). I indicated that also in this case the test power analysis may be disturbed because of varying size of tests. In my report **WP23** I extended this discussion and used a randomized approach, free of the test size change problem. The analysis of Kupiec test power indicates unambiguously that with typical lengths of samples and under typical test significance levels this **test should not be used at all for 1% VaR** tolerance and only with a great caution for 5% tolerance level. For test significance of 5% and 250 observation time series length a model giving 3% of exceedance instead of 5% is identified as incorrect only in 35% of instances. I also demonstrated that **frequency-of-exceedances test based on Berkowitz procedure shows a significantly higher power**; for 5% tolerance level of Value at Risk this was the truth for all lengths of time series that were analysed and observed in practice, for 1% tolerance level of Value at Risk – only for time series longer than 500 observations. In this work I demonstrated also that **Christoffersen and Berkowitz test of exceedance independence failed** (for typical length of time series) when verified for artificial data with probability of exceedance doubled or decreased by a half after the day on which Value at Risk was exceeded. Even for 1000 observation long time series the powers of these tests are so low that they should not be used. Using Christoffersen or Berkowitz tests to check for independence of exceedances gives the actions taken to choose a Value-at-Risk model just the appearance of a formally substantiated procedure, but, at least for typical lengths of time series, it is not credible at all. The power of these tests is too low to use them in this way. I pointed out the need of assuming a minimum power of Value-at-Risk evaluation tests. This would influence of course minimum acceptable lengths of samples and also significance levels of the tests.

The issue of testing for departures of exceedance independence was continued by me in the research **P23**. **I arranged and presented information on an approach to exceedance independence testing which is based on analysis of distribution of the number of observations between exceedances** (Haas test [7, 18, 27]). This solution identifies departures on the basis of hazard function [e.g. 37] shape for distribution of number of days between exceedances. I presented approaches presented by Christoffersen and Pelletier (using continuous Weibull distribution as the alternative), as well as – closer to the nature of the problem – Haas solution (with discrete Weibull distribution proposed by Nakagawa and Osaki). In further part of that research I concentrated on Haas approach. I demonstrated that the method allows to identify more general forms of departures from independence than Christoffersen method, generated by the volatility clustering effect. **I also pointed out that from such difference a risk of accepting an incorrect Value-at-Risk model may arise, due to a misunderstanding about incorrect model definition.** This is a kind of model risk; in this case – of the model underlying the test. This is a different problem than the issue of risk originating from the sources of type I and type II errors when testing statistical hypotheses. **In the empirical part I presented a concept of procedure of test power assessment for Haas and Christoffersen tests. The procedure used simulated data with properties close to those observed in practice.** This approach guarantees that the number of exceedances is always correct (thanks to using empirical quantile of the unconditional distribution) and allows to test just for departures from independence of exceedances (the nature of potential departures from independence of exceedances was assumed to be connected with volatility clustering effect, which is often observed in empirical data; in the research there were used GARCH models to describe this effect). **Using simulations I demonstrated a significant advantage of Haas procedure over the Christoffersen test**, which still remains very popular in practice. I showed that, due to low power, Christoffersen test fails to be reliable for typical lengths of time series and typical deviations from exceedance independence. If formulated a number of recommendations about Value at Risk model evaluation.

In the work **P24** I considered tests based on the concept of loss functions [7, 15]. The loss functions used in the research are defined in such a way that they allow to take into account also small exceedances of Value at Risk. Moreover, the loss functions may be used as tools assessing the quality of Value-at-Risk models not only from the point of view of the number of exceedances, but also their magnitudes. This concept is in compliance with the preferred approach of supervisory authorities that prefer such Value-at-Risk models that if an exceedance occurs, it is rather small than big. **In the publication I substantiated the thesis that the method may be applied both to identify incorrect models (model testing) and to compare between not-rejected models in order to select the best model from amongst the ones that have "passed" the previous phase of verification (model ordering).** I analysed in details the concept of loss functions, discussing various possibilities in the area of loss function choice, as well as specification of the function that aggregates the information about losses throughout the whole period. I indicated possible natural generalizations and advantages of some chosen loss functions. **In the empirical part I compared results of test power analysis for Kupiec and Berkowitz tests and tests using two (most popular) loss functions.** I demonstrated that the loss-function-based approach had no advantage over Berkowitz test (as far as verification of the number of exceedances was considered, both for Value-at-Risk tolerance level of 5% and 1%). I pointed out a strong dependence between the chosen loss function and power of the test.

I also indicated that, in general, even one big (in magnitude) exceedance may cause model rejection. It is thus necessary to take into account the influence that operations on securities, such as: granting rights to dividend, granting pre-emptive rights or split of stocks, have on stock prices, and to introduce appropriate corrections. **A direct conclusion is the recommendation of a two-stage procedure, in which Value-at-Risk models are first verified to reject those that do not pass tests, and then, in the second stage, from amongst the models that have not been rejected the best one is selected.** The first stage of the model verification is best performed when Berkowitz test is used for testing of the number of exceedances and Haas test is used for testing independence of exceedances. In Poland I have not come across any research on power of statistical tests using loss functions done by Polish author. This approach is usually used only as a tool of ranking Value-at-Risk measurement models.

Results of my research in the area of backtesting of Value-at-Risk models may be concluded with the following general recommendations:

1) **Evaluating of Value-at-Risk model performance should be based on more than one test.**
2) **Backtests should take into account both number and magnitude of exceedances.**
3) **A two-stage procedure should be implemented:**
   a) **Identification of a set of acceptable models (using at least Berkowitz test, but a combination of Berkowitz for number and Haas for independence of exceedance is more recommended),**
   b) **Selection of "the best" model on the ground of an appropriate loss function.**
4) **Analysis of the methods should be extended by stress testing.**
5) **Models should be tested for different data sets, long and short positions and different periods.**
6) **It cannot be assumed that a model that was once identified as acceptable (not rejected) will be always correct.**

Moreover, it is necessary to discuss the minimum acceptable test power when evaluating internal models used by financial institutions.

Synthetically, **the contribution of the thematically related series of publication to the development of economic sciences in the discipline of finance** may be presented as follows:

1) I discussed the notion and importance of model risk in financial problems, and pointed out and explained the need of using measures that take into account economic effects when evaluating financial models (**P3**, **P8**, **P9**, **P12**, **P15**, **P17**, **P21**).
2) I systematized knowledge about skewness testing methods for fat-tailed distributions (which are characteristic of daily returns). I indicated that for Polish market data

the hypothesis of distribution symmetry is over twice too often rejected by the classical Jarque-Bera test (**P17**).

3) I proposed a correction of conformity test for sub-samples to adjust the test construction to the observed phenomenon of a big number of zero returns in empirical time series (this property of Polish market was not taken into account in former research) (**P17**).
4) For about 30% of stocks and stock indices in Polish market I identified significant skewness of distributions after having applied a procedure of extreme value correction for the cases when extreme values were results of operations on securities, that is – granting right to dividend, granting right issue, split of stocks, and I indicated that considering models with asymmetric distributions is well grounded (**P8**, **P17**).
5) I Indicated that the FIGARCH model shows an advantage over classical GARCH as far as long memory in volatility time series is concerned (i.e., the ability of the models to describe the shape of autocorrelation function for squared residuals). Data from Polish market were used in the analysis (**P3**).
6) I demonstrated that Pearson type IV (with constant parameters) may be useful in modelling of return distributions for data from Polish market (**P8**).
7) I indicated that introducing AR-GARCH models allowing for variable kurtosis of conditional distribution of residuals, on the basis of Person type IV distribution, improves the model ability of describing properties of return time series for data from Polish market (**P12**).
8) I showed that diagonal VECH model is in most analysed cases the optimal (in respect of Akaike criterion) choice for describing dynamics of two-component portfolios. I analysed practical challenges of using it, like the number of parameters and the need of guaranteeing positive definiteness and finiteness of covariance matrix (**P15**, **P9**).
9) I demonstrated advantages of some chosen models with higher intricacy (vectors of conditional expected values and matrices of conditional covariances, copula functions) over classical approaches to Value at Risk estimation (**P21**).
10) I systematized knowledge in the area of Value-at-Risk model evaluation methods for different sets of information used in these methods, and I indicated threats resulting from ignorance of concepts, assumptions and construction of these methods (neglecting test power analysis and incorrect interpretation of test results) (**P18**, **P22**, **P23**, **P24**).
11) I identified the source of model risk in backtesting which consists in using asymptotic critical values whereas the sample lengths are finite and usually of relatively small length, like 250 or 500 observations. Another aspect of model risk arises from using some of models underlying independence-of-exceedances tests (**P22**, **P23**).

12) In simulation research I analysed test powers (for three the most popular groups), demonstrating unsuitability or limited suitability of some most popular tests (Kupiec test of unconditional number of exceedances, Christoffersen test of independence of exceedances) for time series of typical lengths (250, 500 observations) and typical Value-at-Risk tolerance levels (0.01, 0.05) used in practice of finance. I formulated the following recommendation on procedures of evaluation of internal models of risk in financial institutions: use Berkowitz test instead Kupiec test, use Haas test instead of Christoffersen test and then select, using loss functions, the best model from amongst those that have not been rejected by neither of the two tests (**P22**, **P23**, **P24**).

4. ACHIEVMENTS NOT INCLUDED INTO SERIES OF PUBLICATIONS

Quantitative tools of analysis of financial markets and instruments play an important role also in the remaining part of my post-doctoral research achievements. Each of the research areas was considered from the point of view of suitability of methods and strategies, taking into account, to the highest extent possible, specific characteristics of Polish market, including organizational and legal aspects. **Particular hypotheses formulated there was in all cases verified by my own empirical research with the use of real data.**

This part of my achievements may be divided into the following areas:

1) Verification of arbitrage and para-arbitrage strategy feasibility on Polish market of derivatives.
2) Verification of option pricing models for data from Polish market.
3) Verification of hedge ratio estimation methods for futures on WIG20.
4) Verification of volatility and correlation forecasting methods for time series of returns.
5) Verification of a yield-curve-based investment strategy in the market of Polish Treasury bonds.

VERIFICATION OF ARBITRAGE AND PARA-ARBITRAGE STRATEGY FEASIBILITY ON POLISH MARKET OF DERIVATIVES

Some relations must hold between prices of derivatives and their underlying instruments. Departures from these relations may result in emergence of arbitrage possibilities. The use of arbitrage strategies should, at least in theory, bring the market back to the state of equilibrium. As a result of the research 3 publications were prepared. I formulated in them the necessary conditions of feasible arbitrage strategies between different instruments, fully taking into account specificity of Polish market. **I also showed examples of arbitrage and para-arbitrage possibilities in the past, on the basis of historical quotations.**

In the publication **P11** I demonstrated that the way the short sales is technically organized disqualifies it as an element of pure arbitrage strategies (of the first and second type). **I showed and discussed in details one of historical examples of arbitrage strategy construction possibility, together with an analysis of its economic effect**, and my conclusion was that arbitrage of the second type is more advantageous (because of costs of credit).

In the work **P13** I explained why strategies on the lack of call-put-spot parity can not be treated as arbitrage in the literal sense. I concentrated then on the discussion about the idea of a synthetic instrument and analysis of prices parity between a portfolio of options on WIG20 and futures on WIG20 (call-put futures), because an identical way of settlement price determination guaranties elimination of risk, that would otherwise be present (due to different settlement modes) and the corresponding call-put-spot strategy would be at most a para-arbitrage one. I specified conditions of entering into arbitrage strategies taking costs and deposits into account. **On the basis of the research and for historical data I demonstrated that apart from very few exceptions market in 2004 was in equilibrium.** Possible profits from arbitrage were small because of low volume of trade in derivative instruments.

In the publication **P19** I explained, on the basis of the regulations being in effect in that time in Poland, why only a para-arbitrage strategy using an index-tracking instrument might be considered. Because not all components of the portfolio could be sold short, I limited my analysis to the cases when the index-tracking unit was underpriced. I took into account costs and fees. **In the research I demonstrated that the proposed strategy was profitable in the period spanned by the analysis. This implies that the market was not efficient during that period.**

VERIFICATION OF OPTION PRICING MODELS FOR DATA FROM POLISH MARKET

This part of **my research concentrates on the model risk that is incurred when pricing European options**. The source of risk I analysed was incorrect price-dynamics model specification for the underlying instrument. In the classical model the underlying instrument price follows geometric Brownian motion process, which is the most popular model for this kind of applications. The considered alternative was AR-GJR-GARCH, allowing for autocorrelation of returns, volatility clustering, autocorrelation of squared residuals, as well as leverage effect and fatter tails. In this area, I prepared 2 publications.

In the theoretical part of **P1** publication I discussed in details European option pricing procedure assuming a property of local risk neutrality (Locally Risk-Neutral Valuation) and presented forms of the model developed in respect of actual (natural) probabilistic measure and arbitrage measure. I identified the source of model risk that was incorrect specification of the model. **An example presented in the empirical part demonstrated that the implied-volatility surface**

corresponding to option prices obtained from AR-GARCH-based model stays in agreement with observed shapes of the surface implied from real market prices. This may be treated as an argument for taking more advanced models into consideration.

The aim of the work **P7** was determining the amount of model risk by comparing delta coefficients (sensitivity of option value to changes of the underlying price) obtained in classical Black-Scholes-Merton approach and in AR-GARCH-based approach. I demonstrated by an empirical example relationships between delta coefficient values in the two models. For at-the-money options delta coefficients are identical in the two models, regardless time to maturity and conditional variance on the day of analysis. For in-the-money options, delta coefficients obtained in AR-GARCH model are higher than in Black-Scholes model if conditional variance is below average level and lower than for Black-Scholes model if conditional variance is above average level. For out-of-the-money options the opposite relationship is observed. **Only for deep in-the-money and deep out-of-the-money options the differences between absolute values of delta coefficients become negligible.**

As part of this course of research activity I gave also two conference speeches (**WP17** and **WZ8**) in which suitability of Black-Scholes and AR-GARCH models to pricing of WIG20 index option was verified. **The analysis was based on almost 100,000 transactions. Only for out-of-the-money options the advantage of AR-GARCH model was confirmed.** An article that sums up and concludes results of this part of my research is in preparation.

VERIFICATION OF HEDGE RATIO ESTIMATION METHODS FOR FUTURES ON WIG20

Using futures contracts in hedging strategies entails determining of optimal hedge ratio, that describes the quotient of the size of position in futures to the value of the portfolio to be hedged. The discussion about hedge ratio determination for contracts on WIG20 index were presented by be in two conference speeches (**WP19** and **WP22**).

I presented possible goal functions used as part of definition of hedging strategy (usually variance minimization), strategy performance evaluation measures (usually percentage ratio of risk reduction where risk is measured with variance). I also presented possible methods of hedge ratio estimation, based on different models of spot and futures price changes. In the empirical **part I identified the following practical problems**: the need of constructing the so called continued futures series, possible asynchronicity of spot and futures data, market illiquidity for contracts with longer term to expiration, estimation of models with big number of parameters and conditions. These problems are often neglected in analyses, which makes their results hardly reliable. **The most important conclusion from this part of research is that there is no evidence for advantages of more complicated models over simpler ones if the last are calibrated for well specified data window lengths**. The comparison was based on the criterion of reduction of variance of portfolio value changes in whole test sample. A very simple and

popular model of exponentially weighted moving average proved to be the best. Moreover, in a more detailed research I showed that this model, by its nature, guarantees smoothing day-to-day hedge ratio changes, which, in turn, reduces transaction costs by reduction of portfolio rebalancing frequency in regard to the futures part of the whole portfolio.
Currently I am continuing research in this area.

VERIFICATION OF VOLATILITY AND CORRELATION FORECASTING METHODS FOR TIME SERIES OF RETURNS

Covariance and correlation, analogously to volatility, are variables that are not directly observable. This hinders their measurement, modelling and forecasting. Correct determination of these parameters is, however, necessary in such areas as: portfolio analysis, market equilibrium models, pricing of classical and exotic options, market risk measurement using Value-at-Risk based approaches, as well as in hedging for a single financial instrument or portfolio. I presented the discussion in articles **P2** and **P14**.

In the work **P2** I compared unconditional volatility forecasting methods. The forecasts were made for a given period in the future (e.g. the next month). I considered two cases. The first, when the analysed forecasting technique assumed constant (conditional) volatility on subsequent days, which gives a constant volatility throughout the whole period as a result. The second, in turn, encompassed the approaches allowing for conditional volatility changing from day to day. The forecast of unconditional volatility was in the second case constructed as an average of conditional volatilities from subsequent days of the longer future period. I also presented possible measures of ex-post errors of the forecasts (symmetric and asymmetric). The subject of an empirical research presented there was estimation of ex-post errors of monthly volatility forecasts for 3 instruments (stock index, foreign currency and commodity). The teaching sample was 30 month long and the length of the test sample was 60 months. **For the chosen stock index and commodity simple averages (3-month, with equal weights, as well as with exponential weighting – for obsoleting of older-periods information) turned out to be the best. Only for the chosen foreign exchange rate the best approach was the one that used a GARCH(1,1)-based model.** This piece of research allowed to formulate a general conclusion that volatility forecasts with lower ex post error were obtained for the variants of volatility estimators that assumed expected value of return to be zero.

In the work **P14** I presented possible concepts of correlation matrix modelling and forecasting (for two-component portfolios). I discussed merits and limitations of particular methods for a bigger number of portfolio components. In empirical part of the research I presented correlation coefficient forecasting results for some examples of financial time series (the correlation forecasts were made on the basis of covariance matrix forecasts). I used forecasting techniques based on a constant covariance matrix model, exponentially weighted model and also multivariate GARCH model. **Obtained results confirmed that correlation coefficient forecasting is harder than volatility forecasting. The forecasts suffer from high ex-post error and only to a minor extent explain values observed indeed in the future. A simple and popular exponentially-weighted-moving-average model turned out to be the best.** There is also such advantage of this solution that it may be easily extended to model portfolios of more than two components.

VERIFICATION OF A YIELD-CURVE-BASED INVESTMENT STRATEGY IN THE MARKET OF POLISH TREASURY BONDS

The aim of the work denoted here with the label **P20** was presenting methods of modelling term structure of interest rates, with a particular focus on whole-yield-curve approximation (Nelson-Siegel and Svensson models), and then constructing an investment strategy based on the estimated model. The general concept of the strategy was identification of mispriced debt instruments.

The research hypothesis to be verified was that market of Polish Treasury fixed-interest bonds was not informationally efficient (in a weak form) and it was possible to obtain over-expected profits by means of active investment strategies based on identification of underpriced and overpriced bonds and, consistently, buying the first and selling the last. **In the research there had been reconstructed the true conditions under which investment decisions were made on Polish market.** The results of obtained for different starting dates, investment horizons, portfolio rebalancing days and pricing error limits, **did not confirm the hypothesis of informational inefficiency of Polish Treasury fixed-income bond market after all costs and taxes** had been taken into account. It theoretical layer of the research it was shown that fitting of yield curve with Svensson model gives better result than Nelson-Siegel (in the sense of mean absolute errors), but it has no significant impact on investment strategy performance. The publication was **prepared in cooperation** with dr. hab. Katarzyna Kuziak from Department of Financial Investments and Risk Management of Wroclaw University of Economics (co-author's contribution: 50%). The contribution by dr. Katarzyna Kuziak was the concept of the research, description of the course of works and preparation of conclusions. My contribution was empirical research (calculations using my own original procedures in MATLAB), analysis of the obtained results and cooperation in conclusion preparation.

5. TEACHING, POPULARIZING AND ORGANIZATIONAL CONTRIBUTIONS

Here I would like to present information on my teaching, popularizing and organizational achievements, as well as on my cooperation with universities abroad.

Teaching activity

After doctorate, that is – since February 2003, I gave lectures and was an **instructor of classes and laboratories in the following academic subjects**: Capital and Money Market, Portfolio Analysis and Management, Application of Mathematical Methods in Finance, Financial Markets and Instruments, Analysis of Financial Instruments, Financial Mathematics, Management of Financial Instrument Portfolio, Analysis of Financial Time Series.
Since 2009 I am also a lecturer and laboratory instructor in the Master Studies in Finance program, taught in English. In this program, the subject I am a tutor of is **Analysis of Financial Time Series**, which was prepared by me on the basis of my own original concept of teaching method, encompassing lectures, classes and laboratories.

Each year the number of teaching hours I am assigned exceeds the teaching load assigned to my current position.

I am also a lecturer at “Analityk finansowy” (“**Financial Analyst**”) and “Wycena przedsiębiorstw” (“**Enterprise Valuation**”) post-diploma studies. Within the framework of both study courses I am responsible for a block of subjects called “**Quantitative Methods**”.

The approach oriented on practical verification of discussed methods and models, that has been presented in this report so far, is reflected also in the teaching part of my achievements. I put a strong emphasis in my teaching work on indicating where and in what way a given solution may be used, what are the benefits of doing so and what are the limitations. Giving lectures and tutoring classes and laboratories I make efforts not only to present theoretical knowledge but also give my students a broader practical context of this knowledge, particularly from the point of view of household finance and in the perspective of financial market investors. This approach was also at the root of the subject “**Analysis of Financial Time Series**”, which was prepared by me on the basis of my own original concept of teaching method, encompassing lectures, classes and laboratories.

I was also a **reviewer of master and bachelor theses** in part-time study courses. Currently I am a **supervisor of bachelor theses in full-time studies** at the degree course of Finance and Accounting.

I am an author of two chapters in a monographic publication called "*Zastosowanie metod ekonometryczno-statystycznych w zarządzaniu finansami zakładów ubezpieczeń*" ("Applications of econometric-statistic methods in insurance company management"). **Chapters prepared by me** "*Metody budowy portfeli inwestycyjnych*" ("Methods of investment portfolio construction") – section 7.1, pp. 335-358 and chapter "*Klasyfikacja i porządkowanie zakładów ubezpieczeń – przegląd metod i badania empiryczne*" ("Classification and ordering of insurance companies – a review of methods and empirical research") – subsection 8.4.1., pp. 420-466 **are of a teaching character**. In these chapters the knowledge in the area is organized, the current state of the arts is summed up and practical aspects are pointed out.

Popularization activity

After doctorate I endeavoured to be still active in popularization of science and academic knowledge and to reinforce cooperation with business practice, which I perceive as a vital prerequisite for ensuring my own development as well as for promotion of my University and academic community as important players in solving practical problems.

My cooperation with business practice may be divided into the following fields: application of mathematical models, organizational and legal issues of financial markets and evaluation of investment projects.

Since July to November 2004 I served as a **Senior Specialist in Department of Analysis and Market Risk at KGHM SA**, where I supported construction of a copper price forecasting model, contributing to the project my knowledge in the area of modelling and forecasting of prices and volatility.

I was giving popularization lectures as part of **Festival of Science** and in the years 2006–2007 I was a lecturer in a training course "**Szkoła Giełdowa**", organized by Warsaw Stock Exchange in cooperation with Wroclaw University of Economics (Wroclaw edition).

Moreover, I **popularized the subject of financial econometrics at the invitations of**

- **Olsztyn Branch of the Polish Economic Society** (speech "Financial econometrics – theory and applications") and
- **Financial Modelling Research Group at the Faculty of Applied Mathematics of AGH in Cracow** (speech "Financial econometrics – ARMA-GARCH models – theory and applications").

I was also a speaker at:

- "**Science Meets Social Science**" seminar, which is periodically organized by Institute of Organization and Management of Wroclaw Institute of Technology (speech "Test power analysis for some chosen tests of Value-at-Risk estimation methods – a simulation approach") and

- **community seminar in financial econometrics SEFIN** organized at the Faculty of Mathematics and Informatics of Adam Mickiewicz University in Poznan (speech "Test power analysis for Value-at-Risk back-testing procedures – a hit-sequence-based simulation approach").

In the years 2006–2008 I was a member of supervisory boards of 3 exchange-quoted joint-stock companies. At present I cooperate in the field of financial market practice with **Supra-Regional Network of Business Angels (PSAB)** and **Association of Individual Investors (SII)**, supporting these both organizations with my knowledge and skills.

In 2010 I set up, together with associates, a DB Energy company (I was also graduated in electronics Wroclaw University of Technology) and became a board member there. That allowed me to apply a combination of my technical end economic knowledge to practical problems. **DB Energy works on technical scenarios of efficient energy use improvement for the industry, together with complete economic analysis, which helps reducing investment risk.** In DB Energy I am responsible for economic analysis of investment projects. As president of DB Energy **I am an active member of Lower Silesian Lodge of Business Centre Club**. Business activity of DB Energy got picked up and highly rated by the market. In 2012 DB Energy was **awarded the Innovation category Lower Silesian Griffin Prize** (Dolnośląski Gryf) for the best **achievements in the area of academic entrepreneurship**. In 2013 we received **the European Medal awarded by Business Centre Club** with support from the Ministry of Foreign Affairs and under the patronage of European Economic and Social Committee. We were also granted the **Lower Silesian Business Certificate**. I am an **author of a series of 4 short articles**[12] published in "Biznes Dolnośląski - Lower Silesia Business" quarterly (new bilingual business magazine). The aim of the articles was bringing the readers closer to financial aspects of activities improving efficiency of energy use in the industry.
When planning my teaching, scientific and popularization activity I ensure that they are coherent, complement and support one another and show a synergy effect as a result.

[12] 1) „Ceny energii rosną…. i co dalej?" (Energy prices are increasing… what next?) – Bizness Dolnośląski 02/2012,
2) „Są środki na poprawę efektywności…" (Resources to improve the efficiency) – Biznes Dolnośląski 03/2012
3) "Ekologia nie tylko modna, ale i opłacalna" (Ecology is not only fashionable, but also profitable) – Biznes Dolnośląski 04/2012
4) "Efektywność energetyczna jednym z priorytetów w Unii Europejskiej" (Energy efficiency to bo one of the UK's key priorities), Biznes Dolnośląski 01/2013

Organizational activity

Besides my research, teaching and popularization activity I also engage myself in faculty and department organizational work.

Since 2006 **I coordinate postgraduate program „Financial Analyst"** organized at the Faculty of Management, Computer Science and Finance of Wroclaw University of Economics. At the same time, in the framework of this postgraduate study course, I give lectures in a subject called "Quantitative Methods".

I was twice a **scientific secretary of "INWEST"** conference ("Financial Investments and Insurance – World Tendencies and Polish Market"), organized in cooperation by the Department of Financial Investments and Risk Management and Department of Insurance of Wroclaw University of Economics.

In 2014 I was a member of a 3-person organizational **board of the international conference** INWEST.

During the "INWEST" 2014 conference **I was an instructor of my own independent workshop program for 30 young academic researchers and doctoral students** from various academic centers. The title of the workshops was "Construction and verification of quantile-based models of risk measurement using MATLAB packet". The workshops were organized in cooperation with Oprogramowanie Naukowo Techniczne, a Cracow-located company, which is a sole distributor and representative of MathWorks company (MATLAB producer) in Poland.

This is my second term as a **member of the Faculty Board at the Faculty of Management, Computer Science and Finance** of Wroclaw University of Economics.

I am also a **regular reviewer of „Przegląd Statystyczny" journal**.

On Dec. 20. 2013 I was appointed by His Magnificence, Rector of the University of Economics in Wroclaw, prof. dr. hab. Andrzej Gospodarowicz, to the position of **statistics editor of "Argumenta Oeconomica"** (JCR-listed journal).

I am a **member of The Classification and Data Analysis Section** (SKAD) of The Polish Statistical Association (PTS).

Having cooperated with academic centres abroad, I actively participated in two editions of „Modelovani, simulace a rizeni pojistnych rizik" seminar, organized by Faculty of Economy and Administration of **Pardubice University**:

- in 2009 with a speech on "Application of ARMA-GARCH Models - Value at Risk Measuring and Backtesting"
- in 2010 with a speech on "Value at Risk Backtesting Procedures".

In 2013 I was an active participant of the Third Bilateral German-Polish Symposium on Data Analysis and Its Applications (GPSDAA2013) organized by **Dresden University of Technology**. As part of this symposium I gave a speech called "Analysis of the Power for Backtesting Procedures Based on the Hit Process - Simulation Approach".

AWARDS

By order of the President of the Republic of Poland of July 31. 2013 I was awarded the Bronze Medal for Long-Standing Service.

My work has been noticed and rewarded. In May 2013 during the conference "Modelowanie I prognozowanie zjawisk społeczno-gospodarczych" ("Modelling and Forecasting of Economic Phenomena") **I was awarded honourable mentions and a prize funded by StatSoft Polska** for a conference poster "Analysis of some chosen tests of Value at Risk estimation methods – a simulation approach".

In September 2014 the Scientific Committee of the "Financial Investments and Insurance – INWEST" Conference, appreciating the level of my research, rewarded me with a **proposal for the publication in "Argumenta Oeconomica"** – a magazine published by the University of Economics in Wroclaw, the only Polish journal in economic sciences with an impact factor.

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SUMMARY OF PUBLICATIONS, CONFERENCE SPEECHES AND CITATIONS

Beneath I would like to present summary tables of my publications (with citation information) and of my conference speeches.

total number of papers: 40					
before the PhD:			**after the PhD:**		
number: 16, in it:			**number: 24, in it:**		
	in Polish:	in English:		in Polish	in English:
author:	**13**	**0**	author	**17**	**3**
co-author:	**3**	**0**	co-author	**4**	**0**

Moreover I am also an author of 2 chapters in a monography that was prepared and published as **part of a grant** by the State Committee for Scientific Research, titled “Zastosowanie metod ekonometryczno-statystycznych w zarządzaniu finansami zakładów ubezpieczeń – 5 H02B 018 21” (“The use of econometric-statistic methods in insurance company management – 5 H02B 018 21”). These are the following chapters: “Metody budowy portfeli inwestycyjnych” (“Methods of constructing investment portfolios”), section 7.1, pp. 335-358, and “Klasyfikacja i porządkowanie zakładów ubezpieczeń – przegląd metod i badania empiryczne”, subsection 8.4.1., pp. 420-446 (“Classification and ranking of insurance companies – a review of methods and empirical research”).

Total number of conference speeches: 54					
before the PhD:			**after the PhD:**		
number: 14, in it:			**number: 40, in it:**		
	in Polish:	in English:		in Polish:	in English:
author:	**11**	**0**	author:	**22**	**14**
co-author:	**3**	**0**	co-author:	**4**	**0**
	Polish conferences	International conferences		Polish conferences	International conferences
author:	**11**	**0**	author:	**20**	**16**
co-author:	**3**	**0**	co-author:	**3**	**1**

total number of citations[1)]: 140	
before the PhD[2)]:	**after the PhD:**
number: 55	**number: 85**
H-INDEX[3)]	
papers before the Phd	**papers after the PhD**
h-index: 4	**h-index: 5**

1) without self-citations, 2) withe PhD thesis citations, 3) taking into account the papers not indicated by Publish or Perish, containing references to my papers (Annex No. 6)

My post-doctoral H-index taking into account only the base Publish or Perish is 3 (without self-citations).

POST-PHD PAPERS WITH THE NUMBER OF CITATIONS (EXCLUDING SELF-CITATIONS)

	PAPERS	Number of citations
P1	**Option pricing with AR-GARCH model** (in Polish), in: Financial Investments and Insurance – World Tendencies and Polish Market, Jajuga K., Ronka-Chmielowiec W. (editors), Research Papers of Wroclaw Academy of Economics, Nr 990, Wrocław, 2003, pp. 331-336 (Wycena opcji w modelu uwzględniającym efekt *AR-GARCH*, in: PN AE we Wrocławiu Nr 990)	7
P2	**Verification of time-series-based techniques of volatility forecasting** (in Polish), in: Financial Investments and Insurance – World Tendencies and Polish Market, Jajuga K., Ronka-Chmielowiec W. (editors), Research Papers of Wroclaw Academy of Economics, Nr 991, Wrocław, 2003, pp. 484-494 (Weryfikacja wybranych technik prognozowania zmienności na podstawie szeregów czasowych, in: PN AE we Wrocławiu Nr 991)	10
P3	**Modelling of the "long memory" in volatility series** (in Polish), in: Preference Modelling and Risk '03, Trzaskalik T. (ed.), published by Academy of Economics in Katowice, Katowice, 2003, pp. 491-504, (Modelowanie „długiej pamięci" szeregów zmienności stóp zwrotu, in: Modelowanie Preferencji a Ryzyko '03),	4
P4	**Application of ARCH models in description of WIG index return series** (in Polish), in: Econometrics nr 14, Dziechciarz J. (ed.), Research Papers of Wroclaw Academy of Economics, Nr 1021, Wrocław, 2004, pp. 152 – 169, (Zastosowanie modeli klasy ARCH do opisu własności szeregu stóp zwrotu indeksu WIG, in: Ekonometria nr 14)	8
P5	**Modelling of leverage effect in financial time series** (in Polish), in:, Financial Science to the contemporary problems of the Polish economy, Czekaj J. (ed.), vol. 4, Financial Markets, Conference Proceedings of Academy of Economics in Cracow, Kraków, 2004, pp. str. 129 – 142, (Modelowanie efektu dźwigni w finansowych szeregach czasowych, in: Nauki Finansowe wobec współczesnych problemów gospodarki polskiej, tom IV (Rynki Finansowe))	9
P6	**Modelling of interest rate volatility on the example of WIBOR** (in Polish), in: Financial Investments and Insurance – World Tendencies and Polish Market, Jajuga K., Ronka-Chmielowiec W. (editors), Research Papers of Wrocław Academy of Economics, Nr 1037, vol. 2, Wrocław, 2004, pp. 128-139, (Modelowanie zmienności stóp procentowych na przykładzie stopy WIBOR, PN AE we Wrocławiu nr 1037)	0

P7	**Delta coefficient in AR-GARCH option pricing model** (in Polish), in: Capital Market – Effective Investment, Tarczyński W. (ed.), Scientific Bulletin nr 389, vol. II, Szczecin University, Szczecin, 2004, pp. 35-50, (Współczynnik delta w modelu wyceny opcji uwzględniającym efekt AR-GARCH, in: Rynek Kapitałowy – Skuteczne Inwestowanie, vol. II)	2
P8	**Modelling of Skewness and Excess Kurtosis in Stock Returns Using Conditional Pearson Type IV Distribution** (in Polish), in: Taxonomy nr 12, Jajuga K., Walesiak M. (scientific editors), Research Papers of Wroclaw Academy of Economics, Nr 1076, Wrocław, 2005, pp. 434-443, (Wykorzystanie warunkowego rozkładu Pearsona typu IV w modelowaniu skośności i leptokurtozy rozkładów stóp zwrotu, in: Taksonomia nr 12),	2
P9	**Application of Multivariate AR-GARCH Models in Value-at-Risk Measuring**, in: Financial Investments and Insurance – World Tendencies and Polish Market, Jajuga K., Ronka-Chmielowiec W. (editors), Research Papers of Wrocław University of Economics, Nr 1088, Wrocław, 2005, pp. 126-138, **my contribution 70%**, (**co-author: Daniel Papla**, **contribution 30%)** (Wykorzystanie wielorównaniowych modeli AR-GARCH w pomiarze ryzyka metodą VaR, in: Inwestycje finansowe i ubezpieczenia – tendencje światowe a polski rynek),	5
P10	**Modeling of financial time series properties – skewness of the distributions** (in Polish), in: Econometrics nr 15 Dziechciarz J. (ed.), Research Papers of Wroclaw Academy of Economics, Nr 1096, Wrocław, 2005, pp. 297-308, (Modelowanie własności szeregów stóp zwrotu - skośność rozkładów, EKONOMETRIA 15)	4
P11	**Arbitrage possibilities on Warsaw Stock Exchange using futures contracts** (in Polish), in: Financing company activities, Stacharska-Targosz J. (ed.), WSB Faculty in Chorzów, Poznań, 2005, pp. 209-220, (Możliwości arbitrażu na Giełdzie Papierów Wartościowych w Warszawie z wykorzystaniem kontraktów terminowych, in: Finansowanie działalności przedsiębiorstw),	0
P12	**Modelling of conditional kurtosis and skewness in financial time series** (in Polish), in **Dynamic Econometric Models** (in Polish), Published by Nicolaus Copernicus University, Toruń, 2005, pp. 111-120, (Modelowanie warunkowej kurtozy oraz skośności w finansowych szeregach czasowych, in: Dynamiczne Modele Ekonometryczne)	3

P13	**Verification of put-call parity for options traded on WSE – Problems and examples of arbitrage strategies** (in Polish), in: Mathematical, Econometric and Computer Methods in Finance and Insurance, Chrzan P. (ed.), vol. II, Research Papers of Academy of Economics in Katowice, Katowice, 2006, pp. 137-148, (Weryfikacja parytetu kupna/sprzedaży dla opcji notowanych na GPW w Warszawie - Problemy oraz przykłady strategii arbitrażowych– Metody Matematyczne, ekonometryczne i informatyczne w finansach i ubezpieczeniach)	0
P14	**Forecasting of Covariance and Correlation Matrices of Financial Time Series** (in Polish), in: Preference Modelling and Risk ’05, Trzaskalik T. (ed.), Academy of Economics in Katowice, Katowice, 2006, pp. 143-160, (Prognozowanie macierzy kowariancji i korelacji finansowych szeregów czasowych, in: Modelowanie preferencji a Ryzyko ’05)	3
P15	**Some Practical Challenges in Multivariate GARCH Modelling** (in Polish), in: Taxonomy nr 13, Jajuga K., Walesiak M. (scientific editors), Research Papers of Wroclaw Academy of Economics, Nr 1126, Wrocław, 2006, pp. 194-205, (Niektóre praktyczne wyzwania w modelowaniu wielowymiarowych procesów GARCH, in: Taksonomia 13)	5
P16	**Using a DCC-GARCH Model and the FGM Copula in Analysis of the Dependency between Returns of Stocks, World Stock Market Indexes and Exchange Rates. Empirical Example.**, in: Financial Investments and Insurance – World Tendencies and Polish Market, Jajuga K., Ronka-Chmielowiec W. (editors), Research Papers of Wroclaw Academy of Economics, Nr 1133, Wrocław, 2006, pp. 376-383, **my contribution 30%, (co-author D. Papla, contribution 70%)**, (Wykorzystanie modelu DCC-GARCH oraz funkcji powiązań FGM w analizie zależności między stopami zwrotu z akcji, indeksów giełd światowych oraz kursami walut. Przykład empiryczny. In: PN AE we Wrocławiu Nr 1133)	0
P17	**Measuring and Testing of Skewnees for Financial Return Distributions** (in Polish), in: Taxonomy nr 14, Jajuga K., Walesiak M. (scientific editors), Research Papers of Wrocław Academy of Economics, Nr 1169, Wrocław, pp. 122-130, (Pomiar i testowanie skośności rozkładów stóp zwrotu instrumentów finansowych, in: Taksonomia 14)	3

P18	**Survey and Comparison of Backtesting Procedures** (in Polish), in: Mathematical and econometric methods in financial risk assessment, Chrzan P. (ed.), Research Papers of Academy of Economics in Katowice, Katowice, 2007, pp. 113-124, (Przegląd i porównanie metod oceny modeli VaR, in: Matematyczne i ekonometryczne metody oceny ryzyka finansowego)	5
P19	**Example of Paraarbitrage Strategy with Index Participation Unit MiniWIG20**, in: Quantitative Methods in Economy, Scientific Bulletin nr 450, Szczecin University, Bulletin of Econometrics and Statistics Department Nr 17, Szczecin, 2007, pp. 489-500, (Przykład strategii paraarbitrażowej z wykorzystaniem jednostki indeksowej MiniWIG20, in: Metody ilościowe w ekonomii)	0
P20	**Investment strategy on the Polish Treasury bonds market using yield curve models**, in: Contemporary problems of modelling and forecasting of socio-economic phenomena, Pociecha J. (ed.), Studies and Research Papers, University of Economics in Cracow, Kraków, 2009, pp. 195-206 **(co-author Katarzyna Kuziak, contribution 50%**), (Strategia inwestycyjna na rynku polskich obligacji skarbowych wykorzystująca modele krzywej dochodowości, in; Współczesne problemy modelowania i prognozowania zjawisk społeczno-gospodarczych),	0
P21	**Application of alpha-stable distributions and the copula functions in Value-at-Risk measuring** (in Polish), in: Modern Finance Challenges, Jajuga K. (ed.), published by Wroclaw University of Economics, Wrocław, 2009, pp. 123-131, **my contribution 70%**, (**co-author: Daniel Papla**, **contribution 30%)**, (Zastosowanie rozkładów alfa-stabilnych i funkcji powiązań (copula) w obliczaniu wartości zagrożonej (VaR), in: Wyzywania współczesnych finansów)	12
P22	**Analysis of Power for Some Chosen VaR Backtesting Procedures: Simulation Approach** (in English), in: Advances in Data Analysis, Data Handling and Business Intelligence, Studies in Classification, Data Analysis and Knowledge Organization., A. Fink, B. Lausen, W. Seidel, A. Ultsch (ed.), Springer-Verlag, Heidelberg, 2010, pp. 481-490	3
P23	**Comparison of Some Chosen Tests of Independence of Value-at-Risk Violations** (in English), in: Algorithms from and for Nature and Life, Studies in Classification, Data analysis, and Knowledge Organization, B. Lausen, D. Van den Poel, A. Ultsch (ed.), Springer-Verlag, Heidelberg, 2013, pp. 407-416	0

P24	**Value-at-Risk Backtesting Procedures Based on the Loss Functions - Simulation Analysis of the Power of Tests** (in English), in: Data Analysis, Machine Learning and Knowledge Discovery, M. Spiliopoulou, L. Schidt-Thieme, R. Janning (ed.), Springer-Verlag, Heidelberg, 2014, pp. 273-281	0

	UNPUBLISHED CONFERENCE WORKING PAPER	**number of citations**
1	**Verification of the Black-Scholes and AR-GARCH Model for Options on WIG20 Index** (in Polish), 10th National Scientific Seminar – Dynamic Econometric Models, September 2007, (Weryfikacja modeli Blacka-Scholesa oraz AR-GARCH dla opcji na WIG20, Ogólnopolskie Seminarium Naukowe - Dynamiczne Modele Ekonometryczne)	3
2	**Analysis of Power for Selected Backtests of Value-at-Risk Procedures – Simulation Approach** (in Polish), 7th International Scientific Conference Modelling and Forecasting of Socio-Economic Phenomena, Prof. A. Zeliaś Conference, Zakopane, May 2013, (Analiza mocy wybranych testów metod szacowania wartości zagrożonej – podejście symulacyjne, VII Międzynarodowa Konferencja Naukowa im. Prof. A. Zeliasia „Modelowanie i prognozowanie zjawisk społeczno-gospodarczych”)	1

BOOK CHAPTERS

Book: **The use of econometric-statistic methods in insurance company management** (Zastosowanie metod ekonometryczno-statystycznych w zarządzaniu finansami zakładów ubezpieczeń), Wrocław, Publishing House of Wroclaw Academy of Economics, Wrocław, 2004

Chapters: section 7.1, Methods of constructing investment portfolios”), pp. 335-358 (Metody budowy portfeli inwestycyjnych),

subsection 8.4.1., Classification and ranking of insurance companies – a review of methods and empirical research, pp. 420-446, (Klasyfikacja i porządkowanie zakładów ubezpieczeń – przegląd metod i badania empiryczne)

POST-DOCTORAL CONFERENCE SPEECHES ABROAD

WZ1	**Testing Skewness of Financial Return Distributions**, 31st Annual Conference of the German Classification Society, Data Analysis, Machine Learning, and Applications (GfKl-2007), March 2007, Freiburg, Germany
WZ2	**Analysis of Power for Some Chosen VaR Backtesting Procedures - Simulation Approach**, 32st Annual Conference of the German Classification Society, Advances in Data Analysis, Data Handling and Business Intelligence, July 2008, Hamburg, Germany
WZ3	**Application of ARMA-GARCH Models - Value at Risk Measuring and Backtesting**, Seminarium Modelovani, simulace a rizeni pojistnych rizik, Faculty of Economy and Administration, University in Pardubice, October 2009, Pardubice, Czech Republic
WZ4	**Analysis of Power for Some VaR Backtesting Procedures Based on the Loss Functions**, International Symposium on the Data Analysis Interface, July 2010, Karlsruhe, Germany
WZ5	**Value at Risk Backtesting Procedures**, Modelovani, simulace a rizeni pojistnych rizik, Faculty of Economy and Administration, University in Bratislava, October 2010, Bratislava, Slovakia,
WZ6	**Comparison of Some Chosen Tests of Independence of Value-at-Risk Violations**, Joint Conference of the German Classification Society (GfKl) and the German Association for Pattern Recognition (DAGM), September 2011, Frankfurt am Main, Germany
WZ7	**Value-at-Risk Backtesting Procedures Based on Loss Functions – Simulation Analysis of the Power of Test**, The 36th Annual Conference of the German Classification Society on Data Analysis, Machine Learning and Knowledge Discovery, August 2012, Hildesheim, Germany
WZ8	**Verification of Black-Scholes and AR-GARCH option pricing models for Polish market**, Joint European Conference on Data Analysis, The German Classification Society (GfKl), the French speaking Classification Society (SFC), July 2013, Luxemburg
WZ9	**Measuring and Testing Skewness of Financial Return Distributions**, Joint European Conference on Data Analysis, The German Classification Society (GfKl), the French speaking Classification Society (SFC), July 2013, Luxemburg,
WZ10	**The power of skewness tests in the presence of fat tailed financial distributions** Conference of the International Federation of Classification Societies (IFCS), United through Ordination and Classification, July 2013, Tilburg, Holland
WZ11	**Analysis of the Power for Backtesting Procedures Based on the Hit Process - Simulation Approach**, The Third German-Polish Symposium on Data Analysis and Applications (GPSDAA2013), Dresden University of Technology, September 2013, Dresden, Germany
WZ12	**Power of skewness tests in the presence of fat tailed financial distributions**, European Conference on Data Analysis 2014, Jacobs University, July 2014, Bremen, Germany

WZ13	**Interval estimation of Value-at-Risk and Expected Shortfall for ARMA-GARCH models**, European Conference on Data Analysis 2014, Jacobs University, July 2014, Bremen, Germany

POST-DOCTORAL CONFERENCE SPEECHES IN POLAND

WP1	**Verification of time-series-based techniques of volatility forecasting** (in Polish), Conference Financial Investments and Insurance – World Tendencies and Polish Market, Szklarska Poręba, October 2003, (Weryfikacja wybranych technik prognozowania zmienności na podstawie szeregów czasowych, Inwestycje finansowe i ubezpieczenia – tendencje światowe a rynek polski)
WP2	**Modelling of the "long memory" in volatility series** (in Polish), Conference Preference Modelling and Risk '03, Ustroń, April 2003, (Modelowanie „długiej pamięci" szeregów zmienności stóp zwrotu, Modelowanie Preferencji a Ryzyko '03)
WP3	**Modelling of leverage effect in financial time series** (in Polish), Conference Modelling and Forecasting of Socio-Economic Phenomena, Zakopane, September 2004, (Modelowanie efektu dźwigni w finansowych szeregach czasowych, Modelowanie i prognozowanie zjawisk społeczno-gospodarczych),
WP4	**Delta coefficient in AR-GARCH option pricing model** (in Polish), Conference Capital Market – Effective Investment, Międzyzdroje, September 2004, (Współczynnik delta w modelu wyceny opcji uwzględniającym efekt AR-GARCH, Konferencja Skuteczne inwestowanie)
WP5	**Modelling of Skewness and Excess Kurtosis in Stock Returns Using Conditional Pearson Type IV Distribution** (in Polish), 13th Conference on Classification and Data Analysis – SKAD 2004, Białowieża, September 2004, (Pomiar i modelowanie skośności rozkładów stop zwrotu - rozkład Pearsona typu IV, Konferencja Naukowa Sekcji Klasyfikacji i Analizy Danych (SKAD 2004))
WP6	**Arbitrage possibilities on Warsaw Stock Exchange using futures contracts** (in Polish), 3rd Chorzow Conference on Banking and Finance - Financing company activities, Chorzów, September 2005, (Możliwości arbitrażu na Giełdzie Papierów Wartościowych w Warszawie z wykorzystaniem kontraktów terminowych, III Chorzowska Konferencja Bankowości i Finansów - Finansowanie działalności przedsiębiorstw)

WP7	**Verification of put-call parity for options traded on WSE – Problems and examples of arbitrage strategies** (in Polish), Conference Mathematical, Econometric and Computer Methods in Finance and Insurance, Ustroń, November 2004, (Weryfikacja parytetu kupna/sprzedaży dla opcji notowanych na GPW w Warszawie - Problemy oraz przykłady strategii arbitrażowych, Konferencja Metody Matematyczne, Ekonometryczne i Informatyczne w Finansach i Ubezpieczeniach)
WP8	**Forecasting of Covariance and Correlation Matrces of Financial Time Series** (in Polish), Conference Preference Modelling and Risk ’05, Ustroń, April 2005, (Prognozowanie macierzy kowariancji i korelacji finansowych szeregów czasowych, Modelowanie Preferencji a Ryzyko)
WP9	**Application of Multivariate AR-GARCH Models in Value-at-Risk Measuring**, Conference Financial Investments and Insurance – World Tendencies and Polish Market, Szklarska Poręba, 2005, (Wykorzystanie wielorównaniowych modeli AR-GARCH w pomiarze ryzyka metodą VaR, Konferencja Inwestycje Finansowe i Ubezpieczenia – tendencje światowe a rynek polski), (**co-author Daniel Papla**)
WP10	**Modelling of conditional kurtosis and skewness in financial time series** (in Polish), 9th National Scientific Seminar Dynamic Econometric Models, Toruń, September 2009, (Modelowanie warunkowej kurtozy oraz skośności w finansowych szeregach czasowych, Seminarium Dynamiczne Modele Ekonometryczne)
WP11	**Example of Paraarbitrage Strategy with Index Participation Unit MiniWIG20** (in Polish), Conference Microeconometrics in theory and in practice, Międzyzdroje, September 2005, (Strategie arbitrażowe i paraarbitrażowe z wykorzystaniem jednostki indeksowej MiniWIG20, Konferencja Mikroekonometria w teorii i praktyce)
WP12	**Some practical Challenges in Multivariate GARCH Modelling** (in Polish), 14th Conference on Classification and Data Analysis – SKAD 2005, Podlesice/Kroczyce, September 2005, (Wyzwania praktyczne w modelowaniu wielowymiarowych procesów GARCH, Konferencja Naukowa Sekcji Klasyfikacji i Analizy Danych (SKAD 2005)
WP13	**Measuring and Testing of Skewnees for Financial Return Distributions** (in Polish), 15th Conference on Classification and Data Analysis – SKAD 2006, Wisła, September 2006, (Pomiar i testowanie skośności rozkładów stóp zwrotu instrumentów finansowych, Konferencja Naukowa Sekcji Klasyfikacji i Analizy Danych (SKAD 2006))
WP14	**Using the DCC-GARCH Model and the FGM Copula in Analysis of the Dependency between Returns of Stocks, World Stock Market Indexes and Exchange Rates. Empirical Example** (in Polish), Conference Financial Investments and Insurance – World Tendencies and Polish Market, Szklarska Poręba, September 2006, (Wykorzystanie modelu DCC-GARCH oraz funkcji powiązań FGM w analizie zależności między stopami zwrotu z akcji, indeksów giełd światowych oraz kursami walut, Inwestycje Finansowe i Ubezpieczenia - tendencje światowe a rynek polski), (**co-author Daniel Papla**)

WP15	**Power Analysis of VaR Backtests – Simulation Approach**, XLIIIth Conference of Statisticians, Econometricians and Mathematicians of Southern Poland Universities SEMPP 2007, Podlesice/Kroczyce, May 2007, (Analiza mocy wybranych testów pomiaru VaR - badania symulacyjne, Konferencja Statystyków, Ekonometryków i Matematyków Polski Południowej)
WP16	**Yield Curve Approximation Models for Polish Treasury Bonds** (in Polish), Conference Microeconometrics in theory and in practice, Świnoujście, September 2007, (Modele aproksymacji krzywej dochodowości polskich obligacji skarbowych, Konferencja Mikroekonometria w teorii i praktyce), (**co-author Katarzyna Kuziak**)
WP17	**Verification of the Black-Scholes and AR-GARCH Model for Options on WIG20 Index** (in Polish), 10th National Scientific Seminar – Dynamic Econometric Models, September 2007, (Weryfikacja modeli Blacka-Scholesa oraz AR-GARCH dla opcji na WIG20, Ogólnopolskie Seminarium Naukowe - Dynamiczne Modele Ekonometryczne)
WP18	**Investment strategy on the Polish Treasury bonds market using yield curve models** (in Polish), 2nd Conference Modelling and Forecasting of Socio-Economic Phenomena, Prof. A. Zeliaś Conference, Zakopane, April 2008, (Strategia inwestycyjna na rynku polskich obligacji skarbowych wykorzystująca modele krzywej dochodowości, konferencja Modelowanie i prognozowanie zjawisk społeczno-gospodarczych), (**co-author Katarzyna Kuziak**)
WP19	**Using Multivariate GARCH Models in Hedge Ratio Estimation for Futures on WIG20** (in Polish), 17th Conference on Classification and Data Analysis – SKAD 2008, Jastrzębia Góra, September 2008, (Zastosowanie wielowymiarowych modeli GARCH do szacowania współczynnika zabezpieczenia dla kontraktów futures na WIG20, Konferencja Naukowa Sekcji Klasyfikacji i Analizy Danych (SKAD 2006))
WP20	**Power Analysis of VaR Backtests based on Loss Functions – Simulation Approach** (in Polish), Conference Innovations in Finance and Insurance – Mathematical, Econometric and Computer methods, Ustroń, November 2008, (Analiza mocy testów pomiaru VaR wykorzystujących funkcje strat - badania symulacyjne, konferencja Innowacje w finansach i ubezpieczeniach – metody matematyczne, ekonometryczne i informatyczne)
WP21	**Survey and Comparison of Backtesting Procedures** (in Polish), Seminar in commemoration of the 10th Anniversary of the Institute of Financial Management, Wrocław, March 2009, (Przegląd i porównanie metod oceny jakości technik pomiaru wartości zagrożonej, Seminarium jubileuszowe z okazji X-lecia Instytutu Zarządzania Finansami)
WP22	**Servey and Comparison of Hedge Ratio Estimation Methods for Futures on WIG20 Index** (in Polish), Conference Modelling and Forecasting of the National Economy, Gdańsk-Jelitkowo, May 2010, (Przegląd i porównanie metod szacowania współczynnika zabezpieczenia kontraktów futures na indeks WIG20, Modelowanie i prognozowanie gospodarki narodowej)

WP23	**Analysis of power for some selected bactests of Value-at-Risk estimation methods – simulation approach** (in Polish), 7th International Conference Modelling and Forecasting of Socio-Economic Phenomena, Prof. A. Zeliaś Conference, Zakopane, May 2013, (Analiza mocy wybranych testów metod szacowania wartości zagrożonej – podejście symulacyjne, Konferencja Modelowanie i prognozowanie zjawisk społeczno-gospodarczych)
WP24	**Confidence Interval for AR-GARCH Value-at-Risk Models** (in Polish), 13th National Scientific Seminar – Dynamic Econometric Models, Toruń, September 2013, (Przedział ufności dla wartości zagrożonej w modelach AR-GARCH, Dynamiczne Modele Ekonometryczne)
WP25	**Interval estimation of VaR and ES using AR-GARCH Models** (in Polish), Conference Financial Investments and Insurance – World Tendencies and Polish Market, Karpacz, September 2013, (Przedziałowa estymacja VaR i ES w modelach klasy AR-GARCH, Konferencja Inwestycje finansowe i ubezpieczenia - tendencje światowe a rynek polski, INWEST 2013)
WP26	**Value-at-Risk and Expected Shortfall Confidence Estimation in AR-GARCH Models** (in Polish), 8th International Conference Modelling and Forecasting of Socio-Economic Phenomena, Prof. A. Zeliaś Conference, Zakopane, May 2014, (Przedziałowa estymacja Value-at-Risk i Expected Shortfall w modelach klasy AR-GARCH, Modelowanie i prognozowanie zjawisk społeczno-gospodarczych)
WP27	**Power analysis of some chosen tests of independence of Value-at-Risk violations** (in English), Conference Financial Investments and Insurance – World Tendencies and Polish Market, Wrocław, September 2014, (Konferencja Inwestycje Finansowe i Ubezpieczenia (INWEST 2014))

POST-DOCTORAL INTERNATIONAL CONFERENCE SPEECHES IN POLAND

WP18	**Investment strategy on the Polish Treasury bonds market using yield curve models** (in Polish), 2nd Conference Modelling and Forecasting of Socio-Economic Phenomena, Prof. A. Zeliaś Conference, Zakopane, April 2008, (Strategia inwestycyjna na rynku polskich obligacji skarbowych wykorzystująca modele krzywej dochodowości, konferencja Modelowanie i prognozowanie zjawisk społeczno-gospodarczych), (**co-author Katarzyna Kuziak**)
WP23	**Analysis of power for some selected bactests of Value-at-Risk estimation methods – simulation approach** (in Polish), 7th International Conference Modelling and Forecasting of Socio-Economic Phenomena, Prof. A. Zeliaś Conference, Zakopane, May 2013, (Analiza mocy wybranych testów metod szacowania wartości zagrożonej – podejście symulacyjne, Konferencja Modelowanie i prognozowanie zjawisk społeczno-gospodarczych)

WP26	**Value-at-Risk and Expected Shortfall Confidence Estimation in AR-GARCH Models** (in Polish), 8th International Conference Modelling and Forecasting of Socio-Economic Phenomena, Prof. A. Zeliaś Conference, Zakopane, May 2014, (Przedziałowa estymacja Value-at-Risk i Expected Shortfall w modelach klasy AR-GARCH, Modelowanie i prognozowanie zjawisk społeczno-gospodarczych)
WP27	**Power analysis of some chosen tests of independence of Value-at-Risk violations** (in English), Conference Financial Investments and Insurance – World Tendencies and Polish Market, Wrocław, September 2014, (Konferencja Inwestycje Finansowe i Ubezpieczenia (INWEST 2014))

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9	**Day Effect and its influence on option pricing** (in Polish), Finance, Banking and Insurance in Poland at the beginning of the XXI century, vol. 4, Financial Markets, Academy of Economics in Poznan, Poznań, 2000, pp. 135-147, (Efekt dni tygodnia i jego wpływ na wycenę opcji, Finanse, Banki i Ubezpieczenia w Polsce u progu XXI wieku, tom IV, Rynki Finansowe)	2
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11	**Modelling conditional variance of financial time series** (in Polish), Financial Investments and Insurance – World Tendencies and Polish Market, Jajuga K., Ronka-Chmielowiec W. (editors), Research Papers of Wroclaw Academy of Economics Nr 890, vol. 1., Wrocław, 2000, pp. 218-226, (Modelowanie finansowych szeregów czasowych z warunkową wariancją PN AE we Wrocławiu Nr 890, tom 1)	14
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14	**Heteroscedasticity of return time series and the concept of risk measurement with Value at Risk measure** (in Polish), Preference Modelling and Risk '01, Trzaskalik T. (ed.), Academy of Economics in Katowice, Katowice, 2002, pp. 339-350, (Heteroskedastyczność szeregu stóp zwrotu a koncepcja pomiaru ryzyka metodą VaR, Modelowanie Preferencji a Ryzyko '01)	8
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