Economics 468

Fall 2020   **R. Davidson**

Textbooks

The principal reference for this course is the textbook *Econometric Theory and Methods* (ETM), Oxford University Press, ISBN 0-19-512372-7, by James MacKinnon and me. I believe that it now exists in a paperback edition, although I have never seen it, and it is probably cheaper than the hardback. Some of you may be interested to know that the book has been translated into Chinese. More information about this book can be found at

https://qed.econ.queensu.ca/ETM/

The main secondary reference for the course is the textbook *Estimation and Inference in Econometrics*, Oxford University Press, ISBN 0-19-506011-3, also by James MacKinnon and me. This book treats things at a more advanced level than is needed for this course. *Estimation and Inference* has undergone around ten printings – I've lost the exact count – and the successive reprintings allowed us to make a few corrections each time. My copy, sent to me by the publisher as an evaluation copy, is from the fourth printing. But even if you had the first printing, that would serve perfectly well, since all corrections, right from the beginning, are available on the book homepage, at

http://qed.econ.queensu.ca/pub/dm-book/

Software

Econometrics is primarily an applied discipline. The theory is rich and satisfying, but it is just an exercise in navel contemplation if it is not used to guide empirical practice. There are two aspects of this practice that I would like to get across. The first is the use of computers in order to implement the various estimation and testing procedures that theory provides us with. Econometrics software is no harder to use than most other sorts of software, although it is highly desirable to get out of the "point and click" frame of mind. Most packages require a certain amount of programming. However, many econometrics packages are so powerful that, if you manage to get them to read in your data, they will do all the rest, with no further thinking on your part. Since thinking is a desirable activity in students (and others), many of the exercises on the assignments and in the exercises to be found at the end of each chapter of ETM will require you not to make use of all the features of sophisticated packages, in order that you may see more clearly how those features can be built up from simpler ones.

For many years, even decades, now, packages like TSP and Shazam have epitomised econometric software. Many such packages exist, and they provide a convenient way to perform most of the numerical operations useful for econometrics. In recent years, however, programs like Matlab, Gauss, and Ox, which are essentially matrix programming languages, have been growing in favour. I must also mention R, a statistical package that has many aficionados. The reason most frequently cited for this move away from the traditional packages is that the modern packages run programs faster, and this is certainly true for

programs involving lots of simulations. You should be warned that, if you want to do "industrial strength" simulations, even these programs waste a good number of CPU cycles compared with programs written in a lower-level language like Fortran or C++ .

This year, at least, the recommended software packages for econometrics are, first, MatLab, a commercial product, but freely available to people at McGill on account of a site licence, and, second, Python, a general-purpose interpreted programming language. Our TA uses MatLab, and can answer questions about it. Python is free software (prefer Python 3 to Python 2) and has a vast number of libraries available to it for many things, including econometric calculations.

Some people seem to think that good empirical practice is all there is to econometrics. In one sense, that is so, but my experience has shown me that there is no good empirical practice without a good mastery of the underlying theory. It can be tempting to think of econometrics as a set of cookbook recipes, especially as so many of these recipes are made available by modern software. But it is all too easy to apply recipes wrongly if you do not understand the theory behind them. (This remark also applies to the cooking of food!) Thus the second vital aspect of econometric practice is *understanding* what data are telling you. Although I can make you do exercises that should make you competent in the implementation of a number of procedures, no one can (directly) teach you how to interpret the results of these procedures. Such interpretation is more an art than a science, and can therefore be taught best by example. Unfortunately, we do not have too much time for that. But even if some of the exercises you will be given in the assignments use simulated rather than real data, I will try to make you think of how your results can be interpreted. Making a practice of that may well save you from purely formal errors in the exercises.

Detailed description

We plan to cover most of chapters 1, 2, 3, 4, 5, 7, and 8 of ETM. Their contents are briefly described below.

Chapter 1: *Regression Models*. A chapter containing a brief review of regressions, along with a few reminders of things from statistics and probability theory that will be needed later. Very important is the subsection of Section 1.3 entitled "Simulating Econometric Models". The ideas in that subsection are essential for understanding the bootstrap and much else, and are not too easily found elsewhere. There are also sections dealing with various useful aspects of matrix algebra. You may find that this is well-known stuff, except perhaps for some of the material on partitioned matrices.

Chapter 2: *The Geometry of Linear Regression*. In this chapter, statistical issues are set aside in order to discuss ordinary least squares as a purely formal procedure. The chapter begins with some straightforward geometry, and introduces the concept of vector, or linear, spaces. The most important concept introduced here is that of **orthogonal projection matrices**, which are an indispensable tool in developing econometric theory. Section 2.4 presents the important **FWL theorem** (FWL = Frisch-Waugh-Lovell). We will spend a little time on this exceedingly useful result. As an application of the theorem, Section 2.6 deals with the phenomenon of leverage, whereby some observations in a sample have

much more influence on OLS parameter estimates than others. This is a topic of great importance that is not treated in all econometrics texts.

Chapter 3: *The Statistical Properties of Ordinary Least Squares.* In this chapter, the most fundamental concept of econometric theory is introduced, that of a **data-generating process**, or **DGP**. This concept allows us to define the almost equally important concept of a statistical or econometric **model**, and how such models are **specified**. Pretty much the simplest regression model is what we call the **classical normal linear model**, and this is introduced in this chapter. Much of the material in later chapters allows us to relax the very restrictive assumptions that are made in specifying this model. Although it is restrictive, it is only for this model that the beautiful, exact, results of classical regression theory are true. Some of these results are developed here, including the **Gauss-Markov theorem**, which proves the efficiency of the OLS estimator under classical assumptions. In this chapter, we also introduce some concepts, most importantly that of **probability limits**, needed for **asymptotic theory**, the approximate theory used for more general models, for which the exact classical results do not hold. Using this theory, we can show that the OLS estimator is **consistent** under much weaker conditions than the classical ones.

Chapter 4: *Hypothesis Testing in Linear Regression Models.* The two chief activities in econometrics are estimation and inference. Estimation of linear regressions is easy – just use OLS – and so this chapter is devoted to inference. The easiest approach to inference is hypothesis testing, and that is the topic of this chapter. After defining the basic concepts that underlie hypothesis testing, we develop tests for linear regressions using the geometric ideas of Chapter 2. Tests can be exact if the assumptions of the classical normal linear model are satisfied, but otherwise asymptotic theory allows us to construct approximate tests. In many cases, we can do better than these approximate tests by using the **bootstrap**; the elements of bootstrap testing are covered in this chapter.

Chapter 5: *Confidence Intervals.* Confidence intervals provide another way to conduct statistical inference. At a rather deep level, there is an equivalence between hypothesis tests and confidence intervals, but this equivalence is not always immediately obvious. Like hypothesis tests, confidence intervals can be exact, under the strong assumptions of the classical normal linear model, for instance, or approximate. Approximate confidence intervals can be based on asymptotic theory or on the bootstrap. Another topic introduced in this chapter, one of the first in which we abandon some of the classical assumptions, is heteroskedasticity-consistent inference.

Chapter 7: *Generalized Least Squares and Related Topics.* We continue the process of relaxing the restrictive classical assumptions by considering models in which the disturbances may have a more complicated specification, in particular by being heteroskedastic, or serially correlated, or both. The Gauss-Markov theorem does not apply in such cases, and so, although the OLS estimator remains consistent, it is no longer asymptotically efficient. The **GLS** estimator replaces the OLS estimator as an asymptotically efficient estimator if the pattern of heteroskedasticity or serial correlation is known, or if it can be consistently estimated, in which case we use the **feasible GLS** estimator. In this chapter, we introduce some ideas related to **time series** that arise naturally from the study of serial correlation. Numerous tests are discussed, exact, asymptotic, and bootstrap, for both heteroskedasticity and serial correlation.

Chapter 8: *Instrumental Variables Estimation*. In economics, typically "everything depends on everything else". In econometric parlance, almost all economic variables are endogenous. Their endogeneity means that they cannot be used as explanatory variables in regression models estimated by least squares, and this is not something that asymptotic theory can get around. A new estimation method is needed, and we are led to the study of instrumental variables. Instrumental variables estimation is a very natural generalization of the **method of moments** that was used earlier to justify least squares.

Method of Evaluation

Since the course will be delivered online, the method of evaluation will necessarily be unconventional. There will be some assignments, just how many is hard to predict, perhaps around four, a midterm exam and a final exam. In the past, it was not possible for me to ask you to work on the computer during exams, that is now quite possible. I will therefore take advantage of this and the exams will involve practical work involving computing.

The formal weights will be one quarter for the midterm, one quarter for the midterm, and one half for the final. However, no student will get a lower grade than the one from the final. Thus the course grade will be the greater of the final mark and the weighted average of the assignments, midterm, and final, with the specified weights.

Academic Honesty

You'll have seen the following in all of your course outlines, because the McGill Senate requires that it should appear in all of them. I used to think of it as a pure formality, but a disturbing number of cases of plagiarism have been detected in recent years, not especially at McGill, but in other North American universities. So, please take seriously all the admonitions in the following text.

1) Right to submit in English or French written work that is to be graded [approved by Senate on 21 January 2009]: In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded. This right applies to all written work that is to be graded, from one-word answers to dissertations.

2) According to Senate regulations, instructors are not permitted to make special arrangements for final exams. Please consult the calendar, section 4.7.2.1, General University Information and Regulations, at http://www.mcgill.ca.

3) Academic Integrity statement [approved by Senate on 29 January 2003]: McGill University values academic integrity. Therefore all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures.

(see http://www.mcgill.ca/students/srr/honest/ for more information).

Et en français:

L'université McGill attache une haute importance à l'honnêteté académique. Il incombe par conséquent à tous les étudiants de comprendre ce que l'on entend par

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http://www.mcgill.ca/students/srr/honest/)