This course considers systems of equations, drawing from two complementary approaches: the structural equation modeling with latent variables (SEM) literature and the econometrics literature (SiEM). In contrast to single equation models, these models have at least two equations. These simultaneous models can be grouped into two major types: recursive models, which do not create any special problems, and nonrecursive models, which require special treatment. For each of these major types of models, we will discuss the specification, identification, estimation, and assessment of these simultaneous equation systems. Nonrecursive models introduce the problem of identification, or how to establish that the parameters of the model are estimable. These models also require alternative estimation techniques.

As time permits, advanced topics will be covered. Students should have a solid understanding of multiple regression and some background in matrix algebra. We will be using various software packages for programming, including SAS, STATA, and R.

Required text:


Readings are also drawn from selected chapters in the following econometric texts:


Additional readings are drawn from the following structural equation modeling (SEM) texts:


All required readings will be made available on the course site on Canvas along with a more detailed reading schedule.
There will be approximately 6 assignments. Due dates of assignments will be announced via the class platform. We will also be discussing application papers as appropriate to non-recursive models (listed on last page of this syllabus). Lab sessions will be announced via the class platform.

**Topics and Readings:**

I. **Introduction to Simultaneous Equation Models**
   a. A brief introduction to simultaneous equation models

II. **Review of the Classical Linear Regression model**
   a. Review of matrix algebra

Readings:
Fox, John. 2009. *A Mathematical Primer for Social Statistics*. SAGE Publications, Inc. QASS. Chapter 1, Section 1.1 pp. 2-18 and Section 1.4 pp. 30-40. OR
Johnston and DiNardo: pp. 459-483

b. Classical linear regression model

Readings:
Gujarati: ch.4 OR
Greene: ch.2 (ch. 6) OR
Johnston & Dinardo: ch.3

Note: for further review, read Gujarati ch.1-3 & 6, or Johnston & DiNardo chp.1-2, etc. first.

III. **Overview of simultaneous equation models**
Recursive vs. nonrecursive models; path diagrams/equations/matrices; reduced vs. structural form; direct, indirect and total effects.

Readings:
Paxton, Hipp, & Marquart-Pyatt: Chps. 1 & 2
Gujarati: chp.18
Bollen: pp.32-34; 36-39
IV: Recursive models

a. Specification

Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 2 p. 4-17
Gujarati: p. 764
Johnston & DiNardo: pp.305-309
Kmenta: pp.719-720

b. Identification

Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 3 p. 24-30
Bollen: p. 88-98
Kenny: p. 34-41, 61-62
Greene: 13.3

c. Estimation

Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 4 p. 46-48
Gujarati: p. 681-682
Johnston: p. 468-469 (ed. 4: 314-318)
Kmenta: p. 720

d. Assessment

 Decomposition of effects

Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 6 (pp. 88-97)
Bollen: pp.36-39

Mediation in SiEM** (**see extended list on shared platform).

Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 6 (pp. 100-114)

Optional Reading:

**V: SUR (seemingly unrelated regressions) models**

Readings:
Greene: 10.2, 15.6.3
Kmenta: 12.3

Example:

**VI: Nonrecursive simultaneous equation models**

a. **Specification**
Reading:
Paxton, Hipp, & Marquart-Pyatt: Chp. 2 (esp p. 17-23)
Gujarati: 18.3-18.4

b. **Identification**
Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 3
Gujarati: chp.19.1-19.3
Greene: 13.3.1-13.3.2

c. **Estimation: ILS, 2SLS, 3SLS, ML**
Reading:
Paxton, Hipp, & Marquart-Pyatt: Chp. 4
Gujarati: 20.1

c1. Indirect least squares
Readings:
c2. Two Stage Least Squares, aka 2SLS
Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 4 p. 48-53
Gujarati: 20.4, 20.5
Greene: 13.4, 13.5.2, and 13.5.3
Kmenta: pp.681-687

Examples:


c3. 3SLS
Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 4 p. 53-54
Johnston: pp.486-490
Kmenta: pp.695-701
Greene 13.6, 13.6.1

c4. MLE
Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 4 p. 55
Greene: 13.6.2

d. Comparison of Estimation Methods
Reading:
Paxton, Hipp, & Marquart-Pyatt: Chp. 4 pp. 51-53 & 56-58
Greene: 13.7
Kmenta: pp.711-714

e. Decomposition of Effects
Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 6
Bollen: pp.376-389
VII. Assessment of models

a. Equation by equation

a1. Assessment of Instruments
Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 5 pp. 73-78

Optional reading** (see extended list on course site of more recent applications):

a2. Endogeneity tests:
Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 5 pp. 78-80
Gujarati: 19.4-19.5
Greene: 13.8

b. Global goodness of fit statistics for overidentified models

Readings:
Paxton, Hipp, & Marquart-Pyatt: Chp. 5 (pages 67-73)
Bollen: pp.263-289
Additional Topics: (including seminal cites and covered as time permits)

Consequences of measurement error
Reading:
Bollen: chp.5; Greene: 9.5

Simultaneous equations with limited dependent variables
Readings:


Optional readings: Maddala 5.1, 5.8, chapter 7 and chapter 8.

Modeling change
Readings:

Optional Reading:

Standard Errors of indirect effects
Readings:
Lagged Endogenous Variables with autocorrelation

Readings:
Kmenta: 13.5

Using simultaneous equations to handle spatial effects

Readings:

Bayesian Simultaneous Equations

Readings:

Autocorrelation or heteroskedasticity in simultaneous equations

Readings:
Kmenta: 13.5

Power Issues in Simultaneous Equations

Readings:

Application Papers with tentative presentation dates (subject to change*):

Nonrecursive I: Presentation & Discussion Thursday August 6

Nonrecursive II: Presentation & Discussion Friday August 7

Nonrecursive III: Presentation & Discussion Tuesday August 11
ADDITIONAL RESOURCES: AN ABBREVIATED LISTING

Regression Review
   Chapter 1, Section 1.1 pp. 2-18 and Section 1.4 pp. 30-40.
   Chapters 3 and 4.

Structural Equation Modeling

Quantitative Empiricism, Models, and Workflow
   o Chap 1, 6