BIOST/STAT 533: THEORY OF LINEAR MODELS
SPRING 2024

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Land acknowledgment The University of Washington acknowledges the Coast Salish people of this land, the land which touches the shared waters of all tribes and bands within the Duwamish, Suquamish, Tulalip and Muckleshoot nations.

Course description This course covers the classical theory of linear models. We will also discuss the implications of the results on the use of linear models. Some numerical examples will be used to illustrate the phenomenon. However, this course is not about data analysis.

The following topics are covered: linear model under various assumptions; ordinary least squares; Gauss-Markov theorem; finite-sample inference under normality; central limit theorems; heteroskedasticity; robust standard errors; Frisch–Waugh–Lovell; analysis of variance; data transformation and specification of design; model fitting, checking and misspecification; ridge regression; restricted least squares; weighted and generalized least squares. However, the course does *not* cover generalized linear models.

Learning objectives Linear model serves as a useful approximation to data-generating process and a stepping stone to more advanced models. The goal is to develop a solid understanding of the properties of linear models under various assumptions. It is also important to develop geometric intuitions that accompany algebraic derivations. To achieve these goals, we will

- develop linear algebra and probability skills and apply them to the linear model;
- understand finite-sample and asymptotic behaviors of least squares;
- develop inference techniques that are robust to error assumptions;
- examine and compare models in a data-driven way.

Prerequisites Introduction to linear statistical models (e.g. BIOST 515 or 518), intermediate statistical inference (e.g. STAT 512-513), linear algebra.

Grading Policy

- *40% Homeworks.* There will be 8 homework assignments, assigned approximately weekly, and due on Fridays at 12:30pm. Each assignment will be worth 5% of the final grade. Homeworks will generally be posted within 24 hours of the Friday lecture. Late homeworks will **not** be accepted. You may work together on homeworks, but you should not copy solutions from other students or other sources.

  Points will be given for correct answers as well as showing your reasoning process and justifying your responses. No credit will be given for answers without justification.

  Please submit your homework on Canvas as a single PDF file. You are encouraged to type up your solution using LaTeX or GNU TeXmacs, but you do not have to, as long as your solutions are legible. If you submit illegible responses, you will be asked to rewrite and resubmit your homework. If this happens repeatedly you will not get credit. Consider compressing your PDF if the file size $>$ 5MB.

- *20% Midterm.* On **Friday, April 26**, we will have an open-notes midterm exam during class time in the classroom (HRC 155).

- *40% Final.* On **Monday, June 3 during 2:30–4:20 PM**, we will have an open-notes final exam in the classroom (HRC 155).

  Both the midterm and the final exams are open notes (paper only). Use of electronic devices (laptop, tablet, calculator, etc.) is not permitted.

Course materials The syllabus, lecture slides and homework will be posted on our Canvas site.

Our main reference will be §1–19 of the following book draft:

- *Peng Ding, Linear Model and Extensions, 2024.*

The book itself points to many useful references. For other resources to consult, consider the following textbooks accessible from UW library:

- *Seber and Lee, Linear Regression Analysis, 2nd Edition, Wiley 2003.*
- *Monahan, A Primer on Linear Models, 1st edition, CRC Press , 2008.*
- *Freedman, Statistical Models: Theory and Practice, 2nd Edition, Cambridge, 2009*
- *Searle and Khuri, Matrix Algebra Useful for Statistics. 2nd edition. Wiley-Interscience 2017.*

- *van der Vaart, A.W. Asymptotic Statistics. Cambridge University Press; 1998.*
- *Weisberg, Applied Linear Regression, Third Edition, Wiley 2005.* A more applied treatment of some of the topics covered in this course.

Course expectations Though attendance in lecture is not required, it is strongly recommended. Students are responsible for all material covered in class unless the instructor specifically states otherwise.

Communication and discussion

- *Discussion forum*: In addition to the office hours, we will use Canvas for posting and answering questions.
- *Announcements*: I will post any updates to Canvas. Please make sure that your Canvas settings for an "Announcement" will alert you "ASAP."
- *Feedback on the textbook draft*: For comments on the book, or typos or errors that you spot, please record them here. I will relay these to the author.
- *Anonymous feedback*: If you would like to send feedback or raise an issue to the instructor anonymously, please use this link (no login is required).
- *Email*: For other issues, please feel free to contact the instructor.

Schedule Below is a tentative schedule. For an up-to-date progress and schedule, check here.

Week	Chapters	Due	Note
1	§1, §2, Appendix A		
2	§3, §4	HW 1	
3	§5, §6	HW 2	
4	§6, §7	HW 3	
5	§8.2, review		Midterm
6	§8, §9, §10, §11	HW 4	
7	§12, §13	HW 5	
8	§13, §14	HW 6	
9	§18, §16, §17	HW 7	
10	§19, review	HW 8	
11			Final exam

Illness protocol If you feel ill or exhibit respiratory or other symptoms, you should not come to class. Seek medical attention if necessary and notify your instructor as soon as possible by email. Follow the COVID-19 Public Health Flowchart if you have COVID-19 symptoms, exposure or test positive, and adhere to the UW Face Covering Policy.

Please make sure to get notified of Canvas announcements. If we need to conduct class remotely because the instructor is unable to attend in person, we will send all registered students an email and/or post a Canvas announcement with a Zoom link for remote instruction or a plan for making up the class.

Academic integrity Students at the University of Washington (UW) are expected to maintain the highest standards of academic conduct, professional honesty, and personal integrity.

The UW School of Public Health (SPH) is committed to upholding standards of academic integrity consistent with the academic and professional communities of which it is a part. Plagiarism, cheating, and other misconduct are serious violations of the University of Washington Student Conduct Code (WAC 478-121). We expect you to know and follow the university's policies on cheating and plagiarism, and the SPH Academic Integrity Policy. Any suspected cases of academic misconduct will be handled according to University of Washington regulations. For more information, see the University of Washington Community Standards and Student Conduct.

Use of generative artificial intelligence in coursework Artificial Intelligence (AI) content generators, such as ChatGPT, present opportunities that can contribute to your learning and academic work. However, using these technologies may also violate academic standards of the University. Under the Student Conduct Code, cheating includes the unauthorized use of assistance, including technology, in completing assignments or exams.

Access and accommodations Your experience in this class is important to me. It is the policy and practice of the University of Washington to create inclusive and accessible learning environments consistent with federal and state law. If you have already established accommodations with Disability Resources for Students (DRS), please activate your accommodations via myDRS so we can discuss how they will be implemented in this course.

If you have not yet established services through DRS, but have a temporary health condition or permanent disability that requires accommodations (conditions include but not limited to; mental health, attention-related, learning, vision, hearing, physical or health impacts), contact DRS directly to set up an Access Plan. DRS facilitates the interactive process that establishes reasonable accommodations. Contact DRS at `https://disability.uw.edu`.

Religious accommodations Washington state law requires that UW develop a policy for accommodation of student absences or significant hardship due to reasons of faith or conscience, or for organized religious activities. The UW's policy, including more information

about how to request an accommodation, is available at Religious Accommodations Policy. Accommodations must be requested within the first two weeks of this course using the Religious Accommodations Request form.

Inclusion & diversity Diverse backgrounds, embodiments and experiences are essential to the critical thinking endeavor at the heart of University education. In SPH, we are expected:

1. To respect individual differences, which may include, but are not limited to, age, cultural background, disability, ethnicity, family status, gender, immigration status, national origin, race, religion, sex, sexual orientation, socioeconomic status and veteran status.

2. To engage respectfully in the discussion of diverse worldviews and ideologies embedded in course readings, presentations and artifacts, including those course materials that are at odds with personal beliefs and values.

3. To encourage students with concerns about classroom climate to talk to their instructor, adviser, a member of the departmental or SPH EDI Committee, the Assistant Dean for EDI, or the program's director.

Classroom climate We are co-creators of our learning environment. It is our collective responsibility to develop a supportive learning environment for everyone. Listening with respect and an open mind, striving to understand others' views, and articulating your own point of view will help foster the creation of this environment. We engage our differences with the intent to build community, not to put down the other and distance our self from the other. Being mindful to not monopolize discussion and/or interrupt others will also help foster a dialogic environment.

Acknowledgment I am grateful to Ting Ye, Amy Willis, Peng Ding, Qingyuan Zhao and Rajen Shah for sharing their materials and experience. All errors are my own — please let me know if you see any!