EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

Module Handbook

Quantitative Data Science Methods

Psychometrics, Econometrics and Machine Learning

Master of Science

Winter Semester 2023/24

Faculty of Economics and Social Sciences
Department of Social Sciences
Methods Center

Current as of: September, 2022

Table of Contents

Preface

Structure and Subject Matter

This handbook describes the modules that make up the Master's program *Quantitative Data Science Methods – Psychometrics, Econometrics and Machine Learning* (QDS) at the Faculty of Economics and Social Sciences, Methods Center (Eberhard Karls University Tübingen).
The Master's program consists of elective-compulsory modules ("Foundations") and a variety of elective and compulsory modules in three areas ("Psychometrics", "Econometrics" and "Machine Learning").
The Master's program QDS is an interdisciplinary study program on Quantitative Methods and Data Science connecting these three areas. The three areas reflect disciplines in which Quantitative Data Science Methods are applied and developed. Credit points have to be obtained in all areas to satisfy the interdisciplinary character, but the program allows specialization in one of these areas.
In this way, the partly different statistical methods in the fields of psychology and economics will be combined with state-of-the-art methods from the field of machine learning. Students will thus learn that the methods in the application areas of psychology and economics overlap (although they are currently converging) and they will learn to apply and understand partly the same or similar methods in different contexts. In addition, they become familiar with methods of machine learning that have only marginally found their application in the two fields of application so far and are enabled to link methods from all fields and to transfer them to the other fields.

Descriptions for the modules and areas of studies are given below, containing among other information the number of credit points required in each. Credit point requirements in a studies area are fulfilled by completing one or more modules belonging to that area and adding up credit points earned. Which module belongs to which area(s) can be seen from this handbook's modules list.

Credit Points

Students earn credit points (also: ECTS points based on the European Credit Transfer System, or simply credits) in study areas and modules. Credit points quantify a student's time investment. Following national as well as international standards (in Germany: Resolution of the Standing Conference of the Ministers of Education and Cultural Affairs, 24 October 1997), a credit point represents a workload of 30 hours in attended classes and autonomous study performed by the student. The overall per-semester workload (including nonterm periods) ought not to exceed 900 hours, resulting in approximately 30 credit points required of the student each semester. Credit points represent not only time spent physically attending classes, but also time spent on preparing for and processing classes, as well as autonomous activities such as preparation for exams, writing the master thesis, and practical projects. Credit points are earned by attending and participating in courses that make up the modules and require the completion of course-related tasks.

Types of Courses

Below we detail the general types of courses in the Master's program (note that some individual courses might give alternative information in their course descriptions).

Lectures, with and without tutorials. In lectures, transfer of knowledge takes the form of a series of talks by the teacher. Lectures often go hand in hand with tutorials that deepen the students' understanding and knowledge about the subject matter and apply the techniques presented in class to concrete examples and scenarios. Homework commonly accompany this course type. Often, programming and other practical exercises, in which tasks are completed under direct supervision, form an important part. Typically, performance measurement and grading are based on a written (or more rarely oral) exam at the end of term.

Seminars are a series of classes in which students take up a specific assigned subject matter and give a presentation about it in front of their teacher and other co-participants. Usually, handing in a written version is an additional requirement. Performance is measured, and grades assigned based on the presentation, the written report, and the student's active participation in class. Seminars can be held weekly over one or two semesters or as block seminars in nonterm periods.

Research Project. This module is intended to give students an opportunity to get engaged in the ongoing research conducted in one of the groups and labs participating in this study program, for the duration of one semester. This course type aims to closely link the Master's program to current research, and to thoroughly prepare students for their upcoming Master's thesis. Study and exam performance are usually evaluated based on active participation, a presentation of results and in written reports. If applicable, students can participate in scientific publications. The Research Project can be used as further specialization in one of the core areas of studies.

Grading

Modules will, as a rule, always be graded. Grades are determined by taking an examination of some sort – in the case of lectures, this is typically a written test. In certain instances, grading can be based on a multi-part examination. Details are given in the module descriptions. Grading is performed by the teachers of individual modules. According to our examination regulations, the grades of each module enter into the cumulative grade (Master's degree final grade), weighted by the module's credit points.

Prerequisites

The following criteria represent the study prerequisites:

- Bachelor grade of at least 2.5 in one of the following or related fields:
    - Mathematics
    - Computer Science
    - Physics
    - Economics
    - Quantitative Psychology
    - A secondary subject in Social and Behavioral Sciences is desirable

- Knowledge in Mathematics / Methods / Programming including at least (approx. 40 CPs)
    - One- and multidimensional Calculus
    - Linear Algebra
    - Statistics / Probability Theory
    - Basic knowledge in algorithms and data structure (e.g., R or Python)
- Knowledge in Social and Behavioral Sciences including at least (approx. 20 CPs)
    - Understanding how to work in Social and Behavioral Sciences empirically
    - Concept of Latent Variables
- Please provide the corresponding descriptions of your courses in your module handbook in your application (and only the corresponding pages not the full module book!)
- Candidates are judged based on their level of interest and their personal fit with the program. As part of the reviewing process we require a CV and highly recommend to hand in a letter of motivation. The final decision is based on the overall impression (e.g., grades, pre-knowledge, letter of motivation, and interview) of the fit to the program.
- English proficiency
    - German Abitur with English as the first or second foreign language, attended until the last year of school (at least "gut").
    - Accredited university degree of at least three years, entirely taught in English
    - University entrance qualification obtained in the UK, Ireland, USA, Canada, Australia or New Zealand
    - Language test corresponding to B2 of the Common European Framework of Reference for Languages (CEFR)
        - TOEFL iBT test (at least 79 points in total and reading: 20; listening: 19; speaking: 21; writing: 19)
        - IELTS (at least 6.5 in total and reading: 6.5; listening: 6; speaking: 6.5; writing: 5.5)
        - Cambridge Certificate in Advanced English (CAE) (B2 or higher)

Cooperation

The interdisciplinary Master's Program QDS covers a variety of methodological developments and applications as well as research in different methodological areas. Under the leadership of the Methods Center, a Core Facility of the University of Tübingen, the Master's Program QDS is a cooperation of four institutions:

Methods Center
Besides the organization and leadership of the Master's program, the Methods Center undertakes teaching especially in the Foundations and Psychometrics and Mathematical Psychology areas.
https://uni-tuebingen.de/en/128147

Psychometrics and Mathematical Psychology

In the study area Psychometrics and Mathematical Psychology (Area 2) the Methods Center cooperates with the Department of Psychology of the Faculty of Science.
https://uni-tuebingen.de/en/15934

Econometrics
The study area Econometrics (Area 3) is carried out with the School of Business and Economics at the Faculty of Economics and Social Sciences in Tübingen.
https://uni-tuebingen.de/en/11321

Machine Learning
In Machine Learning, students benefit from the first-class teaching and research at the Department of Computer Science at the University of Tübingen. Here the QDS program includes teaching and experience of the Machine Learning Master's Program in the study area of Machine Learning (Area 4)
https://uni-tuebingen.de/en/140323

Semester abroad

Students have the possibility to participate in exchange programs organized with partner universities. As part of the exchange, students can earn credit points by attending courses (e.g., in their area of specialization) at the partner university. Students are recommended to take a semester abroad during their 3. semester.
The university of Tübingen is part of the CIVIS network which allows students to participate in many online courses of the participating universities and provides additional capacities for a semester abroad. For further information please visit https://uni-tuebingen.de/en/181783.

Master´s Program Quantitative Data Science Methods

General Information

Subjects

The international Master's Program *Quantitative Data Science Methods – Psychometrics, Econometrics and Machine Learning* (QDS) will enable graduates to analyze, implement, leverage, and modify statistical techniques from psychometrics, econometrics, and statistical learning. The unique position feature of this program is its interdisciplinarity which enables a flexible transfer of procedures between disciplines (for example, the modeling of human behavior with new techniques from statistical learning, instead of traditional methods in psychometrics).

In today's widely digitized labor market, qualified specialists in the field of data science play an increasingly important role. Data analysis and applied statistics are no longer used only in the background for process optimization, but also take on prominent tasks in today's industry. The market for qualified specialists, on the other hand, is usually filled with lateral entrants due to a lack of experts in these fields. The Master's Program *Quantitative Data Science Methods – Psychometrics, Econometrics and Machine Learning* (QDS), together with other initiatives in Tübingen, will contribute to filling this gap by providing students with targeted training in application and research in the aforementioned field.

As future actors and deciders in the field, graduates will be competent across a range of areas, basic and many advanced fields, understanding and suitably applying modern (statistical learning) tools for dealing with (large) datasets, be it in science, industry or alternative domains.

The studies program deals both with generic methods and their applications to specific fields, making it highly relevant for new career and job market purposes, both in science and industry. Education in problem solving capabilities is a central training objective.

To pick up on scientific trends and make the best use of the current state of research, the curriculum relies heavily on the strong research presence on site, in the three areas. Top-level researchers in all major methodological branches of QDS are present in Tübingen – personnel that will actively engage in teaching for the Master's Program QDS. Training will be based on recent insights and interesting research questions from these fields.

Project work and the Master's thesis will offer students the opportunity to develop models and implementations for research purposes and their own scientific projects. In this whole Master's program, besides professional expertise, graduates will also acquire language skills and intercultural competence due to the program's international nature and exchange with international partner universities.

Qualification Objectives

The Master's Program QDS promotes a focus on research and methods development. It expands and deepens methodological and technical knowledge, enables graduates to work

scientifically, provides the basis for advancing the field, and prepares graduates for subsequent PhD studies. The Program specifically empowers graduates to take up responsible leading roles and emphasizes a scientific, research-oriented mindset based on independent thought, judgement and decision-making. The Master's Program QDS is a broad-based methodological program. Graduates are not only able to apply methods, but to evaluate and to develop methods in the three areas of interest. Through the respective specializations further expertise in relevant areas is gained. Strong cooperation with first-class teaching and research institutes within and outside the university, state-of-the-art applications are taught.

The Master's Program QDS explicitly aims to cover the full breadth of the field, ranging from fundamental skills in statistics and data handling to advanced methods of modern data analysis using a variety of methods. We will particular train students to be able to quickly take up new research developments in the three areas. Alongside aiming for breadth, the Master's Program QDS also encourages specialization, in that modules within one area of studies can be freely combined.

Data science today can no longer be operated without programming skills. Therefore, Master students are introduced to the relevant techniques right from the start. Through appropriate accompanying offers, graduates will also be able to reflect the ethical and moral handling of current topics of data science.

In their Master's thesis, graduates can take one approach and combine it with an interesting application from one of the three areas. The requisite depth of knowledge to do so will be obtained due to the Master's Program's consecutive studies plan, which is based on a B.Sc. with strong mathematical/statistical background.

Qualification objectives of this Master's program are as follows:

Graduates…

1. ...have further developed the qualifications obtained in their B.Sc. studies in an ongoing process of academic maturation. They have transferred learned skills to the interdisciplinary field of the three areas and gained facility in applying and implementing technical and non-technical knowledge.
2. ...have obtained expert knowledge in a chosen focus field in the wider area of one of three areas.
3. ...have the necessary breadth as well as depth to quickly acquaint themselves with new developments in their own area of expertise and its adjacent areas.
4. ...are able to successfully utilize, to critically examine and to further advance data science methods in order to formulate and solve complex problems of research and development in the industry as well as research.
5. ...have acquired a diverse technical and social skillset (abstraction, analytical and systematic thinking, teamwork, communication, international and intercultural competence etc.), empowering them to seek positions of leadership.
6. ...are optimally prepared not only for functions related to research and development, but also for further responsible and leading positions in the industry or public administration.

Areas of Studies and Structure

The four-semester Master's Program is split into four areas, covering interdisciplinary Foundations (QDS-FO) and the three core areas of Psychometrics and Mathematical Psychology (QDS-PS), Econometrics (QDS-EC) and Machine Learning (QDS-ML).
To ensure the interdisciplinary character of the program a minimum of 18 CPs have to be earned in each of the three core areas (QDS-PS, QDS-EC, QDS-ML), distributed on three semesters and a maximum of 30 CPs can be earned in each discipline.

Foundations (QDS-FO) – 18 to 27 CPs
The area Foundations covers general statistical and technical modules. Depending on the individual's prerequisites from the qualification degree, this area can serve to compensate for heterogeneity. For this purpose, personalized module combinations can be offered, focusing for example on statistics and probability theory or techniques such as programming. The Foundations area also offers the participation in one elective seminar on ethics in, e.g., technology, Data Science and AI.
In QDS-FO min 18 CPs have to be earned and a maximum of 27 CPs can be earned. It is recommended to cover this area within the first two semesters. In the third semester the Research Project covers this area with 9 CPs.
The modules on Selected Topics in QDS I/II/III (QDS-FO11 / QDS-FO12 / QDS-FO13) are intended to cover changing lectures and seminars or to react on individual needs and wishes. These modules can originate from all areas that provide foundational insides into Data Science. Eligible modules will be announced at the beginning of the semester or in individual discussions.

Psychometrics and Mathematical Psychology (QDS-PS) – 18 - 30 CPs
In Psychometrics and Mathematical Psychology, students learn typical methods used in these fields, such as (semiparametric) latent variable modeling, item response modeling, dynamic longitudinal modeling, Bayesian statistics, knowledge space theory, models for decision-making etc. Students are qualified to reflect the critical assumptions of the methods and to know their limitations. Obligatory courses are defined by the individual curriculum (see next paragraph).
The modules on Core Topics in Psychometrics I/II (QDS-PS11 / QDS-PS12) are intended to cover changing lectures. These modules can originate from the area of Psychometrics. Eligible modules will be announced at the beginning of the semester or in individual discussions.

Econometrics (QDS-EC) – 18 - 30 CPs
In this area, quantitative methods used in econometrics are introduced. The program within this area is flexible. Obligatory courses are defined by the individual curriculum (see next paragraph).
The modules on Core Topics in Econometrics I/II (QDS-EC10 / QDS-EC11) are intended to cover changing lectures. These modules can originate from the area of Econometrics. Eligible modules will be announced at the beginning of the semester or in individual discussions.

Machine Learning (QDS-ML) – 18 - 30 CPs
The area of Machine Learning introduces key concepts of the field. Obligatory courses are defined by the individual curriculum (see next paragraph).

The modules on Core Topics in Machine Learning I/II (QDS-ML7 / QDS-ML8) are intended to cover changing lectures. These modules can originate from the area of Machine Learning. Eligible modules will be announced at the beginning of the semester or in individual discussions.

Obligatory and elective modules

The Research Project (QDS-FO7), the Master Thesis (QDS-MT) and certain other modules are obligatory. Modules that appear in the requirements of other modules become mandatory if attending those modules. Any such prerequisite can be waived if there is proven knowledge of the expected competencies.
Instead of the Research Project (QDS-FO7) students can choose to attend the Master Seminar on Econometrics (QDS-FO8) if they want to focus on topics in Econometrics.

Students from different fields can apply for the QDS program. If deficits in the required basic knowledge in the respective elective areas were determined in the course of the decision according to Examinations Regulation § 2 (2), one or more of the modules QDS-PS1, QDS-EC1a or QDS-EC1b or QDS-ML1 can be required as mandatory and thus become part of the respective elective area in the sense of the Examinations Regulation §5 (2) and (3); otherwise, these modules cannot be selected.

For example, the following curricula are possible:

<u>Curriculum 1 – Psychometrics and Econometrics</u>
This study course applies to students who graduated in computer sciences and similar fields. They are obligated to take the courses Foundations in Psychometrics (QDS-PS1) and Foundations in Econometrics (QDS-EC1a or QDS-EC1b).

<u>Curriculum 2 – Psychometrics and Machine Learning</u>
This study course applies to students who graduated in Economics and similar fields. They are obligated to take the courses Foundations in Psychometrics (QDS-PS1) and Foundations in Machine Learning (QDS-ML1).

<u>Curriculum 3 – Machine Learning and Econometrics</u>
This study course applies to students who graduated in social sciences and similar fields. They are obligated to take the courses Foundations in Machine Learning (QDS-ML1) and Foundations in Econometrics (QDS-EC1a or QDS-EC1b).

The modules QDS-EC1a and QDS-EC1b account for two possibilities to learn the foundations of Econometrics. The students can choose which of the two modules they want to take.

A list of the lectures that can be counted towards QDS-PS1, QDS-EC1a/QDS-EC1b, QDS-ML1, Mathematical Introduction (QDS-FO1), Selected Topics in QDS I/II/III (QDS-FO11/12/13), Core Topics Psychometrics I/II (QDS-PS11/12), Core Topics Econometrics I/II (QDS-EC10/11), and Core Topics Machine Learning I/II (QDS-ML7/8) is published on the website.

Specialization

The program suggests a specialization in one of the three core areas. This specialization can be achieved in three stages

- Modules: The specialization area can cover a total of 30 CPs.
- Research Project: The topic of the Research Project can expand the specialization.
- Master thesis: The master thesis allows for further specialization in one area.

A specialization is not mandatory. The master's program offers a wider path with e.g. 21-24 CPs in each area and interdisciplinary topics in the Research Project and thesis as well.

Table 1: General Study Plan

1.-4. Semester			
Foundations (min 18 CP)			**30**
Foundations and techniques	Foundations and techniques	Research Project	Thesis
Psychometrics and Mathematical Psychologie (min 18 CP)			
Introduction / elective	elective modules	elective modules	
Econometrics (min 18 CP)			
Introdution / elective	elective modules	elective modules	
Machine Learning (min 18 CP)			
Introduction / elective	elective modules	elective modules	
~ 30 CP	~ 30 CP	~ 30 CP	**90 CP**

Table 2: Specialization in Psychometrics and Mathematical Psychology

	1. Semester (WS)		2. Semester (SS)		3. Semester (WS)		4. Semester (SS)	
min 18 CP each	**Foundations (24 CP)**							
	QDS-FO1 – Mathematical Introduction QDS-FO5 – Experimental and Quasi-Experimental Design	3 3	QDS-FO2 – Advanced Statistics QDS-FO10 – Connecting the Threads	3 6	QDS-FO7 – Research Project	9	**Thesis**	30
	Psychometrics and Mathematical Psychology (30 CP)							
	QDS-PS2 – Psychometrics QDS-PS7 – Structural Equation Modeling	6 6	QDS-PS3 – Item Response Theory QDS-PS6 – Multilevel Modeling	6 6	QDS-PS4 – Mathematical Models in Psychology	6		
	Econometrics (18 CP)							
			QDS-EC3 – Advanced Microeconometrics	9	QDS-EC6 – Statistics of Financial Markets	**9**		
	Machine Learning (18 CP)							
	QDS-ML1 – Machine Learning 1 QDS-ML3 – Data Literacy	6 6			QDS-ML4 – Deep Learning	6		
	30 CP		30 CP		30 CP			

Table 3: Specialization in Econometrics

	1. Semester (WS)		2. Semester (SS)		3. Semester (WS)		4. Semester (SS)	
	Foundations (24 CP)							
min 18 CP each	QDS-FO1 – Mathematical Introduction	3	QDS-FO2 – Advanced Statistics QDS-FO6 – Ethics Seminar QDS-FO7 – Bayesian Modeling	3 3 6	QDS-FO8 – Research Project	9	**Thesis**	30
	Psychometrics and Mathematical Psychology (18 CP)							
	QDS-PS2 – Psychometrics	**6**	QDS-PS3 – Item Response Theory	**6**	QDS-PS5 – Longitudinal Data Analysis	**6**		
	Econometrics (30 CP)							
	QDS-EC6 – Statistics of Financial Markets	9	QDS-EC2 – Applied Economics QDS-EC8 – Financial Market Microstructure	6 6	QDS-EC3 – Advanced Times Series Analysis	9		
	Machine Learning (18 CP)							
	QDS-ML2 – Machine Learning 1 QDS-ML3 – Data Literacy	6 6			QDS-ML4 – Deep Learning	6		
	30 CP		30 CP		30 CP			

Table 4: Specialization in Machine Learning

	1. Semester (WS)		2. Semester (SS)		3. Semester (WS)		4. Semester (SS)	
	Foundations (18 CP)							
min 18 CP each	QDS-FO1 – Mathematical Introduction	3	QDS-FO2 – Advanced Statistics QDS-FO6 – Ethics Seminar	3 3	QDS-FO8 – Research Project	9	**Thesis**	30
	Psychometrics and Mathematical Psychology (24 CP)							
	QDS-PS2 – Psychometrics QDS-PS7 – Structural Equation Modeling	**6** **6**	QDS-PS3 – Item Response Theory	6	QDS-PS5 – Longitudinal Data Analysis	**6**		
	Econometrics (18 CP)							
	QDS-EC6 – Statistics of Financial Markets	**9**			QDS-EC3 – Advanced Times Series Analysis	**9**		
	Machine Learning (30 CP)							
	QDS-ML2 – Machine Learning 1	6	QDS-ML5 – Statistical Machine Learning QDS-ML6 – Probabilistic Machine Learning	9 9	QDS-ML4 – Deep Learning	6		
	30 CP		30 CP		30 CP			

Table 5: No Specialization

	1. Semester (WS)		2. Semester (SS)		3. Semester (WS)		4. Semester (SS)	
	Foundations (21 CP)							
min 18 CP each	QDS-FO1 – Mathematical Introduction	3	QDS-FO2 – Advanced Statistics QDS-FO10 – Connecting the Threads	3 6	QDS-FO8 – Research Project	9	**Thesis**	30
	Psychometrics and Mathematical Psychology (24 CP)							
	QDS-PS2 – Psychometrics QDS-PS7 – Structural Equation Modeling	**6** **6**	QDS-PS3 – Item Response Theory	6	QDS-PS5 – Longitudinal Data Analysis	**6**		
	Econometrics (24 CP)							
	QDS-EC6 – Statistics of Financial Markets	**9**	QDS-EC2 – Applied Econometrics	6	QDS-EC3 – Advanced Times Series Analysis	**9**		
	Machine Learning (21 CP)							
	QDS-ML2 – Machine Learning 1	6	QDS-ML5 – Statistical Machine Learning	9	QDS-ML4 – Deep Learning	6		
	30 CP		30 CP		30 CP			

Module catalogue

Overview by Modules

(according to the module overview in the *exam regulations*)

Module Code	Obligatory / Elective	Module Title	Recommended Semester	Frequency	Area	CPs
	Foundations (18-27 CPs)					
QDS-FO1	Obligatory	Mathematical Introduction	1	WS	FO	3
QDS-FO2	Obligatory	Advanced Statistics	2	SS	FO	3
QDS-FO3	Elective	Programming I	1, 2	WS/SS	FO	3
QDS-FO4	Elective	Programming II	1, 2	WS/SS	FO	3
QDS-FO5	Elective	Experimental and Quasi-Experimental Design	1	WS	FO	3
QDS-FO6	Elective	Ethics Seminar	-	WS/SS	FO	3
QDS-FO7	Elective	Bayesian Modeling	2	SS	FO	6
QDS-FO8	Obligatory	Research Project	3	WS	FO	9
QDS-FO9	elective	Master Seminar on Econometrics	3	WS/SS	FO	9
QDS-FO10	Elective	Connecting the Threads	2	SS	FO	6
QDS-FO11	Elective	Selected Topics in QDS I	-	-	FO	3
QDS-FO12	Elective	Selected Topics in QDS II	-	-	FO	6
QDS-FO13	Elective	Selected Topics in QDS III	-	-	FO	9
	Psychometrics and Mathematical Psychology (18-30 CPs)					
QDS-PS1	(Obligatory)	Foundations in Psychometrics	1	-	PS	6
QDS-PS2	Elective	Psychometrics	1	WS	PS	6
QDS-PS3	Elective	Item Response Theory	2	SS	PS	6
QDS-PS4	Elective	Mathematical Models in Psychology	3	WS	PS	6
QDS-PS5	Elective	Longitudinal Data Analysis	3	WS	PS/EC	6
QDS-PS6	Elective	Multilevel Modeling	2	SS	PS	6
QDS-PS7	Elective	Structural Equation Modeling	1, 3	WS	PS	6
QDS-PS8	Elective	Latent Variable Modeling	1	WS	PS	6

QDS-PS9	Elective	Core Topics Psychometrics I	-	-	PS	6
QDS-PS10	Elective	Core Topics Psychometrics II	-	-	PS	9
	Econometrics (18-30 CPs)					
QDS-EC1a	(Obligatory or QDS-EC1b)	Foundations in Econometrics I	1	-	EC	6
QDS-EC1b	(Obligatory or QDS-EC1a)	Foundations in Econometrics II	-	-	EC	9
QDS-EC2	Elective	Applied Econometrics	2	SS	EC	6
QDS-EC3	Elective	Advanced Time Series Analysis	3	WS	EC/PS	9
QDS-EC4	Elective	Advanced Microeconometrics	2	SS	EC	9
QDS-EC5	Elective	Machine Learning in Econometrics	2	SS	EC/ML	6
QDS-EC6	Elective	Statistics of Financial Markets	1, 3	WS	EC	9
QDS-EC7	Elective	Empirical Asset Pricing	2	SS	EC	9
QDS-EC8	Elective	Financial Market Microstructure	2	SS	EC	6
QDS-EC9	Elective	Financial Economics	1, 3	WS	EC	9
QDS-EC10	Elective	Core Topics Econometrics I	-	-	EC	6
QDS-EC11	Elective	Core Topics Econometrics II	-	-	EC	9
	Machine Learning (18-30 CPs)					
QDS-ML1	(Obligatory)	Foundations in Machine Learning	1	-	ML	6
QDS-ML2	Elective	Machine Learning (1)	1	WS	ML	6
QDS-ML3	Elective	Data Literacy	1	WS	ML/FO	6
QDS-ML4	Elective	Deep Learning	3	WS	ML	6
QDS-ML5	Elective	Statistical Machine Learning	2	SS	ML	9
QDS-ML6	Elective	Probabilistic Machine Learning	2	SS	ML	9
QDS-ML7	Elective	Core Topics Machine Learning I	-	-	ML	6
QDS-ML8	Elective	Core Topics Machine Learning II	-	-	ML	9
	Thesis					
QDS-MT	obligatory	Master Thesis	4			30

Module List

Legend

Key	
Grading	g = graded; ug = ungraded (pass/fail)
Type of Exam	W = written exam; O = oral exam; T = term paper; P = classroom presentation, PO = Portfolio, PA = active participation, E = Essay
Duration	duration of the examination in minutes
Weight	courses: weighting of the examination grade towards the module grade modules: weighting of the module grade towards the final grade
Contact Hours	CH; hours spent in the classroom per week during the semester
Status	o = obligatory; e = elective
Type of Course	L = lecture; S = seminar; E = exercise; T = tutorial, B = block, PS = Research Project; PC = PC-Lab
CP	Credit Points (ECTS Credits)
Module origin	PS1: Psychology B.Sc. PS2: Psychology M.Sc. EC1: Economics B.Sc. (31.7.2019) EC2: Economics M.Sc. (23.3.2018) EC3: Data Science in Business and Economics M.Sc. ML: Machine Learning M.Sc. (15.5.2019) N: Neural Information Processing M.Sc. (17/18)

Modules of Study Area Foundations

<table>
<tr><td>Module Code:
QDS-FO-1</td><td colspan="3">Module Title:
Mathematical Introduction</td><td>Type of Module:
obligatory</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="4">3</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Total Workload:
90 h</td><td colspan="2">Time in Class:
30 h / 2 CH</td><td>Self-Study:
60 h</td></tr>
<tr><td>Lecture type</td><td colspan="4">Block / workshop</td></tr>
<tr><td>Duration</td><td colspan="4">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="4">Regularly in the winter</td></tr>
<tr><td>Language of Instruction</td><td colspan="4">English</td></tr>
<tr><td>Type of Exam</td><td colspan="4">Written exam</td></tr>
<tr><td>Content</td><td colspan="4">The module covers key concepts in linear algebra and mathematical statistics. It will in particular deal with matrix algebra (including linear independence and eigenvalue theory), quadratic forms, matrix differentiation, difference equations, basic probability theory and statistical inference.</td></tr>
<tr><td>Objectives</td><td colspan="4">This module is designed for recently enrolled Master students. The aim is to provide participants with the mathematical tools and the fundamentals of probability theory and statistics which are particularly important for successful completion of the Master program. The module is designed to review some basic concepts which are covered in standard bachelor courses and will then expand the field to more advanced methods. After completing the module, students will have acquired the basic mathematical and statistical knowledge that is needed to start the Master’s degree.</td></tr>
<tr><td rowspan="2">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Block / Seminar</td><td>B/S</td><td>o</td><td>2</td><td>3</td><td>W</td><td>-</td><td>g</td><td>100</td></tr>
<tr><td>Requirement for participation</td><td colspan="4">-</td></tr>
<tr><td>Lecturer</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Literature</td><td colspan="4">- Greub, W. (1975). Linear Algebra. Springer New York.
- Billingsley, P. (2012). Probability and Measure Anniversary Edition. Wiley.
- Agresti, A. & Finlay, B. (2009). Statistical Methods for the Social Sciences (4th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.</td></tr>
</table>

Module Code: QDS-FO2 (P2: M2)	**Module Title:** Advanced Statistics								**Type of Module:** obligatory
CP (ECTS Credits)	3								
Workload - Time in Class - Self-Study	Total Workload: 90 h		Time in Class: 30 h / 2 CH						Self-Study: 60 h
Lecture type	Lecture (possibly tutorials), weekly homework								
Duration	1 semester								
Frequency	Regularly in the summer								
Language of Instruction	English								
Type of Exam	Written exam								
Content	Advanced statistical analysis based on multivariate methods an (generalized) mixed regression models.								
Objectives	Knowledge on fundamental multivariate methods and (generalized) mixed regression models, as well as practical application and interpretation in the context of psychological intervention and evaluation research with special regard on hierarchical data structures or experimental designs for change measuring.								
Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Lecture	L	o	2	3	W	-	g	100
Requirement for participation	-								
Lecturer	Prof. Dr. Jürgen Heller								
Literature	Literature will be listed at the beginning of the semester.								

<table>
<tr><td>Module Code:
QDS-FO3</td><td colspan="4">Module Title:
Programming I</td><td>Type of Module:
elective</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="5">3</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td colspan="2">Total Workload:
90 h</td><td colspan="2">Time in Class:
30 h / 2 CH</td><td>Self-Study:
60 h</td></tr>
<tr><td>Lecture type</td><td colspan="5">Seminars or Block (including exercises and tutorials)</td></tr>
<tr><td>Duration</td><td colspan="5">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="5">Depends on chosen course</td></tr>
<tr><td>Language of Instruction</td><td colspan="5">English</td></tr>
<tr><td>Type of Exam</td><td colspan="5">Depends on chosen course</td></tr>
<tr><td>Content</td><td colspan="5">Programming basics in R, Python, or other relevant programming skills. Can be held as weekly seminar or as block seminar.</td></tr>
<tr><td>Objectives</td><td colspan="5">Students’ will be able to
- apply modern statistical methods
- set up programming environments
- load datasets, packages and modules
- write functions and scripts
- handle data in respective statistical software</td></tr>
<tr><td rowspan="2">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Block / Seminar</td><td>B/S</td><td>e</td><td>2</td><td>3</td><td>W/ T/ P</td><td>-</td><td>g</td><td>100</td></tr>
<tr><td>Requirement for participation</td><td colspan="5">-</td></tr>
<tr><td>Lecturer</td><td colspan="5">Depends on chosen course</td></tr>
<tr><td>Literature</td><td colspan="5">Literature will be listed at the beginning of the semester.</td></tr>
</table>

<table>
<tr><td>Module Code:
QDS-FO4</td><td colspan="6">Module Title:
Programming II</td><td colspan="3">Type of Module:
elective</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="9">3</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td colspan="3">Total Workload:
90 h</td><td colspan="3">Time in Class:
30 h / 2 CH</td><td colspan="3">Self-Study:
60 h</td></tr>
<tr><td>Lecture type</td><td colspan="9">Seminars or Block (including exercises and tutorials)</td></tr>
<tr><td>Duration</td><td colspan="9">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="9">Depends on chosen course</td></tr>
<tr><td>Language of Instruction</td><td colspan="9">English</td></tr>
<tr><td>Type of Exam</td><td colspan="9">Depends on chosen course</td></tr>
<tr><td>Content</td><td colspan="9">Programming basics in R, Python, or other relevant programming skills that do not overlap with Programming I (QDS-FO3). Can be held as weekly seminar or as block seminar.</td></tr>
<tr><td>Objectives</td><td colspan="9">Students’ will additionally (to Programming I (QDS-FO3)) be able to
- apply different modern statistical methods
- set up different programming environments
- load datasets, packages and modules in the corresponding additional language
- write functions and scripts in the corresponding additional language
- handle data in the corresponding additional language</td></tr>
<tr><td rowspan="2">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Block / Seminar</td><td>B/S</td><td>e</td><td>2</td><td>3</td><td>W/ T/ P</td><td>-</td><td>g</td><td>100</td></tr>
<tr><td>Requirement for participation</td><td colspan="9">-</td></tr>
<tr><td>Lecturer</td><td colspan="9">Depends on chosen course</td></tr>
<tr><td>Literature</td><td colspan="9">Literature will be listed at the beginning of the semester.</td></tr>
</table>

<table>
<tr><td>Module Code:
QDS-FO5</td><td colspan="4">Module Title:
Experimental and Quasi-Experimental Design</td><td>Type of Module:
elective</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="5">3</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td colspan="2">Total Workload:
90 h</td><td colspan="2">Time in Class:
30 h / 2 CH</td><td>Self-Study:
60 h</td></tr>
<tr><td>Lecture type</td><td colspan="5">Seminar</td></tr>
<tr><td>Duration</td><td colspan="5">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="5">Regularly in the winter</td></tr>
<tr><td>Language of Instruction</td><td colspan="5">English</td></tr>
<tr><td>Type of Exam</td><td colspan="5">Written exam, oral examination, or assignments (data analysis and written report)</td></tr>
<tr><td>Content</td><td colspan="5">In this module, students learn to understand experimental and quasi-experimental designs in empirical research in the social and behavioral sciences. Topics covered in this module are experiments and (generalized) causal inferences, types of validity, quasi-experimental designs with or without control-groups or pre-tests, longitudinal measurement, discontinuity designs, randomized experimental trails, and practical problems.</td></tr>
<tr><td>Objectives</td><td colspan="5">Students learn to understand and explain the pros and cons of different elements of experimental and quasi-experimental designs. They are able to choose designs for empirical research and to reflect critically the assumptions of designs. Given examples form empirical research, students are understanding the weaknesses of design and are able to describe the validity and reasonable inferences of this empirical research.</td></tr>
<tr><td rowspan="2">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Seminar</td><td>S</td><td>E</td><td>2</td><td>3</td><td>W/ T</td><td>-</td><td>g</td><td>100</td></tr>
<tr><td>Requirement for participation</td><td colspan="5">-</td></tr>
<tr><td>Lecturer</td><td colspan="5">Prof. Dr. Augustin Kelava</td></tr>
<tr><td>Literature</td><td colspan="5">Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). Experimental and quasi-experimental designs for generalized causal inference. Boston, MA, US: Houghton, Mifflin and Company.

Further or alternative literature will be given in the seminar.</td></tr>
</table>

Module Code: QDS-FO6	**Module Title:** Ethics Seminar								**Type of Module:** elective
CP (ECTS Credits)	3								
Workload - Time in Class - Self-Study	Total Workload: 90 h		Time in Class: 30 h / 2 CH						Self-Study: 60 h
Lecture type	Seminar								
Duration	1 semester								
Frequency	Depends on chosen course								
Language of Instruction	English								
Type of Exam	Depends on lecturer								
Content	The increasing use of data and data driven applications, for example in decision-making processes, effects our daily lives. Thus, ethical discussion on the responsible usage of data are of growing importance. This module offers changing seminars, for example on ethics in Data Science, Technology, AI, …								
Objectives	Students will learn for example … - what ethical questions are involved in the usage of data - which applications might have ethical implications and how to deal with them								
Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Seminar	S	e	2	3	W/O /T/P	-	g	100
Requirement for participation	-								
Lecturer	Depends on chosen course								
Literature	Literature will be listed at the beginning of the semester.								

Module Code: QDS-FO7	**Module Title:** Bayesian Modeling		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload - Time in Class - Self-Study	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Lecture and Tutorials		
Duration	1 semester		
Frequency	Regularly in the summer		
Language of Instruction	English		
Type of Exam	Written exam, oral examination, or assignments (data analysis and written report)		
Content	Introduction to statistical inference (Bayesian and Frequentist approach) and the Bayesian inference formula. Most practically relevant probability distributions for Bayesian inference (prior and likelihood). Modern methods of Bayesian analysis through computational Markov chain Monte Carlo (examples in R / Stan). Introduction to hierarchical models.		
Objectives	Understand Bayesian statistics and inference form a theoretical and practical point of view (with applications in R). This includes knowledge of - the differences in Frequentists in Bayesian approaches (e.g. confidence intervals and credibility intervals) - posterior distribution estimation by sampling - application of computational methods		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Lecture	L	e	2	6	W/O /T/P	-	g	100
	Tutorial	T	e	2					
Requirement for participation	-								
Lecturer	Prof. Dr. Augustin Kelava, Dr. Pascal Kilian								
Literature	Ben Lambert (2018). A Student's Guide to Bayesian Statistics. SAGE Publications.								

Module Code: QDS-FO8	**Module Title:** Research Project								**Type of Module:** obligatory
CP (ECTS Credits)	9								
Workload - Time in Class - Self-Study	Total Workload: 270 h		Time in Class: 30 h / 2 CH						Self-Study: 240 h
Lecture type	Research Project								
Duration	1 semester								
Frequency	Regularly in the winter								
Language of Instruction	English								
Type of Exam	Essay and /or presentation								
Content	The research project serves to deepen theoretical and practical knowledge in a specific field.								
Objectives	Students: - get an insight into scientific work - learn how to independently pursue a research question - learn independently to identify and compile scientific literature for the question to be worked on - are able to work in a team in an international scientific environment - deepen their problem-solving skills								
Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Research Project	PS	o	2	9	E	-	g	100
Requirement for participation	-								
Lecturer	Lecturers of QDS from all areas (Methods Center, Economics, Psychometrics, Computer Science)								
Literature	Depends on the topic.								

Module Code: QDS-FO9 (S510/520)	**Module Title:** Master Seminar on Econometrics								**Type of Module:** elective
CP (ECTS Credits)	9								
Workload - Time in Class - Self-Study	Total Workload: 270 h		Time in Class: 30 h / 2 CH						Self-Study: 240 h
Lecture type	Seminar (2 SWS) / oral participation, group work, self-study								
Duration	1 semester								
Frequency	Regularly each semester								
Language of Instruction	English								
Type of Exam	Term paper, paper presentation, discussion								
Content	Students work on econometric topics that are close to the research interests of the chairs of Prof. Grammig and Prof. Biewen. Students write a term paper and present their results in front of a seminar audience. The seminar is typically blocked.								
Objectives	Students learn how to write a scientific paper in applied or theoretical econometrics and to present and defend their results. Students should both deepen their technical/-econometric skills by working on their own (but guided by mentors) and learn how to present convincingly and in a scientific correct way. The seminar prepares students for their master thesis.								
Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Seminar	S	e	2	9	T/P	-	g	100
Requirement for participation	At least one successfully completed master course in the field of econometrics								
Lecturer	Prof. Dr. Martin Biewen, Prof. Dr. Joachim Grammig								
Literature	A list of topics and reading material will be announced on the website about 2 weeks before term commences.								

Module Code: QDS-FO10	**Module Title:** Connecting the Threads of Psychometrics, Econometrics and Machine Learning		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload **- Time in Class** **- Self-Study**	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Seminar		
Duration	1 semester		
Frequency	Regularly in the summer		
Language of Instruction	English		
Type of Exam	Written exam, oral examination, or assignments (data analysis and written report)		
Content	In this seminar the three Core Topics of QDS – Psychometrics, Econometrics, and Machine Learning – will be brought together. The methodological differences and similarities of psychometrics and econometrics will be discussed. Furthermore, it will be shown how methods of machine learning can be applied in either field and how methods of psychometrics and econometrics can be used in the other field respectively.		
Objectives	The students know how to distinguish the three fields and how to combine them. They learn the benefits of changing the point of view to find solutions in other fields. The students get to know the proximity of psychometrics and machine learning and where fundamentally different methods are applied that might be used in the other field, respectively. The students learn how machine learning can be integrated in psychometrics and econometrics and can apply certain machine learning methods in both fields.		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Seminar	-	e	-	6	W/O/ T/P	-	g	100

Requirement for participation	-
Lecturer	Prof. Dr. Kelava, Prof. Dr. Brandt
Literature	Literature will be listed at the beginning of the semester.

Module Code: QDS-FO11	**Module Title:** Selected Topics in QDS I		**Type of Module:** elective
CP (ECTS Credits)	3		
Workload - Time in Class - Self-Study	Total Workload: 90 h	Time in Class: Depends on chosen course	Self-Study: Depends on chosen course
Lecture type	Depends on chosen course		
Duration	1 semester		
Frequency	Depends on chosen course		
Language of Instruction	English		
Type of Exam	Written exam, oral examination, or assignments (data analysis and written report)		
Content	In this module students can choose a class that teaches general knowledge for data sciences and statistics. This can include classes that deal with ethical topics (to gain a deeper understanding than in the module QDS-FO6), probability theory, statistics, mathematics, interdisciplinary topics (in psychometrics, econometrics, machine learning, or adjacent fields), and applied methods. Within the scope of QDS, this module is intended for changing lectures and seminars and will be credited according to the origin of the module. It also offers the flexibility to participate in current research seminars. The content in this module does not overlap with the topics in Selected Topics in QDS II and III (QDS-FO12 / QDS-FO13).		
Objectives	Within the area of the chosen seminar or lecture the students have the opportunity to … - deepen their understanding of selected topics that are needed in all fields of statistics (e.g., ethics or interdisciplinary subjects) - gain insights in general applications of statistical methods - broaden their point of view in fundamental areas (e.g., probability theory, statistics, or mathematics)		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Chosen course	-	e	-	3	W/O/ T/P	-	g	100

Requirement for participation	Depends on chosen course
Lecturer	Depends on chosen course
Literature	Depends on chosen course

Module Code: QDS-FO12	**Module Title:** Selected Topics in QDS II		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload **- Time in Class** **- Self-Study**	Total Workload: 180 h	Time in Class: 60 h /4 CH	Self-Study: 120 h
Lecture type	Depends on chosen course		
Duration	1 semester		
Frequency	Depends on chosen course		
Language of Instruction	English		
Type of Exam	Written exam, oral examination, or assignments (data analysis and written report)		
Content	In this module students can choose a class that teaches general knowledge for data sciences and statistics. This can include classes that deal with ethical topics (to gain a deeper understanding than in the module QDS-FO6), probability theory, statistics, mathematics, interdisciplinary topics (in psychometrics, econometrics, machine learning, or adjacent fields), and applied methods. Within the scope of QDS, this module is intended for changing lectures and seminars and will be credited according to the origin of the module. It also offers the flexibility to participate in current research seminars. The content in this module does not overlap with the topics in Selected Topics in QDS I and III (QDS-FO11 / QDS-FO13).		
Objectives	Within the area of the chosen seminar or lecture the students have the opportunity to … - deepen their understanding of selected topics that are needed in all fields of statistics (e.g., ethics or interdisciplinary subjects) - gain insights in general applications of statistical methods - broaden their point of view in fundamental areas (e.g., probability theory, statistics, or mathematics)		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Chosen course	-	e	-	6	W/O/ T/P	-	g	100

Requirement for participation	Depends on chosen course
Lecturer	Depends on chosen course
Literature	Depends on chosen course

Module Code: QDS-FO13	**Module Title:** Selected Topics in QDS III		**Type of Module:** elective
CP (ECTS Credits)	9		
Workload **- Time in Class** **- Self-Study**	Total Workload: 270 h	Time in Class: 90 h / 6 CH	Self-Study: 180 h
Lecture type	Depends on chosen course		
Duration	1 semester		
Frequency	Written exam, oral examination, or assignments (data analysis and written report)		
Language of Instruction	English		
Type of Exam	Depends on chosen course		
Content	In this module students can choose a class that teaches general knowledge for data sciences and statistics. This can include classes that deal with ethical topics (to gain a deeper understanding than in the module QDS-FO6), probability theory, statistics, mathematics, interdisciplinary topics (in psychometrics, econometrics, machine learning, or adjacent fields), and applied methods. Within the scope of QDS, this module is intended for changing lectures and seminars and will be credited according to the origin of the module. It also offers the flexibility to participate in current research seminars. The content in this module does not overlap with the topics in Selected Topics in QDS II and III (QDS-FO11 / QDS-FO12).		
Objectives	Within the area of the chosen seminar or lecture the students have the opportunity to … - deepen their understanding of selected topics that are needed in all fields of statistics (e.g., ethics or interdisciplinary subjects) - gain insights in general applications of statistical methods - broaden their point of view in fundamental areas (e.g., probability theory, statistics, or mathematics) - This module is intended to foster a better understanding the topics in the three specializations.		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Chosen Course	-	e	-	9	W/O/ T/P	-	g	100
Requirement for participation	Depends on chosen course								
Lecturer	Depends on chosen course								
Literature	Depends on chosen course								

Modules of Study Area Psychometrics and Mathematical Psychology

Module Code: QDS-PS1	**Module Title:** Foundations in Psychometrics		**Type of Module:** (Obligatory for certain students, see introduction)
CP (ECTS Credits)	6		
Workload **- Time in Class** **- Self-Study**	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Lecture and Tutorials		
Duration	1 Semester		
Frequency	Written exam, oral examination, or assignments (data analysis and written report)		
Language of Instruction	English		
Type of Exam	Written exam, oral examination, or assignments (data analysis and written report)		
Content	Psychometrics is concerned with the construction of assessment tools, measurement instruments, and formalized models that may serve to connect observable phenomena to theoretical constructs. The assessment is intended to predict future behavior and changes in well-defined situations. Quantitative methods like classical test theory, item response theory, and factor analysis methods will be covered as well applications of those methods.		
Objectives	Students understand Methods of Psychometrics (i.e., measurement of psychological variables) and Assessment. They can evaluate the quality of tests used in Psychological Assessment. Students can use tests and interpret their results as well as construct their own tests.		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Lecture Tutorial	L T	o o	2 2	6	W/ O/ T/ P	-	g	100
Requirement for participation	-								
Responsible	Prof. Dr. Holger Brandt								
Literature	Literature will be listed at the beginning of the semester.								

<table>
<tr><td>Module Code:
QDS-PS2</td><td colspan="4">Module Title:
Psychometrics</td><td>Type of Module:
elective</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="5">6</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td colspan="2">Total Workload:
180 h</td><td colspan="2">Time in Class:
60 h / 4 CH</td><td>Self-Study:
120 h</td></tr>
<tr><td>Lecture type</td><td colspan="5">Lecture and Tutorials</td></tr>
<tr><td>Duration</td><td colspan="5">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="5">Regularly in the winter</td></tr>
<tr><td>Language of Instruction</td><td colspan="5">English</td></tr>
<tr><td>Type of Exam</td><td colspan="5">Written exam, oral examination, or assignments (data analysis and written report)</td></tr>
<tr><td>Content</td><td colspan="5">Psychological Assessment deals with measurement of inter-individual differences and intra-individual changes of human behavior, subjective experience, and the underlying (unobserved) psychological constructs. This information provides both explanations about human behavior and methods that can be used to predict future behavior.
This course will cover theoretical aspects on psychometric modeling with different statistical methods such as classical test theory, item response theory, and factor analysis methods. It will also cover more practical aspects like data collection, item generation, and questionnaire evaluation. Some advanced topics may include Bayesian psychometric scaling and missing data handling.

In the tutorial, all relevant approaches are presented and practiced as hands-on applications from social, educational, and behavioral sciences using statistical software packages like R.</td></tr>
<tr><td>Objectives</td><td colspan="5">Students understand methods of Psychometrics and their application to empirical data (i.e., measurement of psychological variables). They can evaluate the quality of tests and questionnaires. Students can use and design tests and interpret their results with regard to the underlying psychological constructs.</td></tr>
<tr><td>Requirements for Obtaining Credit, Grading, Weight if appl.</td><td colspan="5"><table>
<tr><th></th><th>Type of Course</th><th>Status</th><th>CH</th><th>CP</th><th>Type of Exam</th><th>Duration of Exam</th><th>Evaluation</th><th>Calculation of Module (%)</th></tr>
<tr><td>Lecture

Tutorial</td><td>L

T</td><td>e

e</td><td>2

2</td><td>6</td><td>W/O /T/P</td><td>-</td><td>g</td><td>100</td></tr>
</table></td></tr>
<tr><td>Requirement for participation</td><td colspan="5">-</td></tr>
<tr><td>Lecturer</td><td colspan="5">Prof. Dr. Holger Brandt</td></tr>
<tr><td>Literature</td><td colspan="5">Irwing, P., Booth, T., & Hughes, D. J. (20). The Wiley Handbook of Psychometric Testing, Vol. I and II. Wiley. (Selected chapters).

Mair, P. (2018). Modern Psychometrics with R. Springer Cham. (Selected chapters)

Additional literature will be provided during the course.</td></tr>
</table>

Module Code: QDS-PS3	**Module Title:** Item Response Theory		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload - Time in Class - Self-Study	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Lecture and Tutorials		
Duration	1 semester		
Frequency	Regularly in the summer		
Language of Instruction	English		
Type of Exam	Written exam, or oral examination, or assignments (data analysis and written report)		
Content	The module focuses on both basic and advanced topics in Item Response Theory by offering an overview of the existing models for dichotomous and polytomous items. Both a theoretical and an applicative perspective are considered. Strengths and limitations of the theory are discussed. Particular relevance is given to the theory's foundations and its connection to Factor Analysis and Classic Test Theory. Topics include (but might not be limited to) uni-dimensional, multi-dimensional, and multi-component models, parametric and non-parametric models, identifiability and empirical indistinguishability issues, differential item functioning and measurement invariance, item calibration, dimensionality analysis, parameter linking, and person scoring. An essential part of the seminar focuses on the use of R – packages.		
Objectives	Students gain an intuitive as well as mathematical understanding of Item Response Theory models, assumptions, and practice. They gain perspective on the limitations and usefulness of the theory and of its applications.		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Lecture	L	e	2	6	W/O /T/P	-	g	100
	Tutorial	T	e	2					

Requirement for participation	-
Lecturer	Dr. Stefano Noventa
Literature	Literature will be listed at the beginning of the semester.

Module Code: QDS-PS4	**Module Title:** Mathematical Models in Psychology		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload - Time in Class - Self-Study	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Lecture and Tutorials		
Duration	1 semester		
Frequency	Regularly in the winter		
Language of Instruction	English		
Type of Exam	Written exam, oral examination, or assignments (data analysis and written report)		
Content	The module offers an overview of some mathematical theories and frameworks in Psychometrics and Mathematical Psychology. The focus of the module is on both basic and advanced applications of Discrete Mathematics, Functional Equations, and Stochastic Methods in Psychology with a particular interest on their formal aspects, similarities, and connections. Topics include (but might not be limited to) Knowledge Space Theory, Cognitive Diagnostic Models, Item Response Theory, Representational Theory of Measurement and Meaningfulness, and methods and models for Psychophysics, Decision making, Choice, Preference, and Utility.		
Objectives	Students gain an intuitive as well as mathematical understanding of currently used and relevant methods and models in Mathematical Psychology and Psychometrics. They gain perspective on the limitations and usefulness of the theories and of their applications.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	L	e	2	6	W/O /T/P	-	g	100
Tutorial	T	e	2					

Requirement for participation	Psychometrics or Item Response Theory
Lecturer	Dr. Stefano Noventa
Literature	Literature will be listed at the beginning of the semester.

<table>
<tr><td>Module Code:
QDS-PS5</td><td colspan="6">Module Title:
Longitudinal Data Analysis</td><td colspan="4">Type of Module:
elective</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="10">6</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td colspan="3">Total Workload:
180 h</td><td colspan="3">Time in Class:
60 h / 4 CH</td><td colspan="4">Self-Study:
120 h</td></tr>
<tr><td>Lecture type</td><td colspan="10">Seminar and tutorials</td></tr>
<tr><td>Duration</td><td colspan="10">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="10">Regularly in the winter</td></tr>
<tr><td>Language of Instruction</td><td colspan="10">English</td></tr>
<tr><td>Type of Exam</td><td colspan="10">Written exam, oral examination, or assignments (data analysis and written report)</td></tr>
<tr><td>Content</td><td colspan="10">This course introduces methods for the analysis of longitudinal data with applications. Topics covered in this module include repeated measures (M)ANOVA, multilevel models for longitudinal data, latent growth curve models, models for unobserved heterogeneous trajectories, and modern time series types of models.</td></tr>
<tr><td>Objectives</td><td colspan="10">Students learn several statistical techniques for the analysis of longitudinal data. They can choose and apply the appropriate techniques given the hypotheses and data structure. The students know the pros and cons as well as requirements of the approaches. In the tutorial, all relevant approaches are presented as hands-on applications from social, educational, and behavioral sciences using statistical software packages. Students gain insight into the theoretical properties of the concepts and practical experience in data analysis.</td></tr>
<tr><td rowspan="3">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Lecture</td><td>S</td><td>e</td><td>2</td><td>3</td><td rowspan="2">W/O /T/P</td><td rowspan="2">-</td><td rowspan="2">g</td><td rowspan="2">100</td></tr>
<tr><td>Tutorial</td><td>T</td><td>e</td><td>2</td><td>3</td></tr>
<tr><td>Requirement for participation</td><td colspan="10">Latent Variable Modeling</td></tr>
<tr><td>Lecturer</td><td colspan="10">Prof. Dr. Augustin Kelava, Prof. Dr. Holger Brandt</td></tr>
<tr><td>Literature</td><td colspan="10">Hedeker, D. D., & Gibbons, R. D. (2006). Longitudinal data analysis. Hoboken, NJ: Wiley.

West, B.T., Welch, K.B., & Galecki, A.T. (2015). Linear mixed models: A practical guide using statistical software (2nd ed.). Boca Raton: Chapman & Hall.

Additional literature will be provided during the seminar.</td></tr>
</table>

Module Code: QDS-PS6	**Module Title:** Multilevel Modeling		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload - Time in Class - Self-Study	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Seminar and Tutorial		
Duration	1 semester		
Frequency	unregularly		
Language of Instruction	English		
Type of Exam	Written exam, oral examination, or assignments (data analysis and written report)		
Content	This course introduces to statistical methods for modeling multilevel (hierarchically structured) data. Topics include a short review of ordinary least squares regression analysis, intraclass correlation, multilevel regression, testing and probing interactions, maximum likelihood and Bayesian estimation, as well as the evaluation of model assumptions and model fit. Advanced topics will include the analysis of three-level models and categorical data. Emphasis will be given on the theory underlying multilevel modeling techniques and hands-on applications from social, educational, and behavior sciences using the statistical software.		
Objectives	Students learn the use of multilevel models for the analysis of hierarchical structured data. They can compare competing models given the hypotheses and data structure in order to identify optimal fitting models from a set of candidates. The students know the advantages and limitations of multilevel models as well as underlying assumptions of the approaches. Students gain insight into the theoretical properties of the concepts and practical experience in data analysis including model interpretation and illustration.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	S	e	2	3	W/O /T/P	-	g	100
Tutorial	T	e	2	3				

Requirement for participation	-
Lecturer	Depends on chosen course
Literature	Hox, J. J., Moerbeek, M., & van de Schoot, R. (2018). Multilevel analysis: Techniques and applications (3rd ed.). New York, NY: Routledge. West, B.T., Welch, K.B., & Galecki, A.T. (2015). Linear mixed models: A practical guide using statistical software (2nd ed.). Boca Raton: Chapman & Hall. Snijders, T. A. B. & Bosker, R. (2011). Multilevel analysis: An introduction to basic and advanced multilevel modeling. London: Sage. Additional literature will be provided during the seminar.

Module Code: QDS-PS7	**Module Title:** Structural Equation Modeling		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload - Time in Class - Self-Study	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Seminar and Tutorial		
Duration	1 semester		
Frequency	Regularly in the summer		
Language of Instruction	English		
Type of Exam	Written exam, oral examination, or assignments (data analysis and written report)		
Content	This course introduces latent variable models with a focus on Structural Equation Models. Topics covered in this module are exploratory and confirmatory factor analysis, and structural equation models. More advanced topics include structural equation models with direct and indirect effects (mediator models), multi group analysis, and measurement invariance. Model fit evaluation, estimation methods, and robustness to misspecifications are discussed. The methods introduced are practiced using empirical data.		
Objectives	Students learn to apply and understand latent variable models. Given the structure of data and hypotheses, students can analyze the data with modern statistical software packages, interpret and illustrate the results of their analysis, and modify their models. They understand the assumptions of the estimation approaches, their vulnerabilities and can choose which approach and modeling technique can be used. Students can evaluate results of empirical research and propose alternative modeling techniques or strategies to examine the stability of inferences.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	S	e	2	3	W/O /T/P	-	g	100
Tutorial	T	e	2	3				

Requirement for participation	Introduction to Psychometrics
Lecturer	Depends on chosen course
Literature	Bollen, K. A. (1989). Structural Equations with Latent Variables, John Wiley & Sons, New York. Brown, T. A. (2015). Confirmatory factor analysis in applied research (2nd ed.). New York: Guilford Press. Additional literature will be provided during the seminar.

<table>
<tr><td>Module Code:
QDS-PS8</td><td colspan="6">Module Title:
Latent Variable Modeling</td><td colspan="4">Type of Module:
elective</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="10">6</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td colspan="3">Total Workload:
180 h</td><td colspan="3">Time in Class:
60 h / 4 CH</td><td colspan="4">Self-Study:
120 h</td></tr>
<tr><td>Lecture type</td><td colspan="10">Lecture and Tutorial</td></tr>
<tr><td>Duration</td><td colspan="10">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="10">Regularly in the winter</td></tr>
<tr><td>Language of Instruction</td><td colspan="10">English</td></tr>
<tr><td>Type of Exam</td><td colspan="10">Written exam, oral examination, or assignments (data analysis and written report)</td></tr>
<tr><td>Content</td><td colspan="10">This course introduces generalized latent variable models. Topics covered in this module are (confirmatory) factor analysis, structural equation models, mixture models, multilevel structural equation models, estimation methods, model robustness to structural misspecification and violation of distributional assumptions.</td></tr>
<tr><td>Objectives</td><td colspan="10">Students learn to apply and understand latent variable models. Given the structure of data and hypotheses, students can analyze the data with modern statistical software packages (e.g., R), interpret the results of their analysis, and modify their models. Furthermore, they understand the assumptions of the estimation approaches, their vulnerabilities and can choose which approach and modeling technique can be used. Students can evaluate results of empirical research and propose alternative modeling techniques or strategies to examine the stability of inferences.</td></tr>
<tr><td rowspan="3">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Lecture</td><td>S</td><td>e</td><td>2</td><td>3</td><td rowspan="2">W/O /T/P</td><td rowspan="2">-</td><td rowspan="2">g</td><td rowspan="2">100</td></tr>
<tr><td>Tutorial</td><td>T</td><td>e</td><td>2</td><td>3</td></tr>
<tr><td>Requirement for participation</td><td colspan="10">-</td></tr>
<tr><td>Lecturer</td><td colspan="10">Prof. Dr. Augustin Kelava, Prof. Dr. Holger Brandt</td></tr>
<tr><td>Literature</td><td colspan="10">Bollen, K. A. (1989). Structural Equations with Latent Variables, John Wiley & Sons, New York.

Skrondal, A. and Rabe-Hesketh, S. (2004). Generalized Latent Variable Modeling: Multilevel, Longitudinal and Structural Equation Modeling. Boca Raton, FL: Chapman & Hall/ CRC Press

Further literature will be given.</td></tr>
</table>

<table>
<tr><td>Module Code:
QDS-PS9</td><td colspan="6">Module Title:
Core Topics Psychometrics I</td><td colspan="3">Type of Module:
elective</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="9">6</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td colspan="3">Total Workload:
180 h</td><td colspan="3">Time in Class:
60 h / 4 CH</td><td colspan="3">Self-Study:
120 h</td></tr>
<tr><td>Lecture type</td><td colspan="9">Depends on chosen course</td></tr>
<tr><td>Duration</td><td colspan="9">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="9">Depends on chosen course</td></tr>
<tr><td>Language of Instruction</td><td colspan="9">English</td></tr>
<tr><td>Type of Exam</td><td colspan="9">Written exam, oral examination, or assignments (data analysis and written report)</td></tr>
<tr><td>Content</td><td colspan="9">In this module students can choose a class that teaches specific knowledge in the field of psychometrics. This can include classes that deal with latent variables in specific contexts (e.g., survival analysis), knowledge space theory, and applications thereof.

Within the scope of Psychometrics, this module is intended for changing lectures and seminars and will be credited according to the origin of the module. It offers the flexibility to participate in current research seminars, for example, by guest lecturers.

The content in this module does not overlap with the topics in Core Topics Psychometrics II (QDS-PS10).</td></tr>
<tr><td>Objectives</td><td colspan="9">Within the area of the chosen seminar or lecture the students have the opportunity to …
- deepen their understanding of selected topics in Psychometrics
- gain insights in more specific applications of psychometrical methods
- broaden their knowledge in a variety of topics in Psychometrics</td></tr>
<tr><td rowspan="2">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Chosen course</td><td>-</td><td>e</td><td>-</td><td>6</td><td>W/ O/ T/ P</td><td>-</td><td>g</td><td>100</td></tr>
<tr><td>Requirement for participation</td><td colspan="9">Depends on chosen course</td></tr>
<tr><td>Lecturer</td><td colspan="9">Depends on chosen course</td></tr>
<tr><td>Literature</td><td colspan="9">Literature will be listed at the beginning of the semester.</td></tr>
</table>

<table>
<tr><td>Module Code:
QDS-PS10</td><td colspan="6">Module Title:
Core Topics Psychometrics II</td><td colspan="4">Type of Module:
elective</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="10">9</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td colspan="3">Total Workload:
270 h</td><td colspan="3">Time in Class:
90 h / 6 CH</td><td colspan="4">Self-Study:
180 h</td></tr>
<tr><td>Lecture type</td><td colspan="10">Depends on chosen course</td></tr>
<tr><td>Duration</td><td colspan="10">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="10">Depends on chosen course</td></tr>
<tr><td>Language of Instruction</td><td colspan="10">English</td></tr>
<tr><td>Type of Exam</td><td colspan="10">Written exam, oral examination, or assignments (data analysis and written report)</td></tr>
<tr><td>Content</td><td colspan="10">In this module students can choose a class that teaches specific knowledge in the field of psychometrics. This can include classes that deal with latent variables in specific contexts (e.g., survival analysis), knowledge space theory, and applications thereof.

Within the scope of Psychometrics, this module is intended for changing lectures and seminars and will be credited according to the origin of the module. It offers the flexibility to participate in current research seminars, for example, by guest lecturers.

The content in this module does not overlap with the topics in Core Topics Psychometrics I (QDS-PS9).</td></tr>
<tr><td>Objectives</td><td colspan="10">Within the area of the chosen seminar or lecture the students have the opportunity to …
- deepen their understanding of selected topics in Psychometrics
- gain insights in more specific applications of psychometrical methods
- broaden their knowledge in a variety of topics in Psychometrics</td></tr>
<tr><td rowspan="2">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Chosen course</td><td>-</td><td>e</td><td>-</td><td>9</td><td>W/ O/ T/ P</td><td>-</td><td>g</td><td>100</td></tr>
<tr><td>Requirement for participation</td><td colspan="10">Depends on chosen course</td></tr>
<tr><td>Lecturer</td><td colspan="10">Depends on chosen course</td></tr>
<tr><td>Literature</td><td colspan="10">Literature will be listed at the beginning of the semester.</td></tr>
</table>

Modules of Study Area Econometrics

<table>
<tr><td>Module Code:
QDS-EC1a</td><td colspan="5">Module Title:
Foundations in Econometrics I</td><td colspan="4">Type of Module:
(This or QDS-EC1b obligatory for certain students, see introduction)</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="9">6</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td colspan="3">Total Workload:
180 h</td><td colspan="3">Time in Class:
60 h / 4 CH</td><td colspan="3">Self-Study:
120 h</td></tr>
<tr><td>Lecture type</td><td colspan="9">Seminar, lecture
Written exams, classroom presentations and essays are typical types of exams to pass the module. At the beginning of the module the lecturer informs about the requirements to pass the module.</td></tr>
<tr><td>Duration</td><td colspan="9">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="9">Depends on chosen course</td></tr>
<tr><td>Language of Instruction</td><td colspan="9">English</td></tr>
<tr><td>Type of Exam</td><td colspan="9">Depends on chosen course</td></tr>
<tr><td>Content</td><td colspan="9">Econometrics is the quantitative application of statistical and mathematical models using data to develop theories or test existing hypotheses in economics and to forecast future trends from historical data.</td></tr>
<tr><td>Objectives</td><td colspan="9">Students understand methods of Econometrics and learn their basic applications. They can evaluate the quality of models. Students can use econometric methods and interpret their results as well as construct their own tests.</td></tr>
<tr><td rowspan="2">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Seminar</td><td>S</td><td>o</td><td>4</td><td>6</td><td>W/P/E</td><td>-</td><td>g</td><td>100</td></tr>
<tr><td>Requirement for participation</td><td colspan="9">-</td></tr>
<tr><td>Responsible</td><td colspan="9">Depends on chosen course</td></tr>
<tr><td>Literature</td><td colspan="9">Literature will be listed at the beginning of the semester.</td></tr>
</table>

Module Code: QDS-EC1b	**Module Title:** Foundations in Econometrics II		**Type of Module:** (This or QDS-EC1a obligatory for certain students, see introduction)
CP (ECTS Credits)	9		
Workload **- Time in Class** **- Self-Study**	Total Workload: 270 h	Time in Class: 90 h / 6 CH	Self-Study: 180 h
Lecture type	Seminar, lecture Written exams, classroom presentations and essays are typical types of exams to pass the module. At the beginning of the module the lecturer informs about the requirements to pass the module.		
Duration	1 Semester		
Frequency	Depends on chosen course		
Language of Instruction	English		
Type of Exam	Depends on chosen course		
Content	Econometrics is the quantitative application of statistical and mathematical models using data to develop theories or test existing hypotheses in economics and to forecast future trends from historical data.		
Objectives	Students understand methods of Econometrics and learn their basic applications. They can evaluate the quality of models. Students can use econometric methods and interpret their results as well as construct their own tests.		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Seminar	S	o	6	9	W/P/E	-	g	100

Requirement for participation	-
Responsible	Depends on chosen course
Literature	Literature will be listed at the beginning of the semester.

Module Code: QDS-EC2 (E1: S321)	**Module Title:** Applied Econometrics		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload **- Time in Class** **- Self-Study**	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Lecture and practice course		
Duration	1 semester		
Frequency	Regularly in the summer		
Language of Instruction	English		
Type of Exam	Written exam		
Content	The module discusses econometric models and estimation techniques. Topics presented include: 1. Regression analysis 2. Estimation and inference 3. Data and specification issues 4. Use of cross-sectional, time series and panel data 5. Sample selection corrections 6. Simultaneous equation models 7. Endogeneity: sources and solutions 8. Instrumental variables estimation and two-stage least squares		
Objectives	Students understand and apply important methods of applied econometrics. They reflect the assumptions and the intuition behind the different methods. The students perform econometric estimations and tests using econometric software and interpret the results in a scientifically correct way.		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Lecture	L	e	3	6	W	60	g	100
	Tutorial	T	e	1					
Requirement for participation	-								
Lecturer	Prof. Dr. Martin Biewen or Prof. Dr. Joachim Grammig								
Literature	Wooldridge: Introductory Econometrics Hayashi: Econometrics Angrist/Pischke: Mostly Harmless Econometrics								

Module Code: QDS-EC3 (E3: S411)	**Module Title:** Advanced Time Series Analysis		**Type of Module:** elective
CP (ECTS Credits)	9		
Workload **- Time in Class** **- Self-Study**	Total Workload: 270 h	Time in Class: 90 h / 6 CH	Self-Study: 180 h
Lecture type	Lecture and PC-Lab		
Duration	1 semester		
Frequency	Regularly in the winter		
Language of Instruction	English		
Type of Exam	Portfolio		
Content	The module deals with a rigorous treatment of state-of-the art univariate and multivariate time series methods used in economics and finance. This includes: 1. Autoregressive moving average models 2. Forecasting 3. Regression analysis with stationary and non-stationary time series 4. Unit root tests 5. Structural vector-autoregressive models and cointegration 6. Equilibrium correction and Johansen methodology 7. Amplification of time series methods in macroeconomics and finance using econometric software 8. Conditional heteroskedasticity in financial time series		
Objectives	Students master state-of-the-art time series econometrics, both univariate and multivariate. They apply time series methods with awareness of their potential and limitations in macroeconomics and finance. They command an econometric programming language independently and productively to perform empirical analyses involving time series data. They present and discuss their results of the application of time series methods in a scientific fashion.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	L	o/e	4	9	PO	-	g	100
PC-Lab	T	o/e	2					

Requirement for participation	-
Lecturer	Prof. Dr. Joachim Grammig
Literature	Literature will be listed at the beginning of the semester.

Module Code: QDS-EC4 (E3: S422)	**Module Title:** Advanced Microeconometrics		**Type of Module:** elective
CP (ECTS Credits)	9		
Workload **- Time in Class** **- Self-Study**	Total Workload: 270 h	Time in Class: 90 h / 6 CH	Self-Study: 180 h
Lecture type	Lecture and Tutorials		
Duration	1 semester		
Frequency	Regularly in the summer		
Language of Instruction	English		
Type of Exam	Written Exam		
Content	The module deals with a rigorous treatment of state-of-the art microeconometrical methods with applications in different fields of economics. The topics include: 1. Conditional Expectations and Linear Projections 2. Basic Asymptotic Theory 3. Single Equation OLS estimation 4. Single Equation IV estimation 5. Systems of Equations OLS/GLS estimation 6. Systems of Equations IV estimation 7. Linear Unobserved Effects Panel Data Models 8. M-estimation, Nonlinear Regression, and Quantile Regression 9. Generalized Method of Moments and Maximum Likelihood Estimation 10. Discrete Response Models 11. Corner Solutions, Censoring, and Selection Models 12. Treatment Evaluation 13. Duration Analysis		
Objectives	Students master the state of the art of microeconometrical techniques. They understand derivations and proofs. Students are able to assess the applicability and the limitations of the methods in fields such as labor economics, industrial economics, finance, and marketing. Students to apply the different methods in practical applications using the statistical software Stata.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	L	o/e	4	9	W	90	g	100
Tutorials	T	o/e	2					

Requirement for participation	-
Lecturer	Prof. Dr. Martin Biewen
Literature	Wooldridge: Econometric Analysis of Cross Section and Panel Data Cameron/Trivedi: Microeconometrics Cameron/Trivedi: Microeconometrics Using Stata

Module Code: QDS-EC5 (E3: S415)	**Module Title:** Machine Learning in Econometrics		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload - Time in Class - Self-Study	Total Workload: 180 h	Time in Class: 75 h / 5 CH	Self-Study: 105 h
Lecture type	Lecture and PC-Lab		
Duration	1 semester		
Frequency	Regularly in the summer		
Language of Instruction	English		
Type of Exam	Written Exam		
Content	This module illustrates how machine learning techniques can be used in economic research and applications. It offers a thorough analysis of a variety of tools in statistical learning and links them to econometric analysis. The course focuses on supervised machine learning techniques, such as: decision/regression trees, (logistic) regressions, naïve Bayes, local regressions, nearest neighbors, artificial neural networks, and support vector machines. The lecture also covers hyper-parameter tuning methods and various feature selection and regularization techniques. A practical PC-Lab class is an essential part of the module.		
Objectives	Students apply machine learning techniques and understand how these are linked to standard econometrics. They command different machine learning methods and apply them to economic problems using statistical software. They are aware of the respective advantages and shortcomings of these methods and discuss their results critically.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	L	e	3	6	W	90	g	100
PC-Lab	PC	e	2					

Requirement for participation	Successful participation in either QDS-EC2 Advanced Time Series Analysis or QDS-EC3 Advanced Microeconometrics
Lecturer	Dr. Jantje Sönksen
Literature	Hastie/Tibshirani/Friedman: The Elements of Statistical Learning Bishop: Pattern Recognition and Machine Learning selected papers

Module Code: QDS-EC6 (E3: S420)	**Module Title:** Statistics of Financial Markets		**Type of Module:** elective
CP (ECTS Credits)	9		
Workload **- Time in Class** **- Self-Study**	Total Workload: 270 h	Time in Class: 90 h / 6 CH	Self-Study: 180 h
Lecture type	Lecture and Tutorials		
Duration	1 semester		
Frequency	Regularly in the winter		
Language of Instruction	English		
Type of Exam	Written Exam		
Content	The module deals with statistical models and methods for the analysis of financial data. The following topics are covered: 1. Univariate Return Distributions, Extreme Value Theory 2. Multivariate Return Distributions, Copulas, Value at Risk 3. ARIMA Time Series. Random Walks, Market Efficiency 4. Stochastic Volatility, GARCH Times Series 5. CAPM-Model, Performance Measures 6. Stochastic Dominance, Brownian Motion, Stochastic Calculus 7. Option Pricing, Black-Scholes Model		
Objectives	Students master the most commonly used statistical methods for analyzing financial variables. The module enables them to understand the motivation and derivation of the different methods. Students apply these methods in practical applications using the statistical software Stata.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	L	e	4	9	W	90	g	100
Tutorials	T	e	2					

Requirement for participation	-
Lecturer	Prof. Dr. Martin Biewen
Literature	Literature will be listed at the beginning of the semester.

Module Code: QDS-EC7 (E3: S412)	**Module Title:** Empirical Asset Pricing		**Type of Module:** elective
CP (ECTS Credits)	9		
Workload **- Time in Class** **- Self-Study**	Total Workload: 270 h	Time in Class: 90 h / 6 CH	Self-Study: 180 h
Lecture type	Lecture and PC-Lab		
Duration	1 semester		
Frequency	Regularly in the summer		
Language of Instruction	English		
Type of Exam	Portfolio		
Content	Principles of modern financial economics, generalized methods of moments- and regression-based estimation and evaluation of asset pricing models, econometric software (Matlab) is used for financial applications in practical course. The theoretical part emphasizes the link of financial economics and the econometric modelling. The methods are applied in a practical class in the PC laboratory.		
Objectives	Students should gain practical experience and the theoretical background in the application of econometric methods for the analysis of price formation processes in financial markets. They should be able to estimate and evaluate linear and nonlinear factor models and they should develop an understanding of the econometric methods and their limitations in asset pricing. Students should also learn how to present and discuss their results in a scientific proper fashion, which is dealt with in the practical class. They should be able to productively use Matlab for their own analyses in empirical finance, e.g. their master's thesis. Equally important is that the students master the important theoretical concepts of asset pricing in financial economics and the econometric theory, which are closely intertwined.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	L	e	4	9	W	90	g	100
PC-Lab	PC	e	2					

Requirement for participation	-
Lecturer	Prof. Dr. Joachim Grammig
Literature	Literature will be listed at the beginning of the semester.

Module Code: QDS-EC8 (E1: S310)	**Module Title:** Financial Market Microstructure		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload - Time in Class - Self-Study	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Lecture and Tutorials		
Duration	1 semester		
Frequency	Regularly in the summer		
Language of Instruction	English		
Type of Exam	Portfolio		
Content	The module starts with institutional background and market microstructure basics, in particular market types (dealer or limit order book markets), order types and market participants. It moves on to the main theoretical models of price formation (Roll model, Kyle model, Glosten model, and others). The module then covers structural models of the trading process (Huang/Stoll, Glosten/Harris, Madhavan/Richardson/Roomans model). Finally, insight is given into recent developments in the analysis of high frequency financial data (such as realized volatility, microstructure noise, algorithmic trading). The theoretical aspects are illustrated in empirical applications using SAS. Case studies covering the different topics will be treated in the practical sessions.		
Objectives	Students know about the design of financial markets. They understand the influence of market characteristics on market efficiency and trading patterns. Students discuss how different traders and different trading strategies impact on the behavior of other market participants, on the interactions of markets and the market as a whole. Besides gaining an insight into theoretical models, students also apply their knowledge within the framework of empirical case studies using the econometric/statistical software (SAS). This prepares them to conduct their own research, for example in a master thesis.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	L	e	2	6	PO	-	g	100
Tutorials	T	e	2					

Requirement for participation	-
Lecturer	Prof. Dr. Joachim Grammig
Literature	Literature will be listed at the beginning of the semester.

Module Code: QDS-EC9 (E2: S413)	**Module Title:** Financial Economics		**Type of Module:** elective
CP (ECTS Credits)	9		
Workload - Time in Class - Self-Study	Total Workload: 270 h	Time in Class: 90 h / 6 CH	Self-Study: 180 h
Lecture type	Lecture and PC-Lab		
Duration	1 semester		
Frequency	Regularly in the winter		
Language of Instruction	English		
Type of Exam	Portfolio		
Content	The module deals with a rigorous treatment of modern financial economics. This includes: 1. Relationship of state preferences, risk-neutral probabilities and the pricing kernel 2. Existence of a positive stochastic discount factor and fundamental theorem of financial economics 3. Relationship of stochastic discount factor representations of asset pricing models, mean-variance frontier and expected return-beta representation 4. Recent advances in financial economics 5. Applications in financial economics using SAS		
Objectives	Students master the theoretical background of price formation processes in financial markets. They command an econometric software (SAS) to independently and productively perform empirical analyses in empirical financial economics and they present and discuss their results in a scientific fashion.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	L	e	3	9	PO	-	g	100
PC-Lab	PC	e	3					

Requirement for participation	-
Lecturer	Prof. Dr. Joachim Grammig
Literature	Literature will be listed at the beginning of the semester.

<table>
<tr><td>Module Code:
QDS-EC10</td><td colspan="3">Module Title:
Core Topics Econometrics I</td><td>Type of Module:
elective</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="4">6</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Total Workload:
180 h</td><td colspan="2">Time in Class:
60 h / 4 CH</td><td>Self-Study:
120 h</td></tr>
<tr><td>Lecture type</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Duration</td><td colspan="4">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Language of Instruction</td><td colspan="4">English</td></tr>
<tr><td>Type of Exam</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Content</td><td colspan="4">In this module students can choose a class that teaches specific knowledge in the area of Econometrics. This can include classes on statistics in economy, specific topics of financial economics, and specific applications of econometric applications.

Within the scope of Econometrics, this module is intended for changing lectures and seminars and will be credited according to the origin of the module. It offers the flexibility to participate in current research seminars, for example, by guest lecturers.

The content in this module does not overlap with the topics in Core Topics in Econometrics II (QDS-EC11).</td></tr>
<tr><td>Objectives</td><td colspan="4">Within the area of the chosen seminar or lecture the students have the opportunity to …
- deepen their understanding of selected topics in Econometrics
- gain insights in more specific applications of Econometrics
- broaden their knowledge in a variety of topics in Econometrics</td></tr>
<tr><td>Requirements for Obtaining Credit, Grading, Weight if appl.</td><td colspan="4"><table>
<tr><th></th><th>Type of Course</th><th>Status</th><th>CH</th><th>CP</th><th>Type of Exam</th><th>Duration of Exam</th><th>Evaluation</th><th>Calculation of Module (%)</th></tr>
<tr><td>Block / Seminar</td><td>-</td><td>e</td><td>-</td><td>6</td><td>-</td><td>-</td><td>g</td><td>100</td></tr>
</table></td></tr>
<tr><td>Requirement for participation</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Lecturer</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Literature</td><td colspan="4">Literature will be listed at the beginning of the semester.</td></tr>
</table>

<table>
<tr><td>Module Code:
QDS-EC11</td><td colspan="3">Module Title:
Core Topics Econometrics II</td><td>Type of Module:
elective</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="4">9</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Total Workload:
270 h</td><td colspan="2">Time in Class:
90 h / 6 CH</td><td>Self-Study:
180 h</td></tr>
<tr><td>Lecture type</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Duration</td><td colspan="4">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Language of Instruction</td><td colspan="4">English</td></tr>
<tr><td>Type of Exam</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Content</td><td colspan="4">In this module students can choose a class that teaches specific knowledge in the area of Econometrics. This can include classes on statistics in economy, specific topics of financial economics, and specific applications of econometric applications.

Within the scope of Econometrics, this module is intended for changing lectures and seminars and will be credited according to the origin of the module. It offers the flexibility to participate in current research seminars, for example, by guest lecturers.

The content in this module does not overlap with the topics in Core Topics in Econometrics I (QDS-EC10).</td></tr>
<tr><td>Objectives</td><td colspan="4">Within the area of the chosen seminar or lecture the students have the opportunity to …
- deepen their understanding of selected topics in Econometrics
- gain different insights in more specific applications of Econometrics
- broaden their knowledge in a variety of topics in Econometrics</td></tr>
<tr><td rowspan="2">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Block / Seminar</td><td>-</td><td>e</td><td>-</td><td>9</td><td>-</td><td>-</td><td>g</td><td>100</td></tr>
<tr><td>Requirement for participation</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Lecturer</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Literature</td><td colspan="4">Literature will be listed at the beginning of the semester.</td></tr>
</table>

Modules of Study Area Machine Learning

<table>
<tr><td>Module Code:
QDS-ML1</td><td colspan="3">Module Title:
Foundations in Machine Learning</td><td>Type of Module:
(Obligatory for certain students, see introduction)</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="4">6</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Total Workload:
180 h</td><td colspan="2">Time in Class:
60 h / 4 CH</td><td>Self-Study:
120 h</td></tr>
<tr><td>Lecture type</td><td colspan="4">Seminar, lecture
Written exams, classroom presentations and essays are typical types of exams to pass the module. At the beginning of the module the lecturer informs about the requirements to pass the module.</td></tr>
<tr><td>Duration</td><td colspan="4">1 Semester</td></tr>
<tr><td>Frequency</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Language of Instruction</td><td colspan="4">English</td></tr>
<tr><td>Type of Exam</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Content</td><td colspan="4">Machine learning is an important component of the growing field of data science. Through the use of statistical methods, algorithms are trained to make classifications or predictions, uncovering key insights within data mining projects. ML algorithms might improve automatically through experience and by use of data.</td></tr>
<tr><td>Objectives</td><td colspan="4">Students understand methods of Machine Learning and learn their basic applications. They can evaluate the quality of models. Students can use Machine Learning methods and interpret their results as well as construct their own tests.</td></tr>
<tr><td rowspan="2">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Seminar</td><td>S</td><td>o</td><td>4</td><td>6</td><td>W/P/E</td><td>-</td><td>g</td><td>100</td></tr>
<tr><td>Requirement for participation</td><td colspan="4">-</td></tr>
<tr><td>Responsible</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Literature</td><td colspan="4">Literature will be listed at the beginning of the semester.</td></tr>
</table>

Module Code: QDS-ML2 (N: NIP-02)	**Module Title:** Machine Learning (1)		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload **- Time in Class** **- Self-Study**	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Lecture and Assignments / Exercise Sessions		
Duration	1 semester		
Frequency	Regularly in the winter		
Language of Instruction	English		
Type of Exam	Written exam		
Content	We provide a comprehensive overview of contemporary approaches in Machine Learning. Topics include (but are not limited to) probability theory, frequentist and Bayesian statistics, basic methods for classification and regression, elementary methods for unsupervised learning and dimension reduction, statistical learning theory, kernel methods, support vector machines, Bayesian inference and model selection, stochastic processes, graphical models, Hidden Markov Models, and approximation methods for learning and inference. We will exemplify the applicability of these approaches to various problem domains, e.g. neural data analysis and computer vision. Relevant software packages will be discussed. In addition, open problems in machine learning research will be discussed.		
Objectives	Students will learn the theoretical basis of fundamental methods in machine learning. They will learn to establish and prove simple relationships in probabilistic modeling and inference. They will be enabled to choose the appropriate machine learning tools for given problems in data analysis and modeling. As a consequence of the homework exercises, students will also be familiarized with the implementation and application of methods of machine learning research and relevant software tools. By working on concrete problems students will be familiarized with the practical realization of machine learning algorithms and the related implementation issues.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	L	o	3	6	W	120	g	100
Tutorial	T	o	3					

Requirement for participation	-
Lecturer	Prof. Dr. Philipp Berens and Prof. Dr. Martin Giese
Literature	Literature will be listed at the beginning of the semester.

Module Code: QDS-ML3 (ML: ML-4102)	**Module Title:** Data Literacy		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload - Time in Class - Self-Study	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Lecture and Tutorials		
Duration	1 semester		
Frequency	Regularly in the winter		
Language of Instruction	English		
Type of Exam	Written exam		
Content	This course equips students with the concepts and tools that should be familiar to anyone who works with (large) data. It is centered around the following five central topics: conceptual framework of data, data collection, data management, data evaluation, and data application. Based on practical experiments and examples, frequently encountered pitfalls and problems are discussed alongside best practices. We will encounter common datatypes, and techniques for data preparation and cleaning. Several forms of bias are studied. Basic tools for data analysis and visualization are introduced and used hands-on. We will also discuss best practices for scientific data presentation and documentation — how to make expressive figures and tables and perform reproducible experiments — and explore ethical and technical considerations in the context of privacy and transparency.		
Objectives	Students develop a sensitivity for common problems and misconceptions in empirical work with data. They understand the mathematical, epistemological, ethical, technical and social challenges surrounding the use of data, and know best practices to address them. They also collect a concrete box of software tools to collect, document, explore, visualize, and draw conclusions from structured, large, small, corrupted and expensive data.		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Lecture	L	e	2	3	W	90	g	100
	Tutorials	T	e	2	3				

Requirement for participation	basic math and coding skills. The practical part will use several different, and largely open-source software packages.
Lecturer	Kay Nieselt, Philipp Henning
Literature	Literature will be listed at the beginning of the semester.

Module Code: QDS-ML4 (ML: ML-4103)	**Module Title:** Deep Learning		**Type of Module:** elective
CP (ECTS Credits)	6		
Workload - Time in Class - Self-Study	Total Workload: 180 h	Time in Class: 60 h / 4 CH	Self-Study: 120 h
Lecture type	Lecture and Tutorials		
Duration	1 semester		
Frequency	Regularly in the winter		
Language of Instruction	English		
Type of Exam	Written exam		
Content	Within the last decade, deep neural networks have emerged as an indispensable tool in many areas of artificial intelligence including computer vision, computer graphics, natural language processing, speech recognition and robotics. This course will introduce the (practical and theoretical) principles of deep neural networks and give an overview over the most established training and regularization techniques. The lecture will further discuss the most important network variants, including convolutional neural networks, generative neural networks, recurrent neural networks and deep reinforcement learning. Furthermore, the course will give an overview over the most important architectures (hourglass networks, skip connections, dense connections, dilated convolutions, permutation invariant networks, Siamese networks, etc.). In addition, applications from various fields will be presented throughout the course. The tutorials will deepen the understanding of deep neural networks by implementing, training and applying them using modern deep learning frameworks.		
Objectives	Students gain an understanding of the practical and theoretical concepts of deep neural networks including, optimization, inference, various architectures and application domains. After this course, students should be able to develop and train deep neural network architectures for a particular task and understand the potentials and pitfalls when applying deep neural networks in practice.		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Lecture	L	e	2	3	W	90	g	100
	Tutorials	T	e	2	3				

Requirement for participation	Basic math (linear algebra & analysis) and coding skills (Python).
Lecturer	Prof. Dr. Andreas Geiger, Prof. Dr. Andreas Zell
Literature	Literature will be listed at the beginning of the semester.

Module Code: QDS-ML5 (ML: ML-4201)	**Module Title:** Statistical Machine Learning		**Type of Module:** elective
CP (ECTS Credits)	9		
Workload **- Time in Class** **- Self-Study**	Total Workload: 270 h	Time in Class: 90 h / 6 CH	Self-Study: 180 h
Lecture type	Lecture and Tutorials		
Duration	1 semester		
Frequency	Regularly in the summer		
Language of Instruction	English		
Type of Exam	Written exam		
Content	The focus of this lecture is on algorithmic and theoretical aspects of statistical machine learning. We will cover many of the standard algorithms, learn about the general principles for building good machine learning algorithms, and analyze their theoretical and statistical properties. The following topics will be covered: Supervised machine learning, for example linear methods; regularization; SVMs; kernel methods. Bayesian decision theory, loss functions, Unsupervised learning problems, for example dimension reduction, kernel PCA, multi-dimensional scaling, manifold methods; spectral clustering and spectral graph theory. Introduction to statistical learning theory: no free lunch theorem; generalization bounds; VC dimension; universal consistency; Evaluation and comparison of machine learning algorithms. Advanced topics in statistical learning, for example low rank matrix completion, compressed sensing, ranking, online learning.		
Objectives	Students get to know the most important classes of statistical machine learning algorithms. They understand why certain algorithms work well and others don't. They can evaluate and compare the results of different learning algorithms. They can model machine learning applications and get a feeling for common pitfalls. They can judge machine learning algorithms from a theoretical point of view.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	L	e	4	6	W	90	g	100
Tutorials	T	e	2	3				

Requirement for participation	Students need to know the contents of the basic math classes, in particular linear algebra and probability theory.
Lecturer	Prof. Dr. Matthias Hein, Prof. Dr. Ulrike von Luxburg
Literature	Literature will be listed at the beginning of the semester.

Module Code: QDS-ML6 (ML: ML-4202)	**Module Title:** Probabilistic Machine Learning		**Type of Module:** elective
CP (ECTS Credits)	9		
Workload - Time in Class - Self-Study	Total Workload: 270 h	Time in Class: 90 h / 6 CH	Self-Study: 180 h
Lecture type	Lecture and Tutorials		
Duration	1 semester		
Frequency	Regularly in the summer		
Language of Instruction	English		
Type of Exam	Written exam		
Content	Probabilistic inference is a foundation of scientific reasoning, statistics, and machine learning. The lecture course begins with a general introduction to basic principles (rules of probability theory, graphical models), then covers the probabilistic view on many standard settings, like supervised regression and classification, and unsupervised dimensionality reduction and clustering. In a parallel thread through the lecture, we will also encounter a number of popular algorithms for inference in probabilistic models, including exact inference in Gaussian models, sampling, and free-energy methods. At specific points, connections and differences to non-probabilistic frameworks will be made.		
Objectives	Students gain an intuitive, as well as a mathematical and algorithmic understanding of probabilistic reasoning. They acquire a mental toolbox of probabilistic models for various problem classes, along with the algorithms required for their concrete implementation. Over the course of the lecture, they also become proficient in the fundamental concept of uncertainty, and the philosophical challenges and pitfalls associated with it. They are empowered to build, analyze, and use their own probabilistic models for concrete use cases.		

Requirements for Obtaining Credit, Grading, Weight if appl.

	Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
Lecture	L	e	4	6	W	90	g	100
Tutorial	T	e	2	3				

Requirement for participation	basic math, in particular linear algebra. Code examples and coding exercises use python.
Lecturer	Prof. Dr. Philipp Henning, Prof. Dr. Nico Pfeifer
Literature	Literature will be listed at the beginning of the semester.

<table>
<tr><td>Module Code:
QDS-ML7</td><td colspan="3">Module Title:
Core Topics Machine Learning I</td><td>Type of Module:
elective</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="4">6</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td>Total Workload:
180 h</td><td colspan="2">Time in Class:
90 h / 4 CH</td><td>Self-Study:
180 h</td></tr>
<tr><td>Lecture type</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Duration</td><td colspan="4">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Language of Instruction</td><td colspan="4">English</td></tr>
<tr><td>Type of Exam</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Content</td><td colspan="4">In this module students can choose a class that teaches specific knowledge in the field of machine learning. This can include classes on (un-)supervised learning, reinforcement learning, and applications in specific contexts.

Within the scope of Machine Learning, this module is intended for changing lectures and seminars and will be credited according to the origin of the module. It offers the flexibility to participate in current research seminars, for example, by guest lecturers.

The content in this module does not overlap with the topics in Core Topics Machine Learning II (QDS-ML8).</td></tr>
<tr><td>Objectives</td><td colspan="4">Within the area of the chosen seminar or lecture the students have the opportunity to …
- deepen their understanding of selected topics in Machine Learning
- gain insights in more specific applications of Machine Learning
- broaden their knowledge in a variety of topics in Machine Learning</td></tr>
<tr><td rowspan="2">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Block / Seminar</td><td>-</td><td>e</td><td>-</td><td>6</td><td>-</td><td>-</td><td>g</td><td>100</td></tr>
<tr><td>Requirement for participation</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Lecturer</td><td colspan="4">Depends on chosen course</td></tr>
<tr><td>Literature</td><td colspan="4">Literature will be listed at the beginning of the semester.</td></tr>
</table>

Module Code: QDS-ML8	**Module Title:** Core Topics Machine Learning II		**Type of Module:** elective
CP (ECTS Credits)	9		
Workload **- Time in Class** **- Self-Study**	Total Workload: 270 h	Time in Class: 90 h / 6 CH	Self-Study: 180 h
Lecture type	Depends on chosen course		
Duration	1 semester		
Frequency	Depends on chosen course		
Language of Instruction	English		
Type of Exam	Depends on chosen course		
Content	In this module students can choose a class that teaches specific knowledge in the field of machine learning. This can include classes on (un-)supervised learning, reinforcement learning, and applications in specific contexts. Within the scope of Machine Learning, this module is intended for changing lectures and seminars and will be credited according to the origin of the module. It offers the flexibility to participate in current research seminars, for example, by guest lecturers. The content in this module does not overlap with the topics in Core Topics Machine Learning I (QDS-ML7).		
Objectives	Within the area of the chosen seminar or lecture the students have the opportunity to … - deepen their understanding of selected topics in Machine Learning - gain different (to QDS-ML7) insights in more specific applications of Machine Learning - broaden their knowledge in a variety of topics in Machine Learning		

Requirements for Obtaining Credit, Grading, Weight if appl.		Type of Course	Status	CH	CP	Type of Exam	Duration of Exam	Evaluation	Calculation of Module (%)
	Block / Seminar	-	e	-	9	-	-	g	100

Requirement for participation	Depends on chosen course
Lecturer	Depends on chosen course
Literature	Literature will be listed at the beginning of the semester.

Module Master Thesis and Research Project

<table>
<tr><td>Module Code:
QDS-ML</td><td colspan="6">Module Title:
Master thesis</td><td colspan="3">Type of Module:
obligatory</td></tr>
<tr><td>CP
(ECTS Credits)</td><td colspan="9">30</td></tr>
<tr><td>Workload
- Time in Class
- Self-Study</td><td colspan="3">Total Workload:
900 h</td><td colspan="3">Time in Class:
0</td><td colspan="3">Self-Study:
900h</td></tr>
<tr><td>Lecture type</td><td colspan="9">Thesis</td></tr>
<tr><td>Duration</td><td colspan="9">1 semester</td></tr>
<tr><td>Frequency</td><td colspan="9">Every semester</td></tr>
<tr><td>Language of Instruction</td><td colspan="9">English</td></tr>
<tr><td>Type of Exam</td><td colspan="9">Written thesis and oral presentation</td></tr>
<tr><td>Content</td><td colspan="9">The Master’s thesis is the final stage of the Master’s degree program, and comprises completing a project in one of the areas of this program, evaluating and processing the results obtained, and finally preparing a written detailed presentation of these results. The results should be of scientific value. In addition, students will give an oral presentation of their thesis’ topic.</td></tr>
<tr><td>Objectives</td><td colspan="9">Students
- are able to become familiar with a current research issue within a given frame. They are able to apply scientific methods and present their results in a scientifically appropriate manner
- are able to independently handle a complex scientific issue, applying their knowledge of quantitative data science methods
- gain a deeper understanding of how to solve problems, and are able to apply their knowledge of methods
- are able to present and defend their evidence before an audience in English</td></tr>
<tr><td rowspan="2">Requirements for Obtaining Credit, Grading, Weight if appl.</td><td></td><td>Type of Course</td><td>Status</td><td>CH</td><td>CP</td><td>Type of Exam</td><td>Duration of Exam</td><td>Evaluation</td><td>Calculation of Module (%)</td></tr>
<tr><td>Master’s thesis</td><td>R</td><td>o</td><td>-</td><td>30</td><td>-</td><td>-</td><td>g</td><td>100</td></tr>
<tr><td>Requirement for participation</td><td colspan="9">If any conditions have been set for admission to a Master’s degree course, students must prove that these conditions have been met prior to registering a thesis topic.</td></tr>
<tr><td>Lecturer</td><td colspan="9">Lecturers of QDS</td></tr>
<tr><td>Literature</td><td colspan="9">Depends on the topic</td></tr>
</table>