



# Contents

<b>1</b>	<b>Introduction</b> .....	<b>1</b>
1.1	Problem Definition and Objectives of this Thesis.....	1
1.2	Course of Investigation.....	4
<b>2</b>	<b>The German Electricity Market</b> .....	<b>7</b>
2.1	Historical Development from a Legal Perspective .....	7
2.1.1	The Market Prior to its Liberalization .....	7
2.1.2	Amendments of EnWG and Liberalization .....	8
2.1.3	The EEG and its Amendments from 2000 to 2017 .....	9
2.1.4	European Union Emission Trading Scheme .....	10
2.2	The Situation in the Retail Market.....	11
2.3	The Wholesale Market .....	13
2.3.1	Power Exchanges EEX and EPEX.....	13
2.3.2	Market Design.....	14
2.3.2.1	Day-Ahead Auction Market .....	14
2.3.2.2	Continuous Intraday Market .....	15
2.3.2.3	Futures Market.....	16
2.3.2.4	Temporal Sequence of Trading Periods .....	16
2.3.3	Balancing Energy .....	17
2.4	Structure of the Power Plant Portfolio.....	18
2.4.1	Marginal Costs of Power Plants .....	18
2.4.2	Recent Developments .....	21
<b>3</b>	<b>Forecasting Performance of Time Series Models: A Quasi-Meta-Analysis</b> .....	<b>23</b>
3.1	Motivation.....	23



3.2	Theory of Modeling and Forecasting Electricity Spot Prices .....	26
3.2.1	Data Transformation .....	27
3.2.2	Types of Models.....	28
3.2.3	In-Sample and Out-of-Sample Horizon.....	30
3.2.4	Forecasting Accuracy Measures .....	32
3.3	Characteristics of the Analyzed Studies .....	33
3.3.1	Characteristics in General .....	34
3.3.2	Frequency and Segmentation of Data .....	35
3.3.3	Data Transformation .....	36
3.3.4	Types of Models.....	36
3.3.5	Exogenous Variables .....	38
3.3.6	In-Sample and Out-of-Sample Horizon.....	39
3.3.7	Forecasting Accuracy Measures .....	41
3.4	Quasi-Meta-Analysis .....	42
3.4.1	Methodology .....	43
3.4.2	Results of Forecasting Performance Evaluation .....	44
3.4.3	Robustness Check.....	48
3.5	Interim Results .....	50
3.6	Appendix.....	53
3.6.1	Definitions of ARMA and GARCH models .....	53
3.6.1.1	AR.....	53
3.6.1.2	MA .....	53
3.6.1.3	ARMA .....	54
3.6.1.4	ARIMA .....	55
3.6.1.5	Seasonal ARIMA.....	55
3.6.1.6	Seasonal ARIMA with Exogenous Input .....	56
3.6.1.7	GARCH and Extensions.....	56
3.6.2	List of Related Literature .....	60
3.6.3	Detailed Vote Count Table .....	73
<b>4</b>	<b>Forecasting Performance of Time Series Models: Empirical Study .....</b>	<b>75</b>
4.1	Motivation.....	75



4.2	Hypotheses .....	77
4.2.1	Performance of Different Time Series Models .....	77
4.2.2	Choice of Data Transformation and Segmentation .....	79
4.2.3	Choice of the In-Sample Time Horizon .....	80
4.3	Methodology .....	80
4.4	Data .....	84
4.5	Model Structures and Identification .....	86
4.6	Forecasting Performance Study .....	91
4.6.1	Performance of Time Series Models .....	91
4.6.2	Choice of Data Transformation and Segmentation .....	97
4.6.3	Choice of the In-Sample Time Horizon .....	99
4.7	Recap of the Obtained Results .....	102
4.8	Interim Results .....	103
4.9	Appendix .....	105
4.9.1	Appendix to Transformation and Segmentation .....	105
4.9.2	Ranking for Different In-Sample Periods .....	106
4.9.3	Results for Different Out-of-Sample Periods .....	107
<b>5</b>	<b>The Effect of Wind and Solar Power on Electricity Prices .....</b>	<b>110</b>
5.1	Motivation .....	110
5.2	Literature Review .....	112
5.2.1	Merit-Order Effect .....	112
5.2.2	Ramping Power Plants .....	116
5.2.3	Forecasting Errors on Wind and Solar Feed-Ins .....	117
5.3	Model Estimation .....	118
5.3.1	Data and Descriptive Analysis .....	118
5.3.2	Model Design .....	121
5.3.2.1	Regression Model Structure .....	121
5.3.2.2	Variable Design: Technology of the Marginal Power Plant .....	124
5.3.2.3	Variable Design: Ramping Effects .....	126
5.3.2.4	Model Modification: Intraday Prices and Forecasting Errors .....	128
5.4	Empirical Results .....	130