In and Outside the Tails: Making and Evaluating Forecasts

In and Outside the Tails: Making and Evaluating Forecasts

In en buiten de staarten: Het maken en evalueren van voorspellingen

Thesis

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Chapter 1

Introduction

In time-series econometrics a large strand of the literature is involved with finding the optimal forecast for some economically relevant random variable. The search for this optimal forecast relies, at least partly, on three types of research. First, we can extend the set of forecasts by proposing new forecasting models. Second, we can develop new tests to evaluate correctness of forecasting models, or to rank forecasting models. Finally, in applied research we can take the models to the data, and test which forecasting models actually outperform others empirically, using the techniques developed in the previous steps.

In this thesis I aim to add to each of these types of research. In Chapter 2 I develop a new estimator for a quantity we call *interquantile expectations*, and which will be elaborated on below. In joint work with Andrew Patton, I extend tests of equal predictive ability of forecasting models in Chapter 3, such that we can test hypotheses that are parameterized uniformly over some parameter space. Parameterized hypotheses are commonly encountered in economics and statistics, and I elaborate below. In joint work with Dick van Dijk and Erik Kole, I investigate the effect of estimation error on recently introduced Expected Shortfall tests in Chapter 4. Simulations show that this effect can be quite substantial, and we therefore propose robust versions of these tests to correct for estimation error. Finally, in Chapters 2 and 3 I include several empirical applications that show that the new estimators and tests are relevant for financial return data.

The starting point to most of the research contained in this thesis has been informed by the risk measure Expected Shortfall (ES). It is therefore of interest to briefly discuss this quantity. ES has recently been given increased attention in the literature, since it is designated to replace Value-at-Risk (VaR) as the new standard risk measure that banks must utilize in their risk models by the Basel Committee on Banking Supervision (BCBS), with the implementation of this replacement expected to happen soon (BCBS, 2016). The reasoning behind the replacement of VaR by ES are now well-known, and relate to the pitfalls of VaR as a risk measure.

VaR, which is defined as a specific tail quantile of some asset return, does not take into consideration the probability distribution of the realizations in the tail below VaR. Two financial asset portfolios can therefore have equivalent VaR, but greatly varying probability of losses beyond VaR. ES, which is defined as the expectation over the potential return realizations below VaR, is considered by the BCBS to be a more *prudent* risk measure, since its value does depend on the probability distributed to tail events.

More generally, VaR violates certain *coherence* properties that make it inappropriate as a risk measure for portfolios of assets (see, e.g, Artzner et al. (1997, 1999)). VaR, for instance, violates subadditivity, such that the VaR of a portfolio can be larger than the sum of the VaR of individual positions. As a result, risk managers cannot reliably infer risk properties for the total portfolio from smaller portfolios. ES is subadditive when returns are continuously distributed (Acerbi and Tasche, 2002), and is therefore preferred in many practical scenarios.

On the other hand, since VaR is defined as a quantile, and ES is the expectation of tail realizations beyond VaR, ES will be more affected by outliers than VaR. It is well-known that this can have considerable impact on estimation and testing. For instance, in their seminal paper Koenker and Bassett (1978) show that the mean is less efficient than the median for several error distributions. Moreover, the definition of ES contains VaR, such that an estimator of ES also requires the estimation of VaR, which can potentially add additional noise to an estimator of ES.

In Chapter 2 I propose a new estimator of ES, and more generally *interquantile expectation*, which I define as the expectation over an interval in between two quantiles, or as one-sided intervals below or above a quantile. ES is the interquantile expectation below VaR.[1] The estimator is semi-parametric in the sense that it does not require a specification of the full conditional distribution, and is based on a new family of *joint consistent scoring functions* for VaR and ES introduced in Fissler et al. (2016). The estimator is identified by

[1] Here we denote ES as and VaR in the left tail of the distribution, such that they are negative. In parts of the literature it is more common to define VaR and ES using a sign change, such that they are positive numbers, and quantify 'large' potential losses.

the expectation of the first order conditions of these scoring functions (up to some measurable constant that differs amongst members of the family.) I find that these identification conditions ensure that the estimation of VaR can be performed at a separate stage, and do not influence the asymptotic covariance matrix of the interquantile expectations, which alleviates some of the issues raised in the previous paragraph. Moreover, in a Monte-Carlo study I find that parameter estimates are usually similarly behaved to VaR parameter estimates, at the appropriate coverage levels suggested by the BCBS, such that it seems that the estimation of ES is not more difficult than VaR in this semi-parametric setup.

Moving beyond ES, in Chapter 2 I also consider an application to asset pricing, in which we study average abnormal returns of size and value strategies on several interquantile intervals of the excess portfolio return. The average abnormal return is defined as the intercept in a regression of the excess return of an asset portfolio on risk factors. Arbitrage pricing theory (Ross, 1976) hypothesizes that it should be zero. However, if non-zero average abnormal returns are found, it is of interest to study when these abnormal returns realize. We find that the abnormal returns found in small size stocks are disproportionally realized in the left and right tail intervals, since the difference in abnormal returns between these intervals is disproportionally large. As a result, investors that use small size stocks in their portfolios are quite dependent on the realization of unlikely tail events, and must therefore be patient in obtaining the average abnormal returns.

In Chapter 4 we study the effect of estimation error on backtests of ES that are based on testing a condition that is similar to the the identification condition in Chapter 2. Tests based on this condition are introduced in Nolde and Ziegel (2017), and have the attractive feature that they do not require an estimate of the conditional density of the return, unlike the tests in Du and Escanciano (2016). On the other hand, these testing condition result in tests for which we must estimate the asymptotic covariance matrix, which can be quite noisy, unlike most VaR tests, for which the asymptotic covariance matrix is a known constant (matrix).[2]

West (1996), West and McCracken (1998), and McCracken (2000) document the effect of estimation error on backtests. These effects are present when the lenghts of in-sample and out-of-sample periods grow proportionally as the sample size increases. Escanciano and Olmo (2010a) extend this framework to correct specification backtests of VaR forecasts, and

[2]This also holds for tests based on the *cumulative hit process*, such as Du and Escanciano (2016). A downside is these tests require an estimate of the conditional density to obtain the cumulative hits.

we extend their framework to the backtests of Nolde and Ziegel (2017). Our simulation study shows that estimation error has a pronounced effect on unconditional and conditional specification of the Nolde & Ziegel backtests. Moreover, relatively large size distortions are observed for small out-of-sample periods in comparison to the VaR backtests of Escanciano and Olmo (2010a) or the ES backtests of Du and Escanciano (2016). This may be caused by the greater effect of outliers on this particular testing condition and the asymptotic covariance matrix estimator being relatively noisy. We derive robust counterparts to the tests that correct for estimation error, and the unconditional robust test and the robust version of the conditional test specification preferred by Nolde and Ziegel (2017) have good size properties for moderately large out-of-sample periods. On the other hand, robust versions of *naive* conditional specifications still have very bad size properties, which suggests that care must be taken in designing conditional specifications of the test.

Chapter 3 is the most general of the chapters contained in this thesis, since we generalize equal predictive ability tests of Diebold and Mariano (1995) and Giacomini and White (2006) in order to test a set of hypotheses of equal predictive ability. This set of hypotheses is parameterized by some parameter vector in Euclidean space. Parameterized hypotheses are common in the economic and statistical literature, and examples include (i) equal expected utility in terms of the power utility function, which is parameterized by a risk aversion parameter, or (ii) equal expected statistical loss, in terms of a set of parameterized loss functions; such Bregman functions that are parameterized by a real scalar parameter (Gneiting, 2011) and which are consistent in evaluating forecasts of the mean. Our generalized tests use as test statistics the supremum or average of the individual test statistics over the parameter space. Inference is based on an extension of the simulation procedure in Hansen (1996b).

We consider two empirical applications. In the first application we evaluate equal expected utility hypotheses of two commonly used portfolio strategies, the equally-weighted portfolio, and the minimum-variance portfolio (see DeMiguel et al. (2007) for an elaborate treatment of these models in terms of out-of-sample performance). We consider power utility and show that, for commonly used parameters, the expected utility difference is insignificant.

In a second application we consider equal predictive ability of multivariate models in terms of VaR forecasts. VaR is only defined for scalar random variables. Comparing the accuracy of VaR forecasts obtained from multivariate models is therefore inherently based on the choice of a weight vector that maps the asset return vector to a portfolio return. Our tests allow the researcher to consider a set of weight vectors to test over, and our test is therefore more robust than testing at a single vector as is common in the literature — especially since in absence of continuous rebalancing of the portfolio, portfolio weights will change over time. We find significant differences between VaR forecasts for some of the samples considered. Like VaR, ES is only defined for scalar random variables, and our testing framework is therefore equally interesting for comparison of ES forecasts.

In summary, in this thesis I develop an estimator of interquantile expectation, with special case Expected Shortfall, in Chapter 2. I extend tests of equal predictive ability in Chapter 3, in joint work with Andrew Patton. Finally, I derive the effect of estimation error on recently proposed expected shortfall tests, and propose tests that are robust to this effect in Chapter 4, in joint work with Dick van Dijk and Erik Kole.

Nederlandse Samenvatting

(Summary in Dutch)

In de tijdreekseconometrie is een behoorlijk deel van de literatuur erop gericht de beste voorspelling te vinden voor een scala aan kansvariabelen. De zoektocht naar de optimale voorspelling is, in ieder geval, afhankelijk van drie typen onderzoek. Ten eerste kunnen we de verzameling van voorspelmodellen uitbreiden door middel van het introduceren van nieuwe modellen. Ten tweede kunnen we nieuwe testen ontwikkelen om voorspellingen te evalueren—enerzijds door individueel te bekijken of voorspellingen correct zijn; anderzijds door een verzameling aan voorspellingen te rangschikken op basis van voorspellende kracht. Ten derde kunnen we de eerder genoemde modellen en testen toepassen op verzamelde data, om zo te bestuderen welke voorspelmodellen het beste werken voor echte data.

In deze dissertatie tracht ik aan alledrie typen onderzoek iets toe te voegen. Het startpunt bij het meeste van dit onderzoek is risicomanagement in het algemeen, en de risicomaatstaven Value-at-Risk (VaR) en Expected Shortfall (ES) in het bijzonder. ES is recentelijk door de *Basel Committee on Banking Supervision* aangewezen om VaR te vervangen als risicomaatstaf in het financieel systeem, waardoor een grote interesse is ontstaan in het introduceren en evalueren van voorspelmethoden voor ES.

In Hoofdstuk 2 introduceer ik daartoe een nieuwe schatter voor ES, welke ook breder ingezet kan worden voor het schatten van *interquantile expectation*. Deze interquantile expectations kunnen worden ingezet om het gemiddelde van een bepaalde variable op te splitsen. In een toepassing in de financiële economie, pas ik de nieuwe schattingsmethode toe en laat ik zien dat de gemiddelde abnormale rendementen van portefeuilles van aandelen met een kleine marktwaarde vooral worden gerealiseerd op dagen met ongebruikelijk grote of kleine rendementen.

In Hoofdstuk 3 breid ik, in samenwerking met Andrew Patton, testen uit waarmee hypotheses kunnen worden geëvalueerd of twee voorspellingen gelijke voorspellingskracht hebben. De noviteit van de testen is dat, in plaats van een specifieke versie van de nulhypothese te evalueren, we alle mogelijke specificaties van de nulhypothese gezamenlijk kunnen evalueren. Dat kan leiden tot testen die beter onderscheid maken tussen voorspellingen. In twee toepassingen met betrekking tot investeringsstrategieën en VaR voorspellingen voor aandelenportefeuilles laten we zien dat er een *continuum* aan nulhypotheses op te stellen is, en de nieuwe testen daardoor toepasselijk zijn. De testen presteren ook goed in relatie tot andere testmethoden.

In Hoofdstuk 4 bekijk ik samen met Dick van Dijk en Erik Kole hoe de aanwezigheid van schattingsfouten het evalueren van ES voorspellingen kan beïnvloeden. Met schattingsfouten bedoelen we de afwijking tussen de populatieparameters van het voorspelmodel en de geschatte parameters. We doen dit door schattingseffecten te kwantificeren voor een scala aan recent geïntroduceerde ES testen. Daarnaast vergelijken we de testen met concurrerende testen waarvoor dit al eerder is gedaan. In een similatiestudie laten we zien dat de onconditionele testen competitief zijn, maar dat nieuwe conditionele testen, waarbij we kijken naar bepaalde interacties van ES voorspellingen met het verleden, vaak onbetrouwbaar zijn en niet gebruikt zouden moeten worden.

Bibliography

Acerbi, C., Székely, B., 2014. Back-testing Expected Shortfall. Risk, 76.

Acerbi, C., Tasche, D., 2002. On the Coherence of Expected Shortfall. Journal of Banking & Finance 26 (7), 1487–1503.

Adrian, T., Brunnermeier, M. K., 2016. CoVaR. American Economic Review 106 (7), 1705–1741.

Ambrosetti, A., Prodi, G., 1995. A Primer of Nonlinear Analysis. Cambridge University Press.

Andersen, T. G., Bollerslev, T., Christoffersen, P. F., Diebold, F. X., 2006. Chapter 15 Volatility and Correlation Forecasting. Vol. 1 of Handbook of Economic Forecasting. Elsevier, pp. 777–878.

Andrews, D. W., 1992. Generic Uniform Convergence. Econometric Theory 8 (2), 241–257.

Andrews, D. W., 1994. Chapter 37 Empirical Process Methods in Econometrics. Vol. 4 of Handbook of Econometrics. Elsevier, pp. 2247–2294.

Artzner, P., Delbaen, F., Eber, J.-M., Heath, D., 1997. Thinking Coherently. Risk, 68–71.

Artzner, P., Delbaen, F., Eber, J.-M., Heath, D., 1999. Coherent Measures of Risk. Mathematical Finance 9 (3), 203–228.

Bai, X., Russell, J. R., Tiao, G. C., 2003. Kurtosis of GARCH and Stochastic Volatility Models with Non-Normal Innovation. Journal of Econometrics 114 (2), 349–360.

Banz, R. W., 1981. The Relationship Between Return and Market Value of Common Stocks. Journal of Financial Economics 9 (1), 3–18.

Barendse, S., 2017. Interquantile Expectation Regression. Working paper.

BCBS, 2016. Minimum Capital Requirements for Market Risk. Tech. rep., Basel Committee on Banking Supervision.

Berkowitz, J., 2001. Testing Density Forecasts, with Applications to Risk Management. Journal of Business & Economic Statistics 19 (4), 465–474.

Berkowitz, J., Christoffersen, P., Pelletier, D., 2011. Evaluating Value-at-Risk Models with Desk-Level Data. Management Science 57 (12), 2213–2227.

Black, F., Jensen, M. C., Scholes, M., 1972. The Capital Asset Pricing Model: Some Empirical Findings. Studies in the Theory of Capital Markets. Praeger.

Bliss, R. R., Panigirtzoglou, N., 2004. Option-Implied Risk Aversion Estimates. The Journal of Finance 59 (1), 407–446.

Bollerslev, T., 1986. Generalized Autoregressive Conditional Heteroskedasticity. Journal of Econometrics 31 (3), 307–327.

Bollerslev, T., 1987. A Conditionally Heteroskedastic Time Series Model for Speculative Prices and Rates of Return. The Review of Economics and Statistics 69 (3), 542–547.

Bradley, R. C., et al., 2005. Basic Properties of Strong Mixing Conditions. A Survey and Some Open Questions. Probability surveys 2, 107–144.

Bühlmann, P., 1995. The Blockwise Bootstrap for General Empirical Processes of Stationary Sequences. Stochastic Processes and Their Applications 58 (2), 247–265.

Chernozhukov, V., Fernández-Val, I., Galichon, A., 2010. Quantile and Probability Curves Without Crossing. Econometrica 78 (3), 1093–1125.

Chernozhukov, V., Fernández-Val, I., Melly, B., 2013. Inference on Counterfactual Distributions. Econometrica 81 (6), 2205–2268.

Chernozhukov, V., Hansen, C., 2006. Instrumental Quantile Regression Inference for Structural and Treatment Effect Models. Journal of Econometrics 132 (2), 491–525.

Christoffersen, P. F., 1998. Evaluating Interval Forecasts. International Economic Review 39 (4), 841–862.

Clark, T. E., McCracken, M. W., 2001. Tests of Equal Forecast Accuracy and Encompassing for Nested Models. Journal of Econometrics 105 (1), 85–110.

Corsi, F., 2009. A Simple Approximate Long-Memory Model of Realized Volatility. Journal of Financial Econometrics 7 (2), 174–196.

Davydov, Y., Lifshits, M. A., Smorodina, N., 1998. Local Properties of Distributions of Stochastic Functionals. American Mathematical Society.

DeMiguel, V., Garlappi, L., Uppal, R., 2007. Optimal Versus Naive Diversification: How Inefficient is the 1/N Portfolio Strategy? The Review of Financial Studies 22 (5), 1915–1953.

Diebold, F. X., Mariano, R. S., 1995. Comparing Predictive Accuracy. Journal of Business & Economic Statistics 13 (3), 253–263.

Dimitriadis, T., Bayer, S., 2017. A Joint Quantile and Expected Shortfall Regression Framework. arXiv preprint arXiv:1704.02213.

Doob, J. L., 1953. Stochastic Processes. Wiley.

Doukhan, P., Lang, G., Leucht, A., Neumann, M. H., 2015. Dependent Wild bootstrap for the Empirical Process. Journal of Time Series Analysis 36 (3), 290–314.

Doukhan, P., Massart, P., Rio, E., 1995. Invariance Principles for Absolutely Regular Empirical Processes. Annales de l'I.H.P. Probabilités et Statistiques 31 (2), 393–427.

Du, Z., Escanciano, J. C., 2016. Backtesting Expected Shortfall: Accounting for Tail Risk. Management Science 63 (4), 940–958.

Engle, R., 2002. Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models. Journal of Business & Economic Statistics 20 (3), 339–350.

Engle, R., Colacito, R., 2006. Testing and Valuing Dynamic Correlations for Asset Allocation. Journal of Business & Economic Statistics 24 (2), 238–253.

Engle, R. F., Manganelli, S., 2004. CAViaR: Conditional Autoregressive Value at Risk by Regression Quantiles. Journal of Business & Economic Statistics 22 (4), 367–381.

Escanciano, J. C., Olmo, J., 2010a. Backtesting Parametric Value-at-Risk With Estimation Risk. Journal of Business & Economic Statistics 28 (1), 36–51.

Escanciano, J. C., Olmo, J., 2010b. Robust Backtesting Tests for Value-at-Risk Models. Journal of Financial Econometrics 9 (1), 132–161.

Fama, E. F., French, K. R., 1992. The Cross-Section of Expected Stock Returns. The Journal of Finance 47 (2), 427–465.

Fama, E. F., French, K. R., 1993. Common Risk Factors in the Returns on Stocks and Bonds. Journal of Financial Economics 33 (1), 3–56.

Fissler, T., Fasciati-Ziegel, J., Gneiting, T., 2015. Expected Shortfall is Jointly Elicitable with Value at Risk - Implications for Backtesting. Risk.

Fissler, T., Ziegel, J. F., et al., 2016. Higher Order Elicitability and Osband's Principle. The Annals of Statistics 44 (4), 1680–1707.

Fitzenberger, B., 1998. The Moving Blocks Bootstrap and Robust Inference for Linear Least Squares and Quantile Regressions. Journal of Econometrics 82 (2), 235 – 287.

Fleming, J., Kirby, C., Ostdiek, B., 2001. The Economic Value of Volatility Timing. The Journal of Finance 56 (1), 329–352.

Fleming, J., Kirby, C., Ostdiek, B., 2003. The Economic Value of Volatility Timing Using "Realized" Volatility. Journal of Financial Economics 67 (3), 473–509.

Giacomini, R., Komunjer, I., 2005. Evaluation and Combination of Conditional Quantile Forecasts. Journal of Business & Economic Statistics 23 (4), 416–431.

Giacomini, R., White, H., 2006. Tests of Conditional Predictive Ability. Econometrica 74 (6), 1545–1578.

Gibbons, M. R., Ross, S. A., Shanken, J., 1989. A test of the efficiency of a given portfolio. Econometrica 57 (5), 1121–1152.

Glosten, L. R., Jagannathan, R., Runkle, D. E., 1993. On the Relation Between the Expected Value and the Volatility of the Nominal Excess Return on Stocks. The Journal of Finance 48 (5), 1779–1801.

Gneiting, T., 2011. Making and Evaluating Point Forecasts. Journal of the American Statistical Association 106 (494), 746–762.

Gneiting, T., Raftery, A. E., 2007. Strictly Proper Scoring Rules, Prediction, and Estimation. Journal of the American Statistical Association 102 (477), 359–378.

Hansen, B. E., 1996a. Inference When a Nuisance Parameter Is Not Identified Under the Null Hypothesis. Econometrica 64 (2), 413–430.

Hansen, B. E., 1996b. Stochastic Equicontinuity for Unbounded Dependent Heterogeneous Arrays. Econometric Theory 12 (2), 347–359.

He, C., Teräsvirta, T., 1999. Properties of Moments of a Family of GARCH Processes. Journal of Econometrics 92 (1), 173–192.

Heber, G., Lunde, A., Shephard, N., Sheppard, K. K., 2009. Oxford-Man Institute's Realized Library. Tech. rep., Oxford-Man Institute, University of Oxford.

Huber, P. J., 1967. The Behavior of Maximum Likelihood Estimates under Nonstandard Conditions. In: Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability, Volume 1: Statistics. University of California Press, Berkeley, Calif., pp. 221–233.

Jegadeesh, N., Titman, S., 1993. Returns to Buying Winners and Selling Losers: Implications for Stock Market Efficiency. The Journal of Finance 48 (1), 65–91.

Jegadeesh, N., Titman, S., 2001. Profitability of Momentum Strategies: An Evaluation of Alternative Explanations. The Journal of Finance 56 (2), 699–720.

Kerkhof, J., Melenberg, B., 2004. Backtesting for Risk-Based Regulatory Capital. Journal of Banking & Finance 28 (8), 1845–1865.

Koenker, R., Bassett, G., 1978. Regression Quantiles. Econometrica 46 (1), 33–50.

Koenker, R., Hallock, K. F., December 2001. Quantile Regression. Journal of Economic Perspectives 15 (4), 143–156.

Kole, E., Markwat, T., Opschoor, A., Van Dijk, D., 2017. Forecasting Value-at-Risk under Temporal and Portfolio Aggregation. Journal of Financial Econometrics 15 (4), 649–677.

Kupiec, P. H., 1995. Techniques for Verifying the Accuracy of Risk Measurement Models. The Journal of Derivatives 3 (2), 73–84.

Marquering, W., Verbeek, M., 2004. The Economic Value of Predicting Stock Index Returns and Volatility. Journal of Financial and Quantitative Analysis 39 (2), 407–429.

McAleer, M., Da Veiga, B., 2008. Single-Index and Portfolio Models for Forecasting Value-at-Risk Thresholds. Journal of Forecasting 27 (3), 217–235.

McCracken, M. W., 2000. Robust Out-of-Sample Inference. Journal of Econometrics 99 (2), 195–223.

McNeil, A. J., Frey, R., 2000. Estimation of Tail-Related Risk Measures for Heteroscedastic Financial Time Series: an Extreme Value Approach. Journal of Empirical Finance 7 (3-4), 271–300.

McNeil, A. J., Frey, R., Embrechts, P., 2015. Quantitative Risk Management: Concepts, Techniques and Tools. Princeton University Press, Princeton, NJ.

Nadarajah, S., Zhang, B., Chan, S., 2014. Estimation Methods for Expected Shortfall. Quantitative Finance 14 (2), 271–291.

Newey, W. K., McFadden, D., 1994. Chapter 36 Large Sample Estimation and Hypothesis Testing. Vol. 4 of Handbook of Econometrics. Elsevier, pp. 2111–2245.

Newey, W. K., Powell, J. L., 1987. Asymmetric Least Squares Estimation and Testing. Econometrica 55 (4), 819–847.

Newey, W. K., West, K. D., 1987a. A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix. Econometrica 55 (3), 703–708.

Newey, W. K., West, K. D., 1987b. A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix. Econometrica 55 (3), 703.

Nolde, N., Ziegel, J. F., 2017. Elicitability and Backtesting: Perspectives for Banking Regulation. The Annals of Applied Statistics 11 (4), 1833–1874.

Patton, A. J., Ziegel, J. F., Chen, R., 2017. Dynamic Semiparametric Models for Expected Shortfall (and Value-at-Risk). arXiv preprint arXiv:1707.05108.

Pollard, D., 1990. Empirical processes: Theory and applications. NSF-CBMS Regional Conference Series in Probability and Statistics 2, i–86.

Portnoy, S., Koenker, R., 1997. The Gaussian Hare and the Laplacian Tortoise: Computability of Squared-Error Versus Absolute-Error Estimators. Statistical Science 12 (4), 279–300.

Powell, J. L., 1984. Least Absolute Deviations Estimation for the Censored Regression Model. Journal of Econometrics 25 (3), 303–325.

Powell, J. L., 1986. Censored Regression Quantiles. Journal of Econometrics 32 (1), 143–155.

Powell, J. L., 1994. Chapter 41 Estimation of Semiparametric Models. Vol. 4 of Handbook of Econometrics. Elsevier, pp. 2443 – 2521.

Riskmetrics, 1996. JP Morgan Technical Document.

Ross, S. A., 1976. The Arbitrage Theory of Capital Asset Pricing. Journal of Economic Theory 13 (3), 341–360.

Ruppert, D., Carroll, R. J., 1980. Trimmed Least Squares Estimation in the Linear Model. Journal of the American Statistical Association 75 (372), 828–838.

Santos, A. A., Nogales, F. J., Ruiz, E., 2012. Comparing Univariate and Multivariate Models to Forecast Portfolio Value-at-Risk. Journal of Financial Econometrics 11 (2), 400–441.

Shao, X., 2010. The Dependent Wild Bootstrap. Journal of the American Statistical Association 105 (489), 218–235.

Taylor, J. W., 2008a. Estimating Value at Risk and Expected Shortfall Using Expectiles. Journal of Financial Econometrics 6 (2), 231–252.

Taylor, J. W., 2008b. Using Exponentially Weighted Quantile Regression to Estimate Value at Risk and Expected Shortfall. Journal of Financial Econometrics 6 (3), 382–406.

Taylor, J. W., 2017. Forecasting Value at Risk and Expected Shortfall Using a Semiparametric Approach Based on the Asymmetric Laplace Distribution. Journal of Business & Economic Statistics, 1–13.

Weiss, A. A., 1991. Estimating Nonlinear Dynamic Models Using Least Absolute Error Estimation. Econometric Theory 7 (1), 46–68.

West, K. D., 1996. Asymptotic Inference about Predictive Ability. Econometrica 64 (5), 1067–1084.

West, K. D., McCracken, M. W., 1998. Regression-Based Tests of Predictive Ability. International Economic Review 39 (4), 817–840.

White, H., 1994. Estimation, Inference and Specification Analysis. Cambridge University Press.

White, H., 2001. Asymptotic Theory for Econometricians. Academic Press, Cambridge, MA.

Wong, W. K., 2008. Backtesting Trading Risk of Commercial Banks Using Expected Shortfall. Journal of Banking & Finance 32 (7), 1404–1415.

Wong, W. K., 2010. Backtesting Value-at-Risk Based on Tail Losses. Journal of Empirical Finance 17 (3), 526–538.

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