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Dr. Katarzyna Bień-Barkowska

Econometrics Institute
Collegium of Economic Analysis
Warsaw School of Economics

Summary of Professional Accomplishments

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1. Concise information about education and employment

After having graduated from the Adam Mickiewicz Secondary School No. 1 in Bialystok in 1996, between 1996 and 2006 I studied in the Warsaw School of Economics (WSE) in two faculties: "Finance & Accounting" and "Quantitative Methods & Information Systems". On 5th April 2001 I graduated from the faculty of "Finance & Accounting". The supervisor of my master's dissertation entitled: "Application of the Value at Risk Methodology to Market Risk Assessment" was Prof. Zofia Zawadzka.

Between October 2001 and September 2005 I attended the doctoral study programme offered by the Collegium of Economic Analysis (CoEA), WSE. During my doctoral studies I also finished an one-semester postgraduate teaching qualifications course, organized by the WSE Teaching Center. Meanwhile, between 2001 and 2004 I was also part time employed in the Market Risk Department at the Headquarter of the Powszechny Bank Kredytowy SA (later: Bank Przemysłowo-Handlowy PBK SA) in Warsaw as an economic inspector, and subsequently, as a senior inspector.

I received the doctoral degree on 20th June 2006, after having defended the dissertation entitled "Selected Econometric Ultra-High-Frequency Financial Data Models", written under the supervision of Prof. Krzysztof Jajuga.

In September 2005 I was employed at the Chair of Economics and Econometrics in the Center of Finance and Econometrics of the University of Konstanz[1] in Germany. I worked there on the research project entitled "Microstructure of Financial Markets in Europe" under the supervision of Prof. Winfried Pohlmeier until February 2007.

After returning to Poland, from April 2007 to November 2014 I was part time employed at the Division of the Financial System Development in the Financial System Department of the National Bank of Poland, as a specialist, and consequently, as a chief specialist and as an economic expert. My duties covered, *inter alia*, conducting research on selected aspects of FX market and stock market functioning.

In October 2007 I was employed as an assistant professor at the Division of Applied Econometrics in the Econometrics Institute of the WSE, where I work to date.

2. Research conducted before the doctoral degree

I began to perform econometrics-oriented research on the market microstructure 15 years ago after undertaking the doctoral study programme in the CoEA WSE. Market microstructure

[1] In 2016, the University of Konstanz was in 7th position in the "150 under 50" ranking, according to the *World University Rankings* of the *Times Higher Education* (https://www.timeshighereducation.com).

should be perceived as a branch of finance[2], whereas the high-frequency data and the ultra-high-frequency (UHF) data constitute the best material for the empirical market microstructure research. UHF data comprise chronological sequences of selected variables that describe the trading process (quoted prices or trade prices, order sizes, trading volumes, bid-ask spread) with the corresponding observation times (usually registered with a precision equal to one hundredth of a second). Observations in the UHF data are irregularly spaced in time. This data is also characterized by many specific statistical properties that require advanced quantitative methods arising from the micro-econometrics or the survival analysis. During my doctoral studies in the CoEA WSE I focused mainly on the stock market microstructure as well as on some modern financial econometric tools that allow for the empirical verification of selected hypotheses resulting from the mathematical, theoretical models of market microstructure.

In my doctoral dissertation I discussed several UHF data modeling methods which were at that time unknown in the Polish research literature. More specifically, I focused on the importance of the concept of time as well as on the discreteness of price changes in the trading process. The main issues touched upon in the dissertation covered numerous extensions of the *autoregressive conditional duration* (ACD) models (cf. Engle and Russell 1998, Pacurar 2008) as well as the dynamic models of discrete variables, such as *autoregressive conditional multinomial* (ACM) models (cf. Russell 2005) and *generalized linear ARMA* (GLARMA) models (cf. Shephard 1995). The empirical results allowed to draw conclusions about the dynamics of the trading process in the Warsaw Stock Exchange. For example, I discussed the time-of-day and the time-of-week seasonality patterns and identified variables that exerted an impact on the trading activity as well as affected the direction of price movements and the dispersion of discrete price change values. My first applications of the ACD models to the Polish stock market were reported in studies [F.1] and [G.3] (see Attachment no. 3 with the list of publications), whereas selected parts of my dissertation were published in [G.1] and [G.2].

After having submitted my Ph.D. dissertation in the CoEA WSE in 2005, but before having received my Ph.D. degree, I began the scientific cooperation with prof. Winfried Pohlmeier and dr. Ingmar Nolte from the Chair of Economics and Econometrics of the University of Konstanz. I treat this cooperation as a separate stage in my academic career. Our research was mainly focused on modelling financial markets using the probabilistic concept of copula function. The topic of our first paper was the dynamics of the instantaneous market liquidity measures, and more specifically, the depiction of the conditional density function for the quote slope (QS) coefficient of the order book (see item [H.1]). For example, we documented a multimodal shape of the QS density function before the NYSE decimalization on 29 January 2001, which stayed

[2] According to the classical definition of Maureen O'Hara, the market microstructure is the study of the process of exchanging assets, whereas the microstructure literature analyses how trading mechanism impacts the price formation (see O'Hara 1995, p. 5). A more up-to-date and comprehensive definition of the market microstructure was suggested by the National Bureau of Economic Research (NBER): "theoretical, empirical, and experimental research on the economics of securities markets, including: the role of information in the price discovery process; the definition, measurement, control, and determinants of liquidity and transactions costs; and their implications for the efficiency, welfare, and regulation of alternative trading mechanisms and market structures" (see. http://www.nber.org/working groups/mm/mm.html).

in line with the existence of several different states of liquidity supply in this market. After the decimalization, the overall liquidity of the market increased, and the multimodal shape of the QS density function flattened. Although this study was published only as an *University of Konstanz Working Paper*, it was presented in many renown conferences, such as for example *European Meeting of the Econometric Society* (ESEM) in Vienna, in August 2006.

3. Research conducted after the doctoral degree

My research output after a doctoral degree can be classified into three main strands of research:

(1) Methodological area – where I propose new econometric models or new extensions of existing models for high-frequency or ultra-high-frequency data.

(2) Empirical market microstructure area – encompassing research on market mechanisms and properties of financial variables measured at a very high frequency,

(3) Gerontological area – encompassing survival analysis as well as studies on mobility and well-being of older adults based on the comprehensive geriatric assessment using selected econometric tools.

While the research area (3) relates to the entirely different issues then the two first areas do. The boundary between the area (1) and (2) is blurred, and in my research I tried to enrich all suggestions of econometric models or of their extensions with the necessary empirical examples as well as with the adequate economic interpretation. Thus, I distinguish these two strands of research only due to my own subjective assessment of their value-added in the methodological field – see (1), or in the empirical field – see (2).

3.1. Research in the methodological area

3.1.1. Multi-dimensional models for discrete price changes

Methodological strand of my research encompasses works [B.1] and [C.7] in co-authorship with Dr. Ingmar Nolte and Prof. Winfried Pohlmeier. The common topic of these studies is a proper parameterization of the joint conditional density function for discrete price changes observed during very short time intervals.

In [B.1] we propose a new multidimensional econometric model for integer-valued variables, i.e. so called Multivariate Integer Count Hurdle (MICH) model. In this model, conditional densities of the dependent variables are described using the dynamic *Integer Count Hurdle* (ICH) of Liesenfeld *et al.* (2006)[3], whereas the concurrent dependence between these integer-valued variables is captured with the copula function. Joint distribution function is obtained

[3] In the MICH model, the joint density function of discrete-valued variables is decomposed into: (1) the distribution of the auxiliary variable *k* taking on possible values: -1, 0, 1; denoting correspondingly negative, zero and positive values taken by the initial variable; (2) the distribution of the auxiliary positive integer-valued variable *l*, denoting the absolute values taken by the initial variable (given that these values were different from zero). Conditional distributions of variables *k* and *l* in the ICH model have their own dynamics.

with the finite difference approximation of the derivatives of copula function (see Meester and MacKay 1994, Cameron *et al*. 2004). The MICH model that we proposed is very general and allows for describing the multidimensional processes characterized by a very complex dynamics. An application of the ICH models to the marginal distributions of the dependent variables allows for inflating the probability mass for their zero values. The autoregressive specification of the model allows for reflecting the strong positive or negative autocorrelation and cross-correlation in variables. Moreover, different types of copula functions allow to depict different dependence patterns between variables. The empirical results presented in [B.1] show that the model satisfactorily describes the bivariate process of the discrete EUR/USD and EUR/GBP price changes observed during very short time intervals. The MICH model also allows to capture the volatility clustering effects, i.e. the specific clusters of absolute price changes that are relatively large in size. The model may also be used to describe dynamic linkages between these two currency pairs observed during very short time intervals.

Joint modeling of correlated integer-valued variables is also the topic of our second study [C.7]. The major aim of this article is to propose a new econometric model called *Inflated Multivariate Count Hurdle Model* (IMICH) as a special extension of the MICH model. A proposed parameterization of the joint discrete distribution allows for inflation of the probability mass for: (1) some special dependent variables' values as well as (2) some special combinations of dependent variables' values. Our intention was to propose an econometric model that most closely imitates the complex dynamics of discrete ask and bid price changes and of the bid-ask spread over very short time intervals. Because both price changes and the bid-ask spread are often equal to some multiples of 5 ticks (pips), in the MICH model we used some suitably-tailored mixtures of statistic distributions. As far as the methodological strand of my research is concerned, another value-added of the paper lies in the application of an error-correction mechanism in the equations that describe discrete price changes, which allows to maintain the cointegration relationship between ask and bid prices, as well as the stationarity of the bid-ask spread. Additionally, in the paper we propose a method for assessing the model goodness of fit with the probability integral transforms and suggest a simulation method for obtaining the joint density of bid and ask price changes with the Metropolis-Hastings algorithm. The results of the empirical analysis performed with the TAQ (*Trade and Quotes)* data from the New York Stock Exchange (NYSE) allow to conclude that the IMICH model captures the most important statistical properties of the high-frequency price changes.

The subject matter focused on econometric modelling of integer-valued variables was also continued in study [D.4]. I propose there a parameterization of the joint conditional (on a given information set) distribution for a positive continuous variable and a dichotomous variable. I suggest to capture the contemporaneous dependencies between both these variables with an appropriate copula function. This model can be treated as an extension of a bivariate probit model proposed by Winkelmann (2012), where a copula function is responsible for the linkages between two latent continuous variables, that underlie the observed binary variables. In the study [D.4] the marginal distributions of the dependent variables are time-varying. I recommend using the ACD model with the Burr distribution for a continuous variable, and the GLARMA model for a dichotomous one. Both these econometric specifications allow for description of very persistent processes. Due to this special property, the bivariate model for a continuous and a binary variable is very general and can be applied to high-frequency and ultra-high-frequency

data. Many such variables measuring for example sizes of limit orders, trading volumes, market depth, bid-ask spread, trade and price durations, are strictly positive and characterized by a strong positive temporal correlation. On the other hand, the binary variable might serve as an indicator of a given event, for example such as: price increase (against a price decrease), market order submission (against a limit order submission), submission of a visible order (against a hidden order), etc. Additional methodological value-added in this paper is the suggestion of a new method for assessing the model goodness-of-fit with the probability integral transforms. It is worth to note that such a validation method allows not only to assess the adequacy of the parametric specifications for marginal distributions, but also to assess a fit of a conditional distribution of a continuous variable given its lagged values and given a contemporaneous value of a binary variable. Such a verification procedure allows to compare competing models with different copula functions.

3.1.2. Extensions of the sequential trade models

In my post-doctoral research I paid a lot of attention to econometric models that allow to estimate the probability of informed trading (PIN), i.e. the probability of an information advantage over other market participants. This specific class of econometric market microstructure models, also called the sequential trade models, is an econometric response to the theoretical information models, i.e. the models according to which market participants gain new information and learn by observing the behavior of others[4]. Under such a framework, observed quantities or sequences of buy or sell trades may clearly indicate market expectations about the future value of a financial instrument. First model of this kind was proposed by Easley, Kiefer, O'Hara and Paperman in 1996, and hence, in the literature it is known as the EKOP model (an acronym from the first letters of its authors' surnames). It describes the bivariate process for the quantities of buy and sell trades using a mixture of three bivariate Poisson distributions (cf. Easley *et al*. 1996). As proposed in Wünsche (2007), in the study [D.6] I use the EKOP model with a mixture of three two-dimensional NegBin distributions. Such an extension allows for a larger degree of dispersion in the buy and sell distribution than it is implied by the Poisson distribution. Based on the estimation results for the interbank FX spot market I identify periods when the good news arrives to the market and the periods when the bad news arrives. Subsequently, I interpret linkages between probability estimates of bad/good news arrival and the EUR/PLN exchange rate.

In the paper [E.1] I propose an extension of the dynamic EKOP model of Easley *et al*. (2008). In the original dynamic EKOP model, some parameter functions are described with the VARMA model, which allows for the time-variance of the PIN measure that is affected by the observed buy-sell imbalance. The methodological contribution of study [E.1] lies in the adaptation of the EKOP model to intraday data while taking account for the diurnality patterns. In the article I use the Fourier Flexible Form to depict conditional expectations of trade quantities executed by informed and uninformed traders. This modification allows for the intraday fluctuation of the PIN measure. The model estimates obtained with the data from the

[4] In this context, very important is the proper distinction between buy trades and sell trades. In the buy (sell) trade, the initiator is a buyer (seller) of a financial instrument. In the limit order markets such a trade is executed as a match between a market buy (sell) order against a limit sell (buy) order prevailing in the order book.

interbank spot market for the Polish zloty allow me to conclude that between 8:00 a.m. and 6:00 p.m. CET the highest fraction of informed trades is executed in the morning, about the noon, and late in the afternoon. I also show that the impact of the buy-sell imbalance on the FX rate depends on the share of informed trading, i.e. it is relatively higher in periods when there is a higher share of informed traders in the market.

3.1.3. Extensions of Asymmetric ACD models

In the next series of my research projects I focus on possible theoretical extensions of the asymmetric ACD (AACD) models of Bauwens and Giot (2003). Due to their bivariate setup and the very complex dynamics, the AACD models were rarely used in empirical analyses based on the UHF data, and hence, have not been modified yet. The construction of the AACD models is based on the dynamic extensions of competing risks models that are used in survival analysis. They describe the two-dimensional density function for the variables x_i and y_i, where x_i denotes an interval between consecutive event times (i.e. waiting time, duration) and y_i is a dichotomous variable, i.e. an indicator of the event type observed at the end of a duration x_i. In the original version of an ACD model, the innovation components of observed durations are exponentially distributed or Weibull distributed random variables. Such model specification is also usually used in empirical studies (cf. Lo and Sapp 2008; Tay *et al*. 2009; Zhang *et al*. 2009). In the study [D.8] I propose a new extension of this model which is based on the Burr distribution or on the generalized gamma distribution for error terms. On the other hand, in the article [C.2] I propose the ACD model where the random components of observed durations follow the generalized beta distribution of the second kind (GB2). The choice of GB2 distribution allows for obtaining non-monotonic hazard functions characterized by very different shapes, which corresponds to the real-world properties of duration variables. Moreover, the GB2 distribution encompasses statistical distributions that are commonly used for modeling financial durations (i.e. exponential distribution, Weibull distribution, Burr distribution) as its special cases. The ACD model extensions that I suggest in [D.8] and [C.2] – according to my knowledge for the first time in the literature worldwide – allow to precisely depict clustering and dispersal effects for interrelated arrival times of two events. In the article [C.2] I show that the ACD models with the GB2 distribution allow for much better goodness-of-fit then the standard ACD model with the Weibull distribution.

In the studies [C.4] and [C.6] I propose – according to my knowledge – the first in the literature extension of AACD models to the multidimensional point process, introducing the so called *Multistate Asymmetric ACD models* (MAACD). The MAACD models can be treated as a generalization of AACD models to the case, where the number of possible values of y_i , and hence, the types (categories) of events observed at the end of duration x_i is more than two. The model has a multiequation structure and its individual equations describe the conditional (on a given information set) expectations of waiting times to selected events. The model is very general and may be used to infer about the dynamics of very complex systems comprised of random event times that can be classified to different categories. In the article [C.6] I describe the general theoretical construction of this model and derive its likelihood function. I also propose an algorithm for simulating the trajectory of durations and the corresponding event categories. The MAACD model with 10 equations is used to thoroughly describe the dynamics

of order submissions and cancellations in the order-driven interbank spot market of the Polish zloty (*Reuters Dealing 3000 Spot Matching System*). The estimation and simulation results are used to formulate conclusions about micro-mechanisms of the trading system as well as to empirically verify seven hypotheses arising from the theoretical mathematical models of market microstructure.

In the paper [C.4] I propose another modification of the MAACD model which is based on the non-linear transformation of the duration expectations. Moreover, I derive definitions of model residuals corresponding to x_i and y_i and show how model estimates can be used to derive the time-varying (conditional on a given information set) probabilities of observing individual event categories in given times. This theoretical discourse might lead to numerous empirical applications of the MAACD model. It can be used as a tool that not only predicts the waiting time to the upcoming event (in the market microstructure – for example to the next trade, price change, order), but also predicts the upcoming event type (in the market microstructure these events can for example discriminate between buy or sell trades, hidden or visible orders, etc.). It should be emphasized, that the theoretical and application-related issues about the ACD models which I describe in English in publications [C.2], [C.4] and [C.6] (in the 'A' list of the MNiSW), and hence, allow them to be evaluated by international researchers, are more widely discussed in the monograph [A.1].

3.1.4. Combining VaR forecasts

In the short article [D.3] I propose a new way of combining VaR (Value at Risk) forecasts. Under this framework I treat VaR estimates that stem from competing conditional volatility models as the potential explanatory variables for the conditional quantile of a return distribution (under given significance level). The VaR which is obtained from the quantile regression is a linear combination of different VaR forecasts, whereas their corresponding weights are equal to the parameter estimates. I recommend using a boosting learning algorithm to determine the optimal combination of individual forecasts. Because this new method of combining forecasts seems promising and the quality of obtained VaR forecasts for S&P500 returns turned out to be considerably improved (in comparison to the quality of VaR forecasts obtained with the standard volatility models), I intend to continue working on this topic in future.

3.2. Empirical studies of the market microstructure

3.2.1. Order flow analysis

In the article [D.9][5] I discuss for the first time in the Polish research literature the issues of modelling the exchange rate under the market microstructure framework. The main subject of this study is the concept of order flow being a fundamental measure of an unequal access to new information in the market (cf. Evans and Lyons 2002a, 2002b). The order flow, usually

[5] The article [D.9] was awarded in the Contest of the President of the National Bank of Poland for the best article published in the journal „Bank i Kredyt" in 2010.

defined as a difference between the amount (or value) of trades initiated by the demand side of the market (buy trades) and the amount (or value) of trades initiated by the supply side of the market (sell trades), might have a high informational content in the context of future FX rate changes, because it aggregates individual information signals and reflects a scale of a difference in expectations of market participants[6].

In this study I document a statistically significant positive impact of the order flow, defined as a quantity of M. EUR (in the interbank *Reuters Dealing 3000 Spot Matching System*), on the changes of the EUR/PLN foreign exchange rate for different frequencies of data aggregation in the second half of 2004 and in 2007. This result stays in line with the findings presented in the literature for other currency pairs. In the article I also show that the scale if this impact varies in time. The reaction of the EUR/PLN FX rate to the net buy of euro was different in 2004 and 2007, which can be explained by a different size of the market in these two periods. Based on the extended version of the GARCH model that I enriched with the Fast Fourier Form components, I show that a scale of an order flow impact on the exchange rate of the Polish zloty varies in parallel with the instantaneous liquidity of the market approximated by a time-of-day variable and a size of the bid-ask spread. Another important contribution of my study lies in the complex analysis of the order flow dynamics. Due to the specific statistical properties of this variable, mostly its discreteness, the considerable concentration of the probability mass at zero and autocorrelation, for its depiction I use the dynamic *Integer Count Hurdle* of Liesenfeld *et al.* (2006). The obtained estimation results allow me to conclude about trend chasing strategies in foreign exchange markets and factors that increase an imbalance between buy and sell trades.

My research on the dependencies between order flow and exchange rate changes was continued in the article [D.7]. In this paper I describe a reaction of the Polish zloty exchange rate to macroeconomic announcements about economic situation in Poland in 2007. In the study I use a bivariate VAR model for the FX returns and the order flow variable aggregated on 2-minute intervals. I show that an immense part of the information surprise is impounded in the new exchange rate within a couple of minutes after a macroeconomic announcement. The indirect transmission channel defined as an imbalance between buy and sell trades is responsible for about 50% of the exchange rate reaction to new information. The residual share of adjustments results from the quotations of the EUR/PLN exchange rate with the incoming limit orders.

3.2.2. Order choice

In my research after receiving a doctoral degree I paid a lot of attention to the identification of factors that impact the order choice. These issues of the market microstructure are very important because the aggregated tiny actions of individual traders, such as when (in which moment?) and which order (what kind of an order?) to submit (or to cancel) in the macro scale determinate both the price level and the core properties of the order-driven market, i.e. its efficiency and liquidity. In the aforementioned article [C.6] by using the MAACD estimates I discuss the factors that impact preferences of the interbank dealers towards market orders (i.e. orders leading to an immediate trade execution) and limit orders (orders that do not lead to an

[6] The subject matter that covers the concept of order flow, definition of information and its role in the FX market, is further developed in the monograph [A.1].

immediate trade execution but increase the depth of the market) submitted on different levels of the order book and on different sides of the market. The results of my study complement the findings documented in the world-wide literature about both exchange rate markets and stock markets (cf. Lo and Sapp 2010, Danielsson and Payne 2012, Malo and Pennanen 2012).

The topic of the study [D.2][7] is the identification of factors that approximate instantaneous liquidity of the market or signal new information arrival, and hence, impact dealers' decisions about submissions of undisclosed (reserve) orders in the *Reuters Dealing 3000 Spot Matching System.* As far as I know, this is the first study about using reserve orders in the FX spot market. Because factors that exert an influence on order submission decisions can be different for orders submitted on each side of the market and at different distance from the mid-price (because of predatory trading strategies), in the study I present the estimation results for different probit models explaining the presence of reserve orders at different levels of the order book. The results of this study are very extensive and detailed. For example I show that the propensity to hide a limit order depends on its entire size. Dealers tend to hide large orders as they avoid the potential disclosure of their expectations and of their trading strategies. The visible small orders usually constitute only the peaks of large orders (iceberg orders), whose major parts are undisclosed. I show that the probability of hiding the entire size of an order increases with the competitiveness of this order (i.e. the decreasing distance from the best orders submitted on the other side of the order book). It also depends on the time of a day, some liquidity measures (i.e. bid-ask spread, an aggregated size of all limit orders in the order book), preceding order categories, an observed direction of exchange rate changes and their volatility. However, the exact impact of these variables is different for orders submitted on different levels of the order book.

3.2.3. Market liquidity analysis

The core issue in the empirical market microstructure lies in measuring and forecasting liquidity. The article [D.1] fits into this strand of research. Its main topic is the description of eight different instantaneous liquidity measures of the interbank EUR/PLN spot market, i.e. bid-ask spread, ask and bid depth, trade impact, and some other coefficients describing the order book structure. I propose the so called 'liquidity area' as a function of buy (sell) order sizes corresponding to orders submitted at five most competitive levels of the order book. In order to account for the long memory feature of the variables under study, I recommend using the fractionally integrated ACD models. In the article I discuss the diurnal patterns for liquidity measures and identify the factors contributing to changes in different dimensions of liquidity. The obtained results show, *inter alia*, that the bid-ask spread widens and the market depth decreases in volatile periods. The higher the trading volume, the smaller the price impact of individual trades. In parallel with the increase in the quantity of market orders there is also an upsurge in the liquidity supply with limit orders. The article [D.1] also shows that the order book structure has an informational value in the context of the quasi-technical analysis, because it reflects some market expectations about the awaited FX rate direction, i.e. in periods of Polish

[7] The article [D.2] was awarded II Prize in the Contest of the President of the National Bank of Poland for the best article published in the journal „Bank i Kredyt" in 2014.

zloty depreciation the market depth, and hence, the amount of limit orders to sell euro (to buy the Polish zloty) decreases.

In the study [D.5] I discuss an impact of trading volume registered in the interbank FX spot market on the different conditional quantiles of a return distribution (for the EUR/PLN FX rate). By using non-linear quantile regression models I conclude about diurnality patterns for the conditional distribution of FX returns, as well as about a non-uniform impact exerted by the expected trading volume (i.e. based on observations from the past) and unexpected trading volume (i.e. that cannot be predicted from the history of the process) on the individual quantiles of a return distribution. Our results indicate that the unexpected trading volume has a significantly higher impact on the size of FX rate changes. The impact of the trading volume is the strongest for the lowest and for the highest quantiles that correspond to extreme observations of returns. This conclusion is of an ultimate importance for modeling market risk, because it indicates the necessity of enriching the models that describe large price changes by a trading volume as an additional explanatory variable.

3.3. Gerontological research

In 2013 I was invited to cooperate with the Department of Geriatrics in the Medical University in Białystok (MUB) in the field of gerontology.

First I was involved in the MUB statutory project No. 133-01615P, where I was responsible for construction, estimation, verification and interpretation of an econometric model of the geriatric patients' survival. In this retrospective study in older adults, among many potential predictors of mortality I included demographic and clinical variables, as well as the biochemical, disease and functional status measurements. The estimation of the conditional (on a given information set) life expectancy which resulted from the Cox proportional hazard model required using the multiple imputation method to fill in the missing values of explanatory variables. The study resulted in publication of an article [C.5], where I am the second author, responsible not only for an application of the suitably-tailored quantitative methods but also for a graphical analysis of obtained estimates of the survival function, their adequate interpretation, and to some extent, discussion. The results of this study show for example that the old age, lower functional status and multimorbidity are not the only factors that predict the shorter life expectancy. A slight obesity, higher cholesterol and the higher blood hemoglobin level exert a beneficial impact on the predicted survival. These findings confirm with the current standpoint in the literature about the metabolism paradox, according to which the lower mortality is explained by the appropriate resources in the oldest, frail and multimorbid population of older adults.

The second research project conducted in cooperation between the Institute of Econometrics WSE represented by me and the Department of Geriatrics, MUB, was the statutory project No. 153-01621P on factors that impact the subjective well-being of geriatric patients. Based on the ordinal multinomial logistic models for selected subjective well-being indicators I identify and interpret the objective factors i.e. demographic variables, variables describing financial situation, health-related variables or variables indicating high-stress situations, which exert an impact on three different dimensions of subjective well-being: feeling of loneliness, self-evaluated health and severity of depression symptoms. The article [C.3] that summarizes these analyses allows to conclude that the subjective health depends not only on the objective health

and the education level, but also on the actual mobility function assessed with the Timed Up & Go test, which is a novel finding in the literature.

The third gerontological project conducted in cooperation with the MUB No. N/ST/ZB/16/002/3301 is about the factors that impact the burden suffered by informal carers (mostly a child or a spouse) of older adults according to the COPE subscale measuring the negative impact of care. In article [C.1], based on the results from a logistic model supported by a cross-validation method, I show that the burden faced by caregivers of old and comorbid seniors results from the self-evaluation of their health status, the support from family, friends and institutions and the subjective feeling of coping well with challenges. Among many patient-related variables the only significant factor that increases the carer's burden is a decreased mobility function of the care-for person. My role as a first author of this publication reflects the fact, that I was not only responsible for conducting econometric analyses, but also for the concept of this study, writing and editing of the manuscript and acting as its corresponding author.

The gerontological strand of my research proves that there is a large demand for the interdisciplinary cooperation between statisticians or econometricians and geriatricians or gerontologists, especially currently, when the world population ages. The heterogeneity of this oldest segment of population requires using more and more sophisticated research methods in order to describe the complex dependencies between the variables resulting from natural aging and the factors that can modify this process.

4. Discussion of the scientific achievement for evaluation

As the scientific achievement referred to in the art. 16 para. 2 of the Law of 14th March 2003 on academic degrees and academic title I submit my monograph entitled "Mikrostruktura rynku. Ekonometryczne modelowanie dynamiki procesu transakcyjnego" [ang. Market Microstructure. Econometric Modeling of the Trading Process Dynamics"] (publication date: 2016, publisher: Oficyna Wydawnicza SGH, reviewer: Prof. Małgorzata Doman).

The subject matter of this monograph is the market microstructure, particularly with attention to the interbank foreign exchange spot market. The main topic of the book is a comprehensive discussion of the trading mechanisms that in the micro scale lead to price, volatility or liquidity formation. The core issue under discussion in the book is dynamics, understood in a very wide meaning, i.e. for example as a time-varying arrival (or cancellation) rate of different orders or a time-varying trade or price change intensity. The main issues touched upon in the monograph are the analytical tools of the market microstructure, in terms of both their theoretical construction and empirical applications. These tools are for example the multidimensional econometric models for order arrival rates or novel methods of estimating instantaneous and daily volatility based on the series of price durations.

Market microstructure issues are discussed in the strictly econometric context, which was reflected in the subject choices and in balancing the individual thematic blocks. Substantial part of the monograph relates *strictly* to the tools used in empirical market microstructure, thus is analytic (formal) in nature. The methods are the specialized tools for the ultra-high-frequency data analysis that allow for modelling the rate of micro-events' arrival: submissions (or cancellations) of orders, trade executions, changes in trading volume. Because times in which

such micro-events are observed are random and irregularly spaced, I describe their joint dynamics with the one-dimensional or multi-dimensional models of point processes. In my opinion, a special value-added of my book lies in the discussion of the original MAACD models and of the new methods for assessing the goodness-of-fit of econometric models tailored for point processes. Additionally, in the monograph I present models that are already known in the world-wide research literature, i.e. the Hawkes models or the Autoregressive Conditional Intensity (ACI) models, and – sometimes – also already known in the Polish research literature, as for example the ACD models. I would like to underline that apart from the ACD models, all methods discussed in the book were not used in the Polish scientific studies.

Apart from a wide literature review or methodological issues I enrich the monograph with my own empirical studies of the interbank foreign exchange spot market (based on the data for the EUR/PLN currency pair obtained from the *Reuters Dealing 3000 Spot Matching*). All the empirical studies presented in the book are original and have not been published before. They touch upon many issues concerning the FX market, i.e. a time-varying impact of the order flow on the FX rate changes, clustering of different micro-events in time, i.e. trades, orders, volume changes, price changes; temporal dependencies between different micro-events. I also confront the results of my empirical studies with the findings that can be deducted from purely theoretical, mathematical market microstructure models proposed in the literature. I also verify eleven hypotheses about systematic sequencing patterns concerning the types of upcoming orders or factors that impact the order choice. Because the detailed aims of the book as well as the empirical results and their scientific contribution are vast and diversified, I discuss them in line with the individual chapters below.

In Chapter 1, entitled "Mikrostruktura rynków kierowanych zleceniami – podstawowe wiadomości" [ang. Microstructure of order-driven markets – the main issues], I discuss the main issues of the market microstructure. Based upon a thorough literature survey, due to the direction of research undertaken in the sequel of the book, in the Chapter 1 I discuss the properties and the dynamics of selected order categories as well as the pitfalls and opportunities associated with the order choice. I also review different theoretical mathematical models that describe the process of order submission as a multitemporal strategic game between market participants. I introduce eleven hypotheses resulting from such models that are empirically verified later in the book. Moreover, I also shed some light on the current hot topics of market microstructure, for example on the concept of dark liquidity, i.e. submitting buy or sell orders whose whole sizes are invisible to other traders; as well as the more and more popular high-frequency trading strategies, in which orders are initiated by computer algorithms within a fraction of a second after a news release.

The issues on market functioning presented in Chapter 1 from the micro perspective and with the special emphasis put on the order choice are novel in the Polish research literature. In my opinion, the main value-added of this chapter lies in the discourse about linkages between the inflow or the executions of individual orders and the time-variation of different liquidity dimensions as well as the observed price changes. In this context I list the variables that describe the instantaneous 'state' of the market as for example its liquidity (i.e. bid-ask spread, market depth, order book structure) or the observed direction of price changes and their volatility, and hence, exert an influence on the individual decisions about the order choice. A wide literature survey allows me to conclude that the choice of both a type of an order and a time of its

submission/cancellation is a very complicated decision problem which depends on observed and awaited actions of other traders in the market.

The subject matter discussed in Chapter 1 is important because it mainly relates to the order-driven markets that become more and more popular mostly thanks to the facilities provided by the electronic trading systems. Shedding light on the essence of the discussed mechanisms is of an utmost importance not only from the viewpoint of academia that is interested *per se* in the basic research in the economy, and hence, in the nature of the observed mechanisms. This can also have a cognitive and practical meaning for the market regulator, i.e. the institutions that are responsible for the stability of financial markets.

The subject matter of Chapter 2, entitled "Mikrostruktura rynku FX" [ang. The microstructure of FX market] is a discussion of the spot FX market, particularly with attention to the electronic trading systems that automatically match incoming buy and sell orders (based on the *Reuters Dealing 3000 Spot Matching* System). The core issue elaborated in this part of a monograph is the definition of information and the possible spectrum of different information signals for FX trading. At the same time, I emphasize the fact that unlike in stock markets, in the FX markets the sources of new information are much more heterogeneous. These can be for example macroeconomic announcements, instantaneous level of liquidity, market trends and exchange rate volatility and also – in the case of the interbank market – customer demand for foreign currency.

As main value added of Chapter 2 I perceive the discourse about the role of information in the price discovery process. I indicate that the aggregated knowledge of market participants and a sum of their preferences and expectations being the result of all information signals are reflected in the observed order flow, i.e. a disproportion between the quantities (or values) of buy and sell trades. I also try to present a relation between an order flow and an exchange rate as a voting mechanism for the appreciation (positive order flow) or depreciation (negative order flow) of the base currency. Thus, order flow can be treated as a transmission channel, according to which different pieces of information dispersed among market participants are systematically impounded into the exchange rate level. On the top of the thorough discussion about the exchange rate formation from the micro perspective, in Chapter 2 I elaborate on some diurnality patterns for selected variables that describe FX market functioning, which I perform on the grounds of both my own empirical analysis as well as a rather scarce number of world-wide studies. My contribution lies in proposing a way of measuring the strength of dependence between order flow and EUR/PLN exchange rate in years 2007-2009 with the time-varying parameter GARCH model (TVP-GARCH). In such a model, the dynamic linkages between variables can be described in a state space, which allows estimating the intentionally unstable (time-varying) parameter that describes an order flow impact on the exchange rate. The estimation results reported in Chapter 2 question the stability of a linear relationship between variables, which can be explained by strong and abrupt depreciation of the Polish zloty between August 2008 and February 2009. I show that in the period of Polish zloty's appreciation between January 2007 and July 2008, the impact of order flow on the EUR/PLN exchange rate was at least a dozen or so pips (one pip corresponds to one hundredth of a Polish grosz) lower than in the period of Polish zloty's depreciation.

The aim of Chapter 3, entitled „ Proces transakcyjny jako wielowymiarowy proces punktowy" [ang. Trading process as the multi-dimensional point process] is a discussion on the

fundamental concepts and quantitative notions that are used in the market microstructure as well as on the specific statistical properties of the ultra-high-frequency data. In this chapter I define the probabilistic and statistic notions as for example a one-dimensional and a multi-dimensional point process or an intensity function. At the same time I emphasize such properties of the UHF data that strictly relate to the time factor and that result in the observed micro-dynamics of the financial market.

The contribution of Chapter 3 lies in broadening the knowledge about sequencing and clustering effects for different micro-events (i.e. orders, trades, price changes, increases in the cumulative trading volume) while taking into account the seasonality components. A special attention should be paid to a uniquely detailed (also when comparing to the international studies) empirical description of the complex dynamics of buy/sell orders submissions and cancellations by currency dealers. In order to describe the joint dynamics of this process I distinguished as many as 10 categories of possible micro-events. These are, *inter alia,* orders which result in immediate trade executions (i.e. market orders and marketable 'aggressive' limit orders) and limit orders classified to different categories according to the distance of their price from the mid-price, i.e. according to the level of the order book, on which they were submitted. The results of the statistical analysis presented in Chapter 3 show that a 'scenario' according to which the individual micro-events, being the traces of traders' activity, follow each other is very complex, nevertheless the patterns are to a large extent regular. In this chapter I document that some events gravitate to each other in time, and hence, occur in 'waves' or in clusters. Moreover, what is very important for the econometric MAACD models, the categories of upcoming events depend to a huge extend on the types of preceding events. My contribution is the documentation, *inter alia*, of (1) long series of market buy orders (and, analogously, sell orders) and infrequent incidents of buy (sell) orders observed immediately after sell (buy) orders; (2) inflow of limit buy (sell) orders between the best ask and bid quotes immediately after a liquidity absorbing sell (buy) trade is observed; (3) inflow of market buy (sell) orders immediately after limit sell (buy) orders were submitted between the best ask and bid quotes; (4) submitting and immediate cancelling of limit buy (sell) orders to build up a liquidity illusion. To my knowledge, these results belong to the pioneer and infrequent findings about the trading process in the foreign exchange market.

In Chapter 4, entitled "Podstawowe koncepcje modeli intensywności" [ang. The basic concepts of intensity models] I discuss definitions and probabilistic theorems that allow for construction of intensity models, their estimation and the statistical inference. By using the random time change theorem I propose a new verification procedure for a one-dimensional or a multidimensional intensity model, which is based on the visual inspection of the histograms for a special transform of the intensity function. In shortcut, the general idea of this verification procedure is based on the visual inspection of the histograms for the probability integral transforms of the inter-event durations. The outcome of this testing procedure is important for assessing the quality of the conditional intensity parametrization of the point process reflecting the random times of selected micro-events.

The subject matter of Chapter 5, entitled "Model Hawkesa" [ang. The Hawkes model], and Chapter 6, entitled "Model autoregresyjnej warunkowej intensywności (ACI)" [ang. The autoregressive conditional intensity model (ACI)] is the analysis of the two main econometric

models for the conditional intensity describing the dynamics of selected micro-events, i.e. a temporal acceleration or deceleration of order submissions, order cancellations, trade executions, fluctuation in trading volume or in price changes. These models can be one-dimensional – if they describe clustering of one-type events, or they can be multi-dimensional – if they describe a multi-dimensional point process comprising of times when different types of events are registered. The conditional intensity function of the point process is described with a dynamic parametric specification. The theoretical presentation of intensity models is important, because these models have not been known in the Polish research literature yet, though, apart from the market microstructure, in the world scientific literature they are also used in other fields of finance, for example to VaR measurement, assessment of credit risk, description of the contagion effects in financial markets. These models are a very important tool in modelling the data with irregularly spaced observations. The conditional (on a given information set) intensity function of individual events might be excited in a different manner, and hence, might jump by a different amount immediately after arrival of an event of the same type then after an event of the different type. In the research based on the UHF data this property allows capturing different and complicated patterns of clustering as well as the causality effects between the individual types of observed events.

The main contribution in Chapters 5 and 6 is the illustration of the theoretical discourse with three different empirical studies. Based on the results obtained with the Hawkes model I describe the interdependencies between the moments when buy and sell trades are observed, especially with reference to two main statistical features of this process: (1) clustering of trade moments in time, which reflects periods of increase and decrease in the trading activity; (2) relatively frequent clustering of trades initiated on the same side of the market. Moreover, another very important element of this discourse lies in the practical implication of intensity models in the context of the pioneering methods of risk management. I show that although the Hawkes models and the ACI models are used to depict *per se* the intensity function of a point process, they can also be applied to estimate the instantaneous volatility and the daily volatility of financial prices. The discussed methods of volatility estimation do not use observations of returns as the standard realized volatility models or the GARCH models do. Instead they rely on the specification of the conditional intensity function for cumulative price changes which is estimated with the time intervals between such events. I estimate the instantaneous and daily volatility with both the Hawkes model and the ACI model appropriately validated with the procedures described in Chapter 4. I show that a two-dimensional ACI model allows for a different intensity of upward and downward exchange rate movements. What is very important, this property of the ACI model captures both the clustering of large price movements (i.e. volatility clustering effects) and the possible interdependencies between the expected times for upward and downward price movements. The tools for the intensity estimation which I discuss in Chapters 5 and 6 are very important and promising from the practical point of view, especially for the sake of market risk evaluation. Unlike a standard method of estimating theoretical volatility with the concept of realized volatility, the intensity-based volatility estimates for example allow reducing the bias in volatility estimates that results from the market microstructure noise.

The subject matter of Chapter 7, entitled "Model autoregresyjnego warunkowego czasu trwania (ACD)" [ang. The autoregressive conditional duration model (ACD)] is a theoretical framework of the ACD models as the most widely-known quantitative method for the UHF data modeling. Because these models have already been described in the Polish scientific literature I present

them in a synthetic fashion. However, for the first time in Polish literature I emphasize the similarities and differences between the ACD models, i.e. models that describe conditional (on a given information set) expectations of the inter-event durations, and the Hawkes and ACI models, i.e. models that describe the conditional intensity function of the point process.

The topic of Chapter 8, entitled "Wielostanowy asymetryczny model ACD (MAACD)" [ang. The multistate asymmetric ACD model (MAACD)] is a thorough elaboration on the original construction of the multi-equation MAACD models that are suitably tailored to the complex dynamics of random event times being the realizations of the underlying multi-dimensional point process. Although I previously synthetically presented these models in the international scientific journals (see [C.4] and [C.6]), the value added of this part of the book lies in the discussion of the main statistical properties of the MAACD models and suggestions of some of their special extensions. The first direction of extensions covers possible non-linear functions of duration expectations corresponding to each of the individual events. The second class of extensions refers to statistical distributions for the random terms in the model. As a most general specification I propose the MAACD model where the random (innovation) variables follow the generalized beta distribution of the second kind with different shape parameters. I this chapter I describe, *inter alia*, the way of deriving transition probabilities for selected event categories using the simulation methods. Moreover, I describe a method of assessing the model goodness-of-fit using appropriately defined residuals and intensity transforms.

In Chapter 8 my contribution in the empirical area of research lies in the presentation of two comprehensive studies. In the first one I use a two-state asymmetric ACD model to describe three different duration series, at the end of which the following events can be observed: (1) buy trades vs. sell trades; (2) an excess buy volume (over sell volume) vs. an excess sell volume (over buy volume); (3) an increase in the EUR/PLN exchange rate vs. a decrease in the EUR/PLN exchange rate of a given amount. The results of this study allow me to articulate detailed findings about the trading mechanism and the exchange rate formation in the micro scale as well as about possible factors (i.e. market trends, exchange rate volatility, market liquidity), which impact this mechanism by appropriate lengthening or shortening the waiting times to individual events. In the second empirical study I use the ten-state MAACD model to depict the process of order submissions and cancellations in the interbank FX spot market in two periods: in April 2008 (the appreciation of the Polish zloty) and in December 2008 (the abrupt depreciation of the Polish zloty). The model allows for the detailed description of individual actions undertaken by interbank FX dealers in different market conditions. This study results also in very detailed findings about the accelerations and decelerations of the order submissions pace in reaction to the actions undertaken by other market participants. It also sheds some light on the characteristic regularities in the sequences of submitted and cancelled orders. The obtained results indicate that FX dealers keep monitoring the time-varying market conditions with reference to the instantaneous liquidity states, observed direction of exchange rate changes and its volatility. Their decisions as what kind of order to submit or to cancel at a particular moment are to a large extent influenced by actions undertaken by other dealers and by many other exogenous factors, which I thoroughly discuss. It should be emphasized that, from a strictly methodological point of view, the MAACD model turns out to be a very good tool for the formal description of the UHF data properties, which has been proved with model simulation results. In the MAACD model, the conditional waiting times to individual events depend on both the time intervals between the order submission/cancellation moments in the past and the observed sequence of submitted/cancelled order types. The results of empirical

study show that the variables that are very important for the observed pace of order arrival are: the observed bid-ask spread (i.e. the wider the bid-ask spread, the shorter the waiting time to limit orders that are submitted between the best quotes and, at the same time, the longer the waiting time to market orders), the direction of exchange rate (i.e. the intensity of market orders reflects the short-term direction of exchange rate) and exchange rate volatility (i.e. the larger the volatility, the shorter is the waiting time to market orders and the longer waiting time to the most competitive limit orders). The findings presented in Chapter 8 allow to undertake a formal verification of eleven hypotheses resulting from the mathematical market microstructure models presented in Chapter 1.

To sum up, as the special achievements in the monograph presented for the evaluation I consider:

(1) Shedding light on the complexity of order-driven markets micro-functioning as well as the exemplification of some of these aspects with the novel models based on the real-world data.

(2) Broadening the knowledge about the microstructure of the interbank FX spot market especially with the reference to the role and significance of information, and the concept of order flow as the mechanism of embedding the new information in the observed FX rate.

(3) Original method for reflecting the unstable relationship between the order flow and the FX rate using the time-varying parameter model with the conditional heteroscedasticity.

(4) Presenting the compendium of knowledge about the intensity and duration models as the tools for modeling financial mechanisms based on the time series with the irregularly-spaced observations.

(5) Identification, formal description and economic interpretation of the specific statistical properties of variables describing the joint dynamics of various micro-events in the market, i.e. orders, trades, volume increments, price changes.

(6) Original class of the MAACD models with their possible detailed specifications as well as the methods of their simulation and verification as the tools for depicting the random micro-event times in financial markets.

(7) Analysis of the FX market from the micro perspective through the comprehensive empirical study of the market participants with the reference to the various endogenous and exogenous factors that affect their individual trading decisions.

Moreover, the monograph is the first publication in Poland that focuses on the FX market microstructure and the second book after the monograph of Doman (2010) that touches upon the topic of market microstructure *per se*. The novelty of both my monograph and my publication output relates mainly to the scientific discipline of economics, and in particular the econometrics – in reference to the methods of ultra-high-frequency data modelling; but also the finance – in reference to the multi-layered discussions about functioning of order-driven markets. This research outlines the entirely new directions of possible extensions in both these scientific fields. It should be expected that it will significantly influence the development of the more specific research disciplines as the behavioral finance or financial econometrics. The empirical studies of the market microstructure are important because they foster understanding the micro-functioning of an order-driven market, fluctuation of market liquidity and the price adjustment to the new information. This knowledge has plentiful practical applications because

it enables to optimize trading strategies, to construct models for the intraday market risk management or to undertake actions that eliminate the risks posed by the high-frequency trading. On the other hand, the quantitative tools proposed in this book might be applied to manifold empirical studies based on irregularly-spaced data conducted by other researchers, not necessarily in the field of market microstructure.

5. Summary of scientific output

5.1. Publication output before Ph.D.

My publication output before having received a Ph.D. degree in economic sciences or after having received a Ph.D. degree, but based on analyses presented in doctoral dissertation encompasses 3 articles published in scientific periodicals from the list B MNiSW (in Polish), 1 chapter in a monograph (in Polish) and 1 research paper made public in the Internet as the *University of Konstanz Working Paper* (in English).

5.2. Publication output after Ph.D.

After having received a Ph.D. degree in economic sciences my publication output encompasses:

- 1 monograph in Polish;
- 1 chapter in a monograph in English (publisher: *Springer*);
- 7 articles published in academic journals listed in the JCR, i.e. from the list A of the Ministry of Science and Higher Education;
- 1 article in a journal which was incorporated into the JCR two years after my article was published[8];
- 10 articles published in scientific periodicals from the B list of the Ministry of Science and Higher Education.

Out of 18 publications in academic journals after having received a Ph.D. degree, 14 were written in English and 4 in Polish. All my papers were published with a publishers of an international range or – in the case of articles written in Polish – of a countrywide range (the exposition of full texts in electronic versions is possible in Internet: in electronic databases or by an open access). Out of 20 publications 19 present original research, and 1 presents a review of a book.

[8] This is the article [E.1] published in *Applied Financial Economics*. The journal was in 2015 incorporated by the publishing house *Taylor & Francis* into its sister journal *Applied Economics* and since then it can be found under such a name in the Thomson Reuters JCR.

5.3. Parametrization of the publication output

Total *Impact Factor* (IF) according to *JCR*	10.621
Total number of citations according to *Web of Science*	11 with self-citations 10 without self-citations
Hirsch Index according to *Web of Science*	3 with self-citations 2 without self-citations
Total number of citations according to *Google Scholar*, out of which: - citations from abroad	46 without self-citations 21
Total number of points according to the Ministry of Science and Higher Education[9]: - before receiving the Ph.D. degree or based on analyses presented in doctoral dissertation - after receiving the Ph.D. degree - monograph - chapter of a monograph in English - publications in academic journals	312 22 290 20 5 265

The detailed list of all my publications with the corresponding *Impact Factors* and scoring of the Ministry of Science and Higher Education is presented in the Attachment no. 3. Besides the aforementioned publications, after receiving the doctoral degree I was an author of 4 reviewed research papers, in which 2 Working Papers were made public in Internet (one as *NBP Working Paper*, and one as a *Department of Applied Econometrics Working Paper*). Because all of these papers were later published in their improved versions in academic journals, I do not list them as a distinct elements of my research output.

In the period of my employment at the Department of Financial System of the National Bank of Poland I was also a co-author of analytical reports, i.e. NBP (2008), NBP (2010), NBP (2011a) and NBP (2011b).

The results of my research were subject to public discussion many times, both before and after receiving a doctor degree, at conferences and seminars; at the international level (16 oral

[9] The total number of points is calculated according to the lists of the graded academic journals which are published by the Ministry of Science and Higher Education. These lists were in operation in the years of my publications. According to the guidelines of the Ministry of Science and Higher Education, for the co-authored publications I leave the total number of points, because the affiliation of my co-authors is not the Collegium of Economic Analysis (WSE).

presentations in English; from which 12 took place abroad) and at the country-wide level (11 oral presentations in Polish). Special attention among my presentations abroad shall be given to ones at the prestigious conferences: *European Economic Association & Econometric Society Meetings (EEA-ESEM), Frontiers of Finance, Econophysics Colloquium, Computational and Financial Econometrics (CFE).* The detailed list of my speeches is presented in the Attachment no. 4.

6. Other research activities

6.1. Grants and research projects

From September 2005 to February 2007 I was employed in the *Center of Finance and Econometrics* (COFE) of the University of Konstanz, in the research network *Microstructure of Financial Markets in Europe* (MCFINMA) financed by the European Union. The results of my research conducted in scientific cooperation with Dr. Ingmar Nolte and Prof. Winfried Pohlmeier were presented in two research papers [H.1] and [C.7] and in the chapter of the book [B.1]. Detailed information about the analyses carried out in this international research project were presented in the section 3.1.1. of this document.

In 2011 I received a DAAD scholarship for realization of a research project *Development of Liquidity-Adjusted Risk Valuation Measures* in an academic institution in Germany. Under this project, from October 2011 to December 2011, in the Chair of Economics and Econometrics of the University of Konstanz I conducted research on econometric methods of modeling the interdependencies between market risk measures and intraday liquidity measures based on the high-frequency data from the stock market.

From September 2013 to February 2016 I led the research project "Microstructure of the interbank FX spot market" granted by the National Science Center (OPUS 5, DEC-2013/09/B/HS4/01319). The research findings of this project were published in two research papers [C.2], [C.4] and [D.1] as well as in a monograph [A.1].

As an assistant professor in the Institute of Econometrics I carried out five research projects, as a leader or as a contractor, in the framework of "own research projects" or "statutory research projects" in the Collegium of Economic Analysis. I also actively cooperated with the Department of Geriatrics of the Medical University of Bialystok. From 2013 I was a contractor in three statutory research projects about factors that influence functioning of older people, their life expectancy and subjective feeling of loneliness.

6.2. Internships and training abroad

I did six research or teaching internships in the Chair of Economics and Econometrics of the University of Konstanz. My research stays at this university were associated with international research projects (from September 2005 to February 2007 and from October to December 2011) and four times I was invited as a lecturer (I gave a cycle of lectures or led seminars for students in June 2012, October 2013, October 2014 and October 2015).

After receiving a doctoral degree I took part in courses and trainings on economics or econometrics. In the context of my research the most important were three stays abroad:

- Conference *Lindau Meeting of the Winners of the Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel* in Lindau, Germany (16-19 August 2006), which was a meeting of the best young scientists with the laureates of the Nobel Memorial Prize in Economic Sciences. I had a honor to listen to a cycle of lectures given by the renowned economists in the world (cf. Prof. Robert F. Engle, Prof. Clive W.J. Granger, Prof. John F. Nash Jr.) and I could actively participate in accompanying discussion sessions.
- Course *Exchange Rate Economics* in Washington D.C., USA (12-16 April 2010), given by prof. Lucio Sarno in the headquarters of the International Monetary Fund. The topic of this course was theoretical and empirical modelling of FX rates both in the macro and in the micro framework.
- Course *Advanced Topics in Empirical Finance* in Gerzensee, Switzerland (4-15 February 2013) financed by the Central Bank of Switzerland. The lecturers were Prof. Michael Rockinger, Prof. Casper G. de Vries and Prof. Thierry Foucault. The course was devoted to advanced tools used in financial mathematics and econometrics for pricing derivatives, risk measurement and the market microstructure.

6.3. Reviewing publications in international and country-wide periodicals

I would like to specially emphasize my active participation in discussions of other researchers' scientific output. As an assistant professor at the WSE I have reviewed 51 papers in scientific journals. Among these were journals from the JCR list:

- *Journal of Banking and Finance* (1 article),
- *The European Journal of Finance* (1 article),
- *Emerging Markets Finance and Trade* (1 article),
- *Applied Economics* (4 articles),
- *Acta Physica Polonica A* (1 article),

and from other international and country-wide periodicals:

- *Acta Scientiarum Polonorum. Oeconomia* (1 article),
- *Acta Universitatis Nicolai Copernici* (1 article),
- *Applied Financial Economics* (2 articles),
- *Bank i Kredyt* (34 articles),
- *Central European Journal of Economic Modelling and Econometrics* (2 articles),
- *Journal for Studies in Economics and Econometrics* (1 article),
- *Przegląd Statystyczny* (1 article),
- *Studia i Prace Kolegium Zarządzania i Finansów* (1 article).

Additionally I was a referee of papers submitted to the *Department of Applied Econometrics Working Papers* (1 article) and to *Materiały i Studia NBP* (1 article), of one chapter of the

monograph (publisher: *ASERS Publishing*) and one research report submitted as a "own research study" in WSE.

6.4. Participation in editorial committees of scientific journals

From February 2009 to December 2014 I was a member of the editorial committee of the research periodical *Bank i Kredyt* (*Bank and Credit*, publisher is the National Bank of Poland). From January 2016 I am the member of the editorial committee of *Economic Research in Finance* (publisher is the Warsaw School of Economics).

7. Teaching and organizational activities

As an assistant professor in the Institute of Econometrics WSE I am teaching undergraduate, graduate and doctoral students. I teach the following courses in Polish:

- Econometrics,
- Financial Econometrics,

and in English:

- Empirical Finance,
- Financial Econometrics,
- Applied Econometrics.

In the Chair of Economics and Econometrics of the University of Konstanz I taught the courses in:

- Econometrics,
- Time Series for Financial Econometrics.

In June 2012 I organized and supervised the seminar for students of the University of Konstanz, entitled *Seminar in Empirical Finance*. In this course students worked on their own projects, i.e. case studies, where they had to use econometric methods to empirically verify selected theorems of finance. My role was to suggest research topics for them, to formulate constructive comments during projects' preparation and during their final presentations given by students, and to evaluate the final dissertations.

Up to date I supervised 15 Master theses and 20 Bachelor theses. The first Master thesis I supervised (written by Piotr Orłowski, MSc) was awarded in 2008 the 3rd Prize in the President of the National Bank of Poland competition for the best Master thesis in economic sciences. Currently, three subsequent Master theses are prepared under my supervision. In the WSE I reviewed many Bachelor and Master theses.

Apart from working with students I also gave lectures for employees of the WSE in the framework of the training workshop in financial econometrics.

In 2012 I took part in the teaching project co-financed from the European Union funds entitled *Innovative WSE – program of development and internationalization*, in which I prepared teaching materials in English (syllabus, literature, presentations for lectures, tasks) for the course in *Financial Econometrics*.

In the academic year 2013/2014 I served as a coordinator of the course in Econometrics for undergraduate studies in the WSE. My responsibilities were to arrange the teaching crew for tutorials (in IT laboratories) for about 1000-1100 students as well as to organize a uniform exam for all full-time, evening and external students.

Between September 2008 and August 2012 I served as an representative of non-Associate Professor/Full Professor academics in the Scientific Board of the Collegium of Economic Analysis WSE. From November 2012 I am a member of the Board of Young Researchers of the Collegium of Economic Analysis – an advisory body of the Dean of the Collegium.

In years 2010-2014 I assisted during student admission process in the WSE as a member or as a secretary of an admission subcommittee.

8. Prizes and distinctions

1. Invitation to the meeting of distinguished young researchers with the Laureates of the Nobel Memorial Prize in Economic Sciences (2nd *Lindau Meeting of the Winners of the Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel*, 16-19 August 2006, Lindau, Germany).
2. Prize in the Contest of the President of National Bank in Poland for the best article published in the research journal *Bank i Kredyt* in 2010 (see the article [D.9]).
3. Prize of the Rector of the Warsaw School of Economics in the area of scientific achievements for publication in a journal listed in the *Journal Citation Reports* in 2011.
4. Diploma for the best research study presented at a II Poster Session of the *VI Country-wide Conference Preventive Cardiology 2013 – Guidelines, Doubts, Hot Topics* organized by the Section of Prevention and Epidemiology of the Polish Cardiologic Committee, Cracow, Poland, 15-16 November 2013 – for the presentation entitled "Preventive Cardiology – Does it Have Sense in the Old Age?" (co-authors: Wojskowicz A., Kasiukiewicz A., Wojszel B., Bień B.).
5. I Prize in the contest of research studies of the *II International Medical Congress Man and Woman 65+. Healthy Ageing* in Białystok, Poland, 10-11 October 2014, for the research study "Predictors for the long-term survival of geriatric patients – retrospective analysis" (co-authors: Wojskowicz A., Kasiukiewicz A., Bień B., Wojszel B.).
6. Distinction of the Rector of the Warsaw School of Economics for the best publication achievements in 2014.
7. Diploma of recognition awarded by the Rector of the Warsaw School of Economics for the best publication achievements in 2014.
8. II Prize in the Contest of the President of the National Bank of Poland for the best article published in the research journal *Bank i Kredyt* in 2014 (see the article [D.2]).
9. Diploma of recognition awarded by the Rector of the Warsaw School of Economics for the best publication achievements in 2015.
10. Distinction in the contest of research studies of the *III International Medical Congress Man and Woman 65+. How to treat and help* in Józefów, Poland, 21-22 October 2016, for the research study "Which factors predict subjective burden suffered by family carers of oldest seniors?" (co-authors: Doroszkiewicz H., Bień B.).

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Ł. Bień

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