



UNIVERSITY OF WARSAW
Faculty of Economic Sciences

VALUE AT RISK ESTIMATION IN TURBULENT AND TRANQUIL STATES

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AGENDA

- Motivation, purpose and research question
- Model concept
- Model proposition
 - possible dimensions of analysis – EWS
 - possible dimensions of analysis – VaR
 - testing process
- Results
 - Data
 - Results for EWS models
 - Results for VaR models

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MOTIVATION

- Market risk is one out of 3 most important risk in banks (BASEL II/III, CRD IV)
- Value at Risk is measure accepted by regulators (BASEL II/III, CRD IV)
- **There is no one (the best) method for VaR calculation** (Beder 1995)
- Growing importance of the following methods:
 - **semi-parametric methods** Angelidis et al. (2007), Ozun et al. (2010), Dimitrakopoulos et al. (2010) and Abad et al.(2013)
 - **switching between states methods** Alexander i Lazar (2006) and Marcucci (2005).

PURPOSE

- **PROPOSITION OF THE MODEL TO PREDICT LEVEL OF MARKET RISK USING VALUE AT RISK, WHICH WOULD MEET FOLLOWING ASSUMPTIONS:**
 - Efficient market risk capital management
 - Avoiding excessive cost of holding capital
 - Model applicable in reality
 - Method that would combine semi-parametric methods and state switching methods

ADDITIONAL MODEL REQUIREMENTS

- **BASEL II/III, CRD IV requirements** (one-day 99% VaR, min. 250 observations)
- **Stylized facts of financial data**
 - Variance clustering (Mandelbrot 1963, Fama 1965) & variance persistence (Engle & Paton 2001)
 - Variance convergence to average (Engle & Paton 2001)
 - Leverage effect (Engle & Paton 2001)
 - Heavy tails (Engle & Paton 2001)
 - States switching (Cai 1994, Hamilton & Susmel 1994)

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MODEL CONCEPT

Step 1

STATE OF
TURBULENCE
PREDICTING MODEL

Step 2

VaR MODEL FOR
STATE OF
TURBULENCE

VaR MODEL FOR
STATE OF
TRANQUILITY

STEP 1 – PREDICTING STATE OF TURBULENCE

TODAY



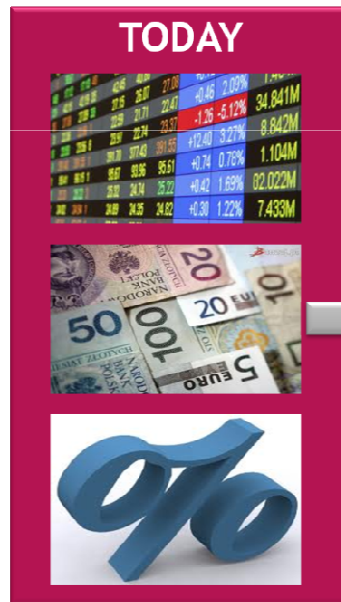
PERSONAL EWS

STATE OF
TURBULENCE



STATE OF
TRANQUILLITY

STEP 2 – VaR MODELS

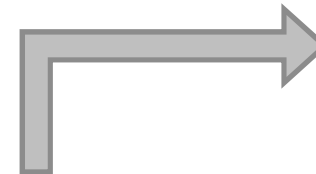
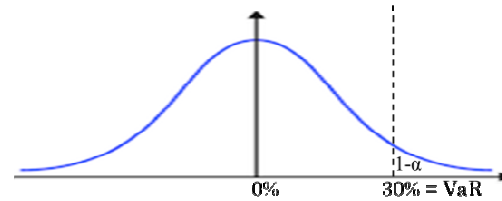


PERSONALEWS

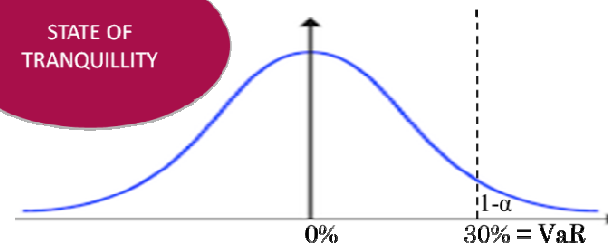


STATE OF
TURBULENCE

STATE OF
TRANQUILLITY



VaR



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STEP I EWS – BINARY MODEL & DV DEFINITION

BINARY MODEL

- PROBIT
- LOGIT
- COMPLEMENTARY LOG-LOG

DEPENDENT VARIABLE DEFINITION – STATE OF TURBULENCE

- 20% of the highest losses
- 10% of the highest losses
- 5% of the highest losses
- 1% of the highest losses

STEP I EWS – INDEPENDENT VARIABLES



Stock indices

- WIG
- WIG20



Exchange rates

- EURO/PLN
- USD/PLN
- CHF/PLN



Interest rates

- WIBOR ON
- WIBOR 3M

VARIABLE TRANSFORMATION:

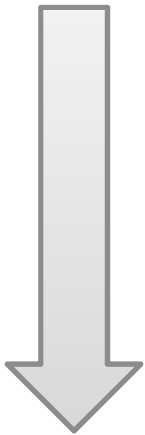
1. Original variable
2. Moving average (15-day)
3. Returns
4. Moving average (15-day of returns)
5. Moving variance (15-day)
6. Moving variance (15-day of returns)

NUMBER OF VARIABLES REDUCTION:

- FACTOR ANALYSIS
- PCA

STEP I EWS – THRESHOLD FITTING

PROBIT, LOGIT, CLOGLOG

PREDICTION		BINARY OUTCOME
0,01	THRESHOLD PRECISION 0,01	1
0,023		0
0,025		0
0,027		0
...		...
0,96		0
0,98		0
0,99		0

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STEP II VaR – CHOICES FOR EWS MODELS

DEPENDENT VARIABLE DEFINITION

- P1, P5, P10, P20

BINARY MODEL

- PROBIT
- LOGIT
- CLOGLOG

VARIABLES SELECTION

- All variables
- Variable selection (STEPWISE)

STEP II VaR – WYBÓR MODELI DLA

STATE OF TRANQUILLITY MODEL

- GARCH (1,1)
- GARCH (1,1) with Engle correction
- EGARCH (1,1,1)
- EGARCH (1,1,1) with Engle correction
- t-GARCH (1,1)
- t-GARCH (1,1) with Engle correction

STATE OF TRANQUILITY
OBSERVATIONS (ALL, NOT FROM
STATE OF TURBULANCE)

STATE OF TURBULENCE MODEL

- GARCH models
- Lognormal
- Weibull
- Gamma
- Exponential
- Pareto
- Empirical

99% VAR LEVEL DEFINITION
80, 90 OR 99 PERCENTILE OF
DISTRIBUTION

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EWS TESTING

DIMENSIONS

- Dependent variable (P1, P5, P10, P20)
- Binary model (LOGIT, PROBIT, CLOGLOG)
- Data type (original PCA, FA)
- Threshold

TESTING

- LN
- HOSMER-LEMESHOW
- GINI
- KROC criterion

ACCEPTED MODELS

SINGLE ASSETS – IN-SAMPLE
PORTFOLIO –
IN-SAMPLE & OUT_OF_SAMPLE

VaR MODELS TESTING

CHOICE CRITERION

- Meeting basic assumptions:
 - Stationary
 - ARCH effect
 - Autocorrelation
 - Normal distribution
- Tail distribution
- Quality of VaR
- Costs of capital holding

TESTING

- Philips-Perron & KPSS
- Durbin & Breusch-Godfrey
- Jarque–Berr
- ARCH (Engla)
- K-S, A-D, C-vM and information criterion
- Kupiec & Christoffersen
- Backtesting
- Costs analysis

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EMPIRICAL RESULTS - DATA

- DATA: Returns of shares listed on WSE
 - State of turbulence models:
 - 43 single shares
 - 5 portfolios (10 random selected shares)
 - PERIOD: 01.01.2006 – 31.01.2012
 - VaR models
 - 79 single shares
 - PERIOD: 01.01.2006 – 31.01.2012
 - BASE SAMPLE: 01.01.2006 - 31.12.2009
 - PREDICTION SAMPLE: 01.01.2010 - 31.01.2012 (525 Value at Risk predictions)

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RESULTS FOR STATE OF TURBULENCE MODELS

DEPENDENT VARIABLES	THRESHOLD	BINARY MODEL	TYPE OF DATA
P10	10%	LOGIT	UNTRANSFORMED
P10	10%	PROBIT	UNTRANSFORMED
P10	10%	CLOGLOG	UNTRANSFORMED
P5	5%	LOGIT	UNTRANSFORMED
P5	5%	PROBIT	UNTRANSFORMED
P5	5%	CLOGLOG	UNTRANSFORMED
P1	1%	LOGIT	UNTRANSFORMED
P1	1%	PROBIT	UNTRANSFORMED
P1	1%	CLOGLOG	UNTRANSFORMED

In-sample analysis: 9 groups of assumptions

Out-of-sample analysis: 6 groups of assumptions

- For the P1 discriminatory & predicting power very unstable
- Only this assumptions use in EWS-GARCH models

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BASIC RESULTS & BENCHMARK MODELS RESULTS

- Meeting all BASEL II/III, CRD IV requirements
- Models are consistent with own assumptions (ARCH effect etc.)
- **GARCH > EGARCH** (asymmetry of innovation influence)
 - $\text{GARCH}(1,1) > \text{EGARCH}(1,1,1)$
 - $\text{GARCH EMP}(1,1) > \text{EGARCH EMP}(1,1,1)$
- **Conservatism of results:**
 - $\text{GARCH-t}(1,1) > \text{GARCH EMP}(1,1) > \text{GARCH}(1,1)$
- All observations for the state of tranquillity VaR models
- Variable selection (STEPWISE)

RESULTS – MODEL EWS- GARCH(1,1)

MPS	MSS	MST	VaR ANALYSIS (WHOLE PERIOD)										STRESSED VALUE AT RISK (WORST 250 DAYS)				
			LP	UP	ABAD	LOPEZ	CAPORIN	EXCESS	EXCE SS SQ	GREE N	ATL YELL.	RED	LP	UP	GREEN	ATL YELL.	RED
BRAK	GARCH-t	BRAK	1,25	0,24%	6,3%	2,46	12,5%	11,6%	11,7%	98,7%	98,7%	1,3%	1,03	0,4%	97,5%	98,7%	1,3%
PROBIT SEL	GARCH	EX9_10	4,39	0,84%	8,4%	4,51	11,1%	10,3%	10,6%	93,7%	98,7%	1,3%	3,56	1,4%	72,2%	93,7%	6,3%
LOGIT SEL	GARCH	EX9_10	4,44	0,85%	8,6%	4,56	11,0%	10,1%	10,4%	93,7%	98,7%	1,3%	3,61	1,4%	68,4%	93,7%	6,3%
CLOGLOG SEL	GARCH	EX9_10	4,53	0,86%	8,7%	4,59	10,9%	10,0%	10,3%	93,7%	98,7%	1,3%	3,66	1,5%	68,4%	93,7%	6,3%
PROBIT	GARCH	EX9_10	4,56	0,87%	8,5%	4,62	11,0%	10,2%	10,5%	93,7%	97,5%	2,5%	3,63	1,5%	70,9%	93,7%	6,3%
PROBIT SEL	GARCH	EM9_10	4,58	0,87%	8,8%	4,71	8,7%	7,8%	7,9%	92,4%	97,5%	2,5%	3,71	1,5%	68,4%	92,4%	7,6%
CLOGLOG	GARCH	EX9_10	4,59	0,88%	8,6%	4,66	10,8%	10,0%	10,3%	93,7%	97,5%	2,5%	3,67	1,5%	73,4%	93,7%	6,3%
BRAK	GARCH EMP	BRAK	4,61	0,88%	9,2%	4,67	7,2%	6,4%	6,5%	94,9%	97,5%	2,5%	3,73	1,5%	68,4%	96,2%	3,8%
LOGIT	GARCH	EX9_10	4,62	0,88%	8,6%	4,68	10,9%	10,0%	10,3%	92,4%	97,5%	2,5%	3,67	1,5%	70,9%	93,7%	6,3%
LOGIT SEL	GARCH	EM9_10	4,63	0,88%	9,0%	4,76	8,6%	7,8%	7,9%	92,4%	98,7%	1,3%	3,78	1,5%	64,6%	93,7%	6,3%
PROBIT SEL	GARCH	EX0_10	4,67	0,89%	9,0%	4,80	7,9%	7,1%	7,1%	92,4%	96,2%	3,8%	3,80	1,5%	65,8%	91,1%	8,9%
CLOGLOG SEL	GARCH	EM9_10	4,71	0,90%	9,1%	4,77	8,5%	7,7%	7,8%	92,4%	98,7%	1,3%	3,82	1,5%	64,6%	93,7%	6,3%
LOGIT SEL	GARCH	EX0_10	4,75	0,90%	9,1%	4,81	7,8%	7,0%	7,1%	92,4%	97,5%	2,5%	3,90	1,6%	59,5%	92,4%	7,6%
CLOGLOG SEL	GARCH	EX9_5	4,76	0,91%	9,0%	4,82	17,1%	16,3%	134,5 %	93,7%	98,7%	1,3%	3,81	1,5%	69,6%	93,7%	6,3%
PROBIT SEL	GARCH	EX9_5	4,77	0,91%	8,9%	4,84	21,6%	20,8%	234,7 %	93,7%	98,7%	1,3%	3,84	1,5%	69,6%	93,7%	6,3%
PROBIT	GARCH	EM9_10	4,77	0,91%	8,9%	4,84	8,6%	7,8%	7,9%	91,1%	97,5%	2,5%	3,80	1,5%	68,4%	93,7%	6,3%
LOGIT SEL	GARCH	EX9_5	4,80	0,91%	9,0%	4,86	17,1%	16,3%	134,5 %	93,7%	98,7%	1,3%	3,87	1,5%	69,6%	92,4%	7,6%
CLOGLOG SEL	GARCH	EX0_10	4,80	0,91%	9,2%	4,80	7,8%	7,0%	7,1%	92,4%	97,5%	2,5%	3,91	1,6%	59,5%	92,4%	7,6%
CLOGLOG	GARCH	EM9_10	4,81	0,92%	9,0%	4,88	8,6%	7,7%	7,8%	91,1%	97,5%	2,5%	3,84	1,5%	69,6%	92,4%	7,6%
PROBIT SEL	GARCH	WE9_10	4,82	0,92%	9,5%	4,95	7,7%	6,9%	6,9%	92,4%	96,2%	3,8%	3,92	1,6%	62,0%	89,9%	10,1%
BRAK	GARCH	BRAK	6,42	1,22%	12,5%	6,42	6,6%	5,8%	5,8%	78,5%	93,7%	6,3%	5,18	2,1%	39,2%	78,5%	21,5%

RESULTS – MODEL EWS-GARCH(1,1)

FORMAL TESTS

MPS	MSS	MST	LR _{UC}	LR _{IND}	LR _{CC}	Z _{UC}	Z ^D _{UC}	Z ^G _{UC}
LOGIT	GARCH	WE9_5	3,80%	8,86%	6,33%	11,39%	2,53%	8,86%
CLOGLOG	GARCH	WE9_5	3,80%	8,86%	6,33%	12,66%	2,53%	10,13%
PROBIT	GARCH	WE9_5	3,80%	8,86%	6,33%	12,66%	2,53%	10,13%
PROBIT SEL	GARCH	WE9_5	3,80%	13,92%	8,86%	10,13%	2,53%	7,59%
LOGIT	GARCH	EX8_5	5,06%	6,33%	5,06%	12,66%	2,53%	10,13%
LOGIT	GARCH	GM9_5	5,06%	7,59%	5,06%	12,66%	3,80%	8,86%
LOGIT	GARCH	LN9_5	5,06%	7,59%	5,06%	12,66%	3,80%	8,86%
PROBIT	GARCH	EX8_5	5,06%	6,33%	5,06%	12,66%	2,53%	10,13%
CLOGLOG	GARCH	EX8_5	5,06%	6,33%	5,06%	13,92%	2,53%	11,39%
CLOGLOG	GARCH	GM9_5	5,06%	7,59%	5,06%	13,92%	3,80%	10,13%
CLOGLOG	GARCH	LN9_5	5,06%	7,59%	5,06%	13,92%	3,80%	10,13%
PROBIT	GARCH	GM9_5	5,06%	7,59%	5,06%	13,92%	3,80%	10,13%
PROBIT	GARCH	LN9_5	5,06%	7,59%	5,06%	13,92%	3,80%	10,13%
PROBIT SEL	GARCH	GM9_5	5,06%	12,66%	7,59%	11,39%	3,80%	7,59%
PROBIT SEL	GARCH	LN9_5	5,06%	12,66%	7,59%	11,39%	3,80%	7,59%
CLOGLOG SEL	GARCH	WE9_5	5,06%	13,92%	8,86%	11,39%	3,80%	7,59%
LOGIT SEL	GARCH	WE9_5	5,06%	13,92%	8,86%	11,39%	3,80%	7,59%
PROBIT SEL	GARCH	EX8_5	6,33%	12,66%	6,33%	10,13%	2,53%	7,59%
CLOGLOG	GARCH	EX9_5	6,33%	10,13%	6,33%	12,66%	5,06%	7,59%
LOGIT	GARCH	EX9_5	6,33%	10,13%	6,33%	12,66%	5,06%	7,59%
PROBIT	GARCH	EX9_5	6,33%	8,86%	6,33%	12,66%	5,06%	7,59%
CLOGLOG	GARCH	EM9_5	6,33%	8,86%	6,33%	13,92%	5,06%	8,86%
LOGIT	GARCH	EM9_5	6,33%	8,86%	6,33%	13,92%	5,06%	8,86%
PROBIT	GARCH	EM9_5	6,33%	7,59%	6,33%	13,92%	5,06%	8,86%
CLOGLOG SEL	GARCH	GM9_5	6,33%	12,66%	7,59%	12,66%	5,06%	7,59%
CLOGLOG SEL	GARCH	LN9_5	6,33%	12,66%	7,59%	12,66%	5,06%	7,59%
LOGIT SEL	GARCH	GM9_5	6,33%	12,66%	7,59%	12,66%	5,06%	7,59%
LOGIT SEL	GARCH	LN9_5	6,33%	12,66%	7,59%	12,66%	5,06%	7,59%
LOGIT SEL	GARCH	EX9_5	6,33%	12,66%	8,86%	11,39%	5,06%	6,33%
LOGIT SEL	GARCH	EM9_5	6,33%	12,66%	8,86%	12,66%	5,06%	7,59%
BRAK	GARCH EMP	BRAK	7,59%	8,86%	5,06%	10,13%	5,06%	5,06%
BRAK	GARCH	BRAK	8,86%	8,86%	7,59%	24,05%	2,53%	21,52%

RESULTS – MODEL EWS-GARCH EMP(1,1)

MPS	MSS	MST	VaR ANALYSIS (WHOLE PERIOD)										STRESSED VALUE AT RISK (WORST 250 DAYS)				
			LP	UP	ABAD	LOPEZ	CAPORI N	EXCESS	EXCE SS SQ	GREEN	ATL YELL.	RED	LP	UP	GREE N	ATL YELL.	RED
BRAB	GARCH-t	BRAB	1,25	0,24%	6,3%	2,46	12,5%	11,6%	11,7%	98,7%	98,7%	1,3%	1,03	0,4%	97,5%	98,7%	1,3%
PROBIT SEL	GARCH EMP	EX9_10	3,06	0,58%	6,4%	3,27	11,6%	10,7%	11,0%	100,0%	100,0%	0,0%	2,56	1,0%	88,6%	100,0%	0,0%
LOGIT SEL	GARCH EMP	EX9_10	3,09	0,59%	6,4%	3,26	11,4%	10,6%	10,9%	100,0%	100,0%	0,0%	2,58	1,0%	89,9%	98,7%	1,3%
CLOGLOG SEL	GARCH EMP	EX9_10	3,16	0,60%	6,6%	3,34	11,3%	10,5%	10,8%	100,0%	100,0%	0,0%	2,62	1,0%	91,1%	98,7%	1,3%
CLOGLOG	GARCH EMP	EX9_10	3,18	0,61%	6,3%	3,31	11,3%	10,5%	10,8%	100,0%	100,0%	0,0%	2,67	1,1%	88,6%	100,0%	0,0%
PROBIT	GARCH EMP	EX9_10	3,18	0,61%	6,3%	3,31	11,5%	10,7%	11,0%	100,0%	100,0%	0,0%	2,66	1,1%	87,3%	100,0%	0,0%
LOGIT	GARCH EMP	EX9_10	3,20	0,61%	6,3%	3,33	11,3%	10,5%	10,8%	100,0%	100,0%	0,0%	2,68	1,1%	88,6%	100,0%	0,0%
PROBIT SEL	GARCH EMP	EM9_10	3,25	0,62%	6,8%	3,48	9,1%	8,3%	8,4%	100,0%	100,0%	0,0%	2,72	1,1%	86,1%	100,0%	0,0%
LOGIT SEL	GARCH EMP	EM9_10	3,28	0,62%	6,8%	3,46	9,1%	8,3%	8,3%	100,0%	100,0%	0,0%	2,76	1,1%	87,3%	98,7%	1,3%
CLOGLOG SEL	GARCH EMP	EM9_10	3,34	0,64%	7,0%	3,52	9,0%	8,2%	8,3%	100,0%	100,0%	0,0%	2,77	1,1%	88,6%	98,7%	1,3%
PROBIT SEL	GARCH EMP	EX0_10	3,34	0,64%	6,9%	3,52	8,4%	7,5%	7,6%	100,0%	100,0%	0,0%	2,80	1,1%	86,1%	100,0%	0,0%
CLOGLOG	GARCH EMP	EM9_10	3,39	0,65%	6,8%	3,53	9,0%	8,2%	8,3%	100,0%	100,0%	0,0%	2,81	1,1%	84,8%	100,0%	0,0%
LOGIT SEL	GARCH EMP	EX0_10	3,39	0,65%	7,0%	3,53	8,3%	7,5%	7,6%	100,0%	100,0%	0,0%	2,86	1,1%	84,8%	98,7%	1,3%
PROBIT	GARCH EMP	EM9_10	3,39	0,65%	6,7%	3,53	9,1%	8,3%	8,4%	100,0%	100,0%	0,0%	2,80	1,1%	83,5%	100,0%	0,0%
PROBIT SEL	GARCH EMP	EX9_5	3,39	0,65%	6,5%	3,48	22,1%	21,3%	235,2%	100,0%	100,0%	0,0%	2,81	1,1%	87,3%	100,0%	0,0%
LOGIT	GARCH EMP	EM9_10	3,42	0,65%	6,8%	3,56	9,0%	8,2%	8,3%	100,0%	100,0%	0,0%	2,82	1,1%	84,8%	100,0%	0,0%
BRAB	GARCH EMP	BRAB	4,61	0,88%	9,16%	4,67	7,23%	6,43%	6,46%	94,9%	97,5%	2,5%	3,73	1,49 %	68,4%	96,2%	3,8%

RESULTS – MODEL EWS- GARCH(1,1) EMP

MPS	MSS	MST	LR _{UC}	LR _{IND}	LR _{CC}	Z _{UC}	Z ^D _{UC}	Z ^G _{UC}
PROBIT SEL	GARCH EMP	EM8_5	5,06%	8,86%	6,33%	11,39%	3,80%	7,59%
PROBIT SEL	GARCH EMP	LN8_5	5,06%	13,92%	7,59%	12,66%	3,80%	8,86%
LOGIT SEL	GARCH EMP	LN8_5	5,06%	12,66%	8,86%	10,13%	2,53%	7,59%
CLOGLOG	GARCH EMP	LN8_5	6,33%	10,13%	6,33%	7,59%	3,80%	3,80%
LOGIT	GARCH EMP	LN8_5	6,33%	10,13%	6,33%	7,59%	3,80%	3,80%
PROBIT	GARCH EMP	LN8_5	6,33%	10,13%	6,33%	7,59%	3,80%	3,80%
CLOGLOG	GARCH EMP	EM8_5	6,33%	8,86%	6,33%	8,86%	3,80%	5,06%
PROBIT	GARCH EMP	EM8_5	6,33%	8,86%	6,33%	11,39%	3,80%	7,59%
CLOGLOG SEL	GARCH EMP	LN8_5	6,33%	11,39%	7,59%	10,13%	3,80%	6,33%
LOGIT SEL	GARCH EMP	EM8_5	6,33%	8,86%	8,86%	10,13%	2,53%	7,59%
BRAK	GARCH EMP	BRAK	7,59%	8,86%	5,06%	10,13%	5,06%	5,06%

RESULTS – MODEL EWS-GARCH- $t(1,1)$

MPS	MSS	MST	VaR ANALYSIS (WHOLE PERIOD)										STRESSED VALUE AT RISK (WORST 250 DAYS)				
			LP	UP	ABAD	LOPEZ	CAPORIN	EXCESS	EXCESS SQ	GREEN	ATL YELL.	RED	LP	UP	GREEN	ATL YELL.	RED
PROBIT SEL	GARCH-t	EX9_10	0,76	0,14%	4,7%	1,94	15,3%	14,4%	14,6%	98,7%	98,7%	1,3%	0,62	0,2%	98,7%	98,7%	1,3%
LOGIT SEL	GARCH-t	EX9_10	0,77	0,15%	5,0%	1,97	15,2%	14,3%	14,5%	98,7%	98,7%	1,3%	0,62	0,2%	98,7%	98,7%	1,3%
PROBIT	GARCH-t	EX9_10	0,78	0,15%	4,9%	2,00	15,2%	14,3%	14,5%	98,7%	98,7%	1,3%	0,65	0,3%	98,7%	98,7%	1,3%
CLOGLOG	GARCH-t	EX9_10	0,78	0,15%	4,8%	1,94	15,1%	14,2%	14,4%	98,7%	98,7%	1,3%	0,66	0,3%	98,7%	98,7%	1,3%
CLOGLOG SEL	GARCH-t	EX9_10	0,80	0,15%	5,0%	1,97	15,1%	14,3%	14,5%	98,7%	98,7%	1,3%	0,63	0,3%	98,7%	98,7%	1,3%
LOGIT	GARCH-t	EX9_10	0,80	0,15%	4,8%	1,97	15,1%	14,2%	14,4%	98,7%	98,7%	1,3%	0,66	0,3%	98,7%	98,7%	1,3%
PROBIT SEL	GARCH-t	EX9_5	0,89	0,17%	5,2%	2,12	26,0%	25,2%	238,9%	98,7%	98,7%	1,3%	0,75	0,3%	98,7%	98,7%	1,3%
CLOGLOG SEL	GARCH-t	EX9_5	0,89	0,17%	5,3%	2,12	21,6%	20,7%	138,7%	98,7%	98,7%	1,3%	0,73	0,3%	98,7%	98,7%	1,3%
LOGIT SEL	GARCH-t	EX9_5	0,89	0,17%	5,7%	2,19	21,5%	20,7%	138,7%	98,7%	98,7%	1,3%	0,73	0,3%	98,7%	98,7%	1,3%
PROBIT	GARCH-t	EX9_5	0,91	0,17%	5,7%	2,33	21,4%	20,5%	138,6%	98,7%	98,7%	1,3%	0,73	0,3%	98,7%	98,7%	1,3%
CLOGLOG	GARCH-t	EX9_5	0,91	0,17%	6,0%	2,40	21,3%	20,4%	138,5%	98,7%	98,7%	1,3%	0,73	0,3%	98,7%	98,7%	1,3%
LOGIT	GARCH-t	EX9_5	0,91	0,17%	6,0%	2,40	21,3%	20,4%	138,5%	98,7%	98,7%	1,3%	0,73	0,3%	98,7%	98,7%	1,3%
PROBIT SEL	GARCH-t	EM9_10	0,95	0,18%	4,5%	1,88	12,8%	12,0%	12,1%	98,7%	98,7%	1,3%	0,78	0,3%	98,7%	98,7%	1,3%
LOGIT SEL	GARCH-t	EM9_10	0,96	0,18%	4,7%	1,90	12,8%	12,0%	12,1%	98,7%	98,7%	1,3%	0,80	0,3%	98,7%	98,7%	1,3%
CLOGLOG SEL	GARCH-t	EM9_10	0,97	0,18%	4,7%	1,93	12,8%	11,9%	12,0%	98,7%	98,7%	1,3%	0,80	0,3%	98,7%	98,7%	1,3%
BRAK	GARCH-t	BRAK	1,25	0,24%	6,26%	2,46	12,48%	11,63%	11,74%	98,73%	98,73%	1,3%	1,03	0,41%	97,5%	98,7%	1,3%

RESULTS – MODEL EWS-GARCH- $t(1,1)$

MPS	MSS	MST	LR _{UC}	LR _{IND}	LR _{CC}	Z _{UC}	Z ^p _{UC}	Z ^G _{UC}
BRAK	GARCH EMP	BRAK	7,59%	8,86%	5,06%	10,13%	5,06%	5,06%
BRAK	GARCH	BRAK	8,86%	8,86%	7,59%	24,05%	2,53%	21,52%
BRAK	EGARCH	BRAK	10,13%	5,06%	8,86%	24,05%	2,53%	21,52%
LOGIT	GARCH-t	LN9_10	68,35%	6,33%	45,57%	68,35%	67,09%	1,27%
PROBIT	GARCH-t	LN9_10	69,62%	6,33%	45,57%	69,62%	68,35%	1,27%
LOGIT SEL	GARCH-t	LN9_10	70,89%	3,80%	40,51%	70,89%	69,62%	1,27%
CLOGLOG	GARCH-t	LN9_10	70,89%	6,33%	44,30%	70,89%	69,62%	1,27%
CLOGLOG SEL	GARCH-t	LN9_10	70,89%	3,80%	44,30%	70,89%	69,62%	1,27%
LOGIT	GARCH-t	WE9_10	70,89%	5,06%	45,57%	70,89%	69,62%	1,27%
PROBIT	GARCH-t	WE9_10	72,15%	5,06%	45,57%	72,15%	70,89%	1,27%
PROBIT SEL	GARCH-t	LN9_10	73,42%	3,80%	41,77%	73,42%	72,15%	1,27%
LOGIT SEL	GARCH-t	WE9_10	73,42%	3,80%	43,04%	73,42%	72,15%	1,27%
CLOGLOG	GARCH-t	WE9_10	73,42%	5,06%	44,30%	73,42%	72,15%	1,27%
CLOGLOG SEL	GARCH-t	WE9_10	73,42%	3,80%	45,57%	73,42%	72,15%	1,27%
PROBIT SEL	GARCH-t	WE9_10	74,68%	3,80%	45,57%	74,68%	73,42%	1,27%
PROBIT	GARCH-t	WE9_5	74,68%	2,53%	46,84%	74,68%	73,42%	1,27%
CLOGLOG	GARCH-t	WE9_5	75,95%	1,27%	46,84%	75,95%	74,68%	1,27%
LOGIT	GARCH-t	WE9_5	75,95%	1,27%	46,84%	75,95%	74,68%	1,27%
PROBIT	GARCH-t	GM9_5	75,95%	2,53%	48,10%	75,95%	74,68%	1,27%
CLOGLOG SEL	GARCH-t	GM9_5	77,22%	2,53%	46,84%	77,22%	75,95%	1,27%
CLOGLOG SEL	GARCH-t	WE9_5	77,22%	3,80%	46,84%	77,22%	75,95%	1,27%
CLOGLOG	GARCH-t	GM9_5	77,22%	1,27%	48,10%	77,22%	75,95%	1,27%
LOGIT	GARCH-t	GM9_5	77,22%	1,27%	48,10%	77,22%	75,95%	1,27%
PROBIT SEL	GARCH-t	GM9_5	77,22%	2,53%	48,10%	77,22%	75,95%	1,27%
PROBIT	GARCH-t	LN9_5	77,22%	2,53%	48,10%	77,22%	75,95%	1,27%
PROBIT SEL	GARCH-t	WE9_5	77,22%	3,80%	48,10%	77,22%	75,95%	1,27%

RESULTS – EWS-GARCH GROUPS

- EWS-GARCH(1,1)
 - All models EWS-GARCH(1,1) lead to reduction in VaR exceedance wrt GARCH(1,1), there are also models that lead to reduction in VaR exceedance wrt GARCH EMP(1,1)
 - Cost reduction wrt GARCH(1,1) – almost all
 - Almost all EWS-GARCH(1,1) are qualified to green or at least yellow zone
 - Share of exceedance closer to expected 1% than for all benchmark models:
 - P5 and conservative definition of 99 percentile for any tail distribution, liberal definition of 99 percentile for exponential distribution
- EWS-GARCH EMP(1,1)
 - There are EWS-GARCH EMP(1,1) models that lead to reduction in VaR exceedance and cost reduction wrt GARCH EMP(1,1)
 - All EWS-GARCH EMP(1,1) are qualified to green zone
 - EWS-GARCH EMP(1,1) can't be more precise than GARCH EMP(1,1) because only more conservative models are taken into consideration
- EWS-GARCH-t(1,1)
 - There are EWS-GARCH-t(1,1) models that lead to reduction in VaR exceedance and cost reduction (all) wrt GARCH-t(1,1)
 - There are EWS-GARCH-t(1,1) which are more precise wrt costs of using
 - **TRADE-OFF:** reduction in VaR exceedance vs. costs of using
 - **BUT!** There are EWS-GARCH-t(1,1) models which are more conservative than GARCH-t(1,1) and cheaper from all perspectives

RESULTS – EWS-GARCH MODELS

- EWS-GARCH models lead to VaR exceedance reduction in comparison to benchmark models
- Optimal assumptions should be chosen wrt purposes of the model (adequacy, conservatism, costs)
- EWS-GARCH models may increase conservatism for each benchmark model, not increasing significantly costs of using
- For EWS-GARCH(1,1) it is possible to build a model for which VaR predictions exceedance is closer to 1% than for all benchmark models.
- **REMARK:** average results are presented, for specific time series different assumptions may be the best

FUTURE DIRECTIONS OF RESEARCH

- MODELS FOR PREDICTING STATE OF TURBULENCE
 - Time series specificity
 - Additional independent variables (i.e. estimate of actual variance or different parameters of fundamental analysis)
- EWS-GARCH MODELS
 - Inclusion of correlation between different assets in portfolio (multivariate EWS-GARCH models)

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