1

INTRODUCTION

1.1 WHAT IS ECONOMETRICS?

Strange as it may seem, there does not exist a generally accepted answer to this question. Responses vary from the silly "Econometrics is what econometricians do" to the staid "Econometrics is the study of the application of statistical methods to the analysis of economic phenomena," with sufficient disagreements to warrant an entire journal article devoted to this question (Tintner, 1953).

This confusion stems from the fact that econometricians wear many different hats. First, and foremost, they are *economists*, capable of utilizing economic theory to improve their empirical analyses of the problems they address. At times they are *mathematicians*, formulating economic theory in ways that make it appropriate for statistical testing. At times they are *accountants*, concerned with the problem of finding and collecting economic data and relating theoretical economic variables to observable ones. At times they are *applied statisticians*, spending hours with the computer trying to estimate economic relationships or predict economic events. And at times they are *theoretical statisticians*, applying their skills to the development of statistical techniques appropriate to the empirical problems characterizing the science of economics. It is to the last of these roles that the term "econometric theory" applies, and it is on this aspect of econometrics that most textbooks on the subject focus. This guide is accordingly devoted to this "econometric theory" dimension of econometrics, discussing the empirical problems typical of economics and the statistical techniques used to overcome these problems.

What distinguishes an econometrician from a statistician is the former's preoccupation with problems caused by violations of statisticians' standard assumptions; owing to the nature of economic relationships and the lack of controlled experimentation, these assumptions are seldom met. Patching up statistical methods to deal with situations frequently encountered in empirical work in economics has created a large battery of extremely sophisticated statistical techniques. In fact, econometricians are often accused of using sledgehammers to crack open peanuts while turning a blind eye to data deficiencies and the many questionable assumptions required for the successful application of these techniques. Valavanis has expressed this feeling forcefully:

> Econometric theory is like an exquisitely balanced French recipe, spelling out precisely with how many turns to mix the sauce, how many carats of spice to add, and for how many milliseconds to bake the mixture at exactly 474 degrees of temperature. But when the statistical cook turns to raw materials, he finds that hearts of cactus fruit are unavailable, so he substitutes chunks of cantaloupe; where the recipe calls for vermicelli he uses shredded wheat; and he substitutes green garment die for curry, ping-pong balls for turtle's eggs, and, for Chalifougnac vintage 1883, a can of turpentine. (Valavanis, 1959, p. 83)

How has this state of affairs come about? One reason is that prestige in the econometrics profession hinges on technical expertise rather than on the hard work required to collect good data:

> It is the preparation skill of the econometric chef that catches the professional eye, not the quality of the raw materials in the meal, or the effort that went into procuring them. (Griliches, 1994, p. 14)

Criticisms of econometrics along these lines are not uncommon. Rebuttals cite improvements in data collection, extol the fruits of the computer revolution and provide examples of improvements in estimation due to advanced techniques. It remains a fact, though, that in practice good results depend as much on the input of sound and imaginative economic theory as on the application of correct statistical methods. The skill of the econometrician lies in judiciously mixing these two essential ingredients; in the words of Malinvaud:

> The art of the econometrician consists in finding the set of assumptions which are both sufficiently specific and sufficiently realistic to allow him to take the best possible advantage of the data available to him. (Malinvaud, 1966, p. 514)

Modern econometrics texts try to infuse this art into students by providing a large number of detailed examples of empirical application. This important dimension of econometrics texts lies beyond the scope of this book. Readers should keep this in mind as they use this guide to improve their understanding of the purely statistical methods of econometrics.

1.2 THE DISTURBANCE TERM

A major distinction between economists and econometricians is the latter's concern with disturbance terms. An economist will specify, for example, that consumption is a function of income, and write $C = f(Y)$ where C is consumption and Y is income. An econometrician will claim that this relationship must also include a *disturbance* (or *error*) term, and may alter the equation to read $C = f(Y) + \varepsilon$ where ε (epsilon) is a disturbance term. Without the disturbance term the relationship is said to be *exact* or *deterministic*; with the disturbance term it is said to be *stochastic*.

The word "stochastic" comes from the Greek "stokhos," meaning a target or bull's eye. A stochastic relationship is not always right on target in the sense that it predicts the precise value of the variable being explained, just as a dart thrown at a target seldom hits the bull's eye. The disturbance term is used to capture explicitly the size of these "misses" or "errors." The existence of the disturbance term is justified in three main ways. (Note: these are not mutually exclusive.)

(1) *Omission of the influence of innumerable chance events* Although income might be the major determinant of the level of consumption, it is not the only determinant. Other variables, such as the interest rate or liquid asset holdings, may have a systematic influence on consumption. Their omission constitutes one type of *specification error*: the nature of the economic relationship is not correctly specified. In addition to these systematic influences, however, are innumerable less systematic influences, such as weather variations, taste changes, earthquakes, epidemics, and postal strikes. Although some of these variables may have a significant impact on consumption, and thus should definitely be included in the specified relationship, many have only a very slight, irregular influence; the disturbance is often viewed as representing the net influence of a large number of such small and independent causes.

(2) *Measurement error* It may be the case that the variable being explained cannot be measured accurately, either because of data collection difficulties or because it is inherently unmeasurable and a proxy variable must be used in its stead. The disturbance term can in these circumstances be thought of as representing this measurement error. Errors in measuring the explaining variable(s) (as opposed to the variable being explained) create a serious econometric problem, discussed in chapter 9. The terminology *errors in variables* is also used to refer to measurement errors.

(3) *Human indeterminacy* Some people believe that human behavior is such that actions taken under identical circumstances will differ in a

random way. The disturbance term can be thought of as representing this inherent randomness in human behavior.

Associated with any explanatory relationship are unknown constants, called *parameters*, which tie the relevant variables into an equation. For example, the relationship between consumption and income could be specified as

$$C = \beta_1 + \beta_2 Y + \varepsilon$$

where β_1 and β_2 are the parameters characterizing this consumption function. Economists are often keenly interested in learning the values of these unknown parameters.

The existence of the disturbance term, coupled with the fact that its magnitude is unknown, makes calculation of these parameter values impossible. Instead, they must be *estimated*. It is on this task, the estimation of parameter values, that the bulk of econometric theory focuses. The success of econometricians' methods of estimating parameter values depends in large part on the nature of the disturbance term; statistical assumptions concerning the characteristics of the disturbance term, and means of testing these assumptions, therefore play a prominent role in econometric theory.

1.3 ESTIMATES AND ESTIMATORS

In their mathematical notation, econometricians usually employ Greek letters to represent the true, unknown values of parameters. The Greek letter most often used in this context is beta (β). Thus, throughout this book, β is used as the parameter value that the econometrician is seeking to learn. Of course, no one ever actually learns the value of β, but it can be estimated: via statistical techniques, empirical data can be used to take an educated guess at β. In any particular application, an estimate of β is simply a number. For example, β might be estimated as 16.2. But, in general, econometricians are seldom interested in estimating a single parameter; economic relationships are usually sufficiently complex to require more than one parameter, and because these parameters occur in the same relationship, better estimates of these parameters can be obtained if they are estimated together (i.e., the influence of one explaining variable is more accurately captured if the influence of the other explaining variables is simultaneously accounted for). As a result, β seldom refers to a single parameter value; it almost always refers to a set of parameter values, individually called $\beta_1, \beta_2, \ldots, \beta_k$ where k is the number of different parameters in the set. β is then referred to as a vector and is written as

$$\beta = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_k \end{bmatrix}.$$

In any particular application, an estimate of β will be a set of numbers. For example, if three parameters are being estimated (i.e., if the dimension of β is three), β might be estimated as

$$\begin{bmatrix} 0.8 \\ 1.2 \\ -4.6 \end{bmatrix}.$$

In general, econometric theory focuses not on the estimate itself, but on the *estimator* – the formula or "recipe" by which the data are transformed into an actual estimate. The reason for this is that the justification of an estimate computed from a particular sample rests on a justification of the estimation method (the estimator). The econometrician has no way of knowing the actual values of the disturbances inherent in a sample of data; depending on these disturbances, an estimate calculated from that sample could be quite inaccurate. It is therefore impossible to justify the estimate itself. However, it may be the case that the econometrician can justify the estimator by showing, for example, that the estimator "usually" produces an estimate that is "quite close" to the true parameter value regardless of the particular sample chosen. (The meaning of this sentence, in particular the meaning of "usually" and of "quite close," is discussed at length in the next chapter.) Thus an estimate of β from a particular sample is defended by justifying the estimator.

Because attention is focused on estimators of β, a convenient way of denoting those estimators is required. An easy way of doing this is to place a mark over the β or a superscript on it. Thus $\hat{\beta}$ (beta-hat) and β^* (beta-star) are often used to denote estimators of beta. One estimator, the ordinary least squares (OLS) estimator, is very popular in econometrics; the notation β^{OLS} is used throughout this book to represent it. Alternative estimators are denoted by $\hat{\beta}$, β^*, or something similar. Many textbooks use the letter *b* to denote the OLS estimator.

1.4 GOOD AND PREFERRED ESTIMATORS

Any fool can produce an estimator of β, since literally an infinite number of them exists; i.e., there exists an infinite number of different ways in which a sample of data can be used to produce an estimate of β, all but a few of these ways producing "bad" estimates. What distinguishes an econometrician is the ability to produce "good" estimators, which in turn produce "good" estimates. One of these "good" estimators could be chosen as the "best" or "preferred" estimator and be used to generate the "preferred" estimate of β. What further distinguishes an econometrician is the ability to provide "good" estimators in a variety of different estimating contexts. The set of "good" estimators (and the choice of "preferred" estimator) is not the same in all estimating problems. In fact, a "good" estimator in one estimating situation could be a "bad" estimator in another situation.

The study of econometrics revolves around how to generate a "good" or the "preferred" estimator in a given estimating situation. But before the "how to" can be explained, the meaning of "good" and "preferred" must be made clear. This takes the discussion into the subjective realm: the meaning of "good" or "preferred" estimator depends upon the subjective values of the person doing the estimating. The best the econometrician can do under these circumstances is to recognize the more popular criteria used in this regard and generate estimators that meet one or more of these criteria. Estimators meeting certain of these criteria could be called "good" estimators. The ultimate choice of the "preferred" estimator, however, lies in the hands of the person doing the estimating, for it is his or her value judgments that determine which of these criteria is the most important. This value judgment may well be influenced by the purpose for which the estimate is sought, in addition to the subjective prejudices of the individual.

Clearly, our investigation of the subject of econometrics can go no further until the possible criteria for a "good" estimator are discussed. This is the purpose of the next chapter.

GENERAL NOTES

1.1 What is Econometrics?

- The term "econometrics" first came into prominence with the formation in the early 1930s of the Econometric Society and the founding of the journal *Econometrica*. The introduction of Dowling and Glahe (1970) surveys briefly the landmark publications in econometrics. Pesaran (1987) is a concise history and overview of econometrics. Hendry and Morgan (1995) is a collection of papers of historical importance in the development of econometrics, with excellent commentary. Epstein (1987), Morgan (1990) and Qin (1993) are extended histories; see also Morgan (1990a). Hendry (1980) notes that the word "econometrics" should not be confused with "economystics," "economic-tricks," or "icon-ometrics."

- The discipline of econometrics has grown so rapidly, and in so many different directions, that disagreement regarding the definition of econometrics has grown rather than diminished over the past decade. Reflecting this, at least one prominent econometrician, Goldberger (1989, p. 151), has concluded that "nowadays my definition would be that econometrics is what econometricians do." One thing that econometricians do that is not discussed in this book is serve as expert witnesses in court cases. Fisher (1986) has an interesting account of this dimension of econometric work. Judge et al. (1988, p. 81) remind readers that "econometrics is *fun*!"
- A distinguishing feature of econometrics is that it focuses on ways of dealing with data that are awkward/dirty because they were not produced by controlled experiments. In recent years, however, controlled experimentation in economics has become more common. Burtless (1995) summarizes the nature of such experimentation and argues for its continued use. Heckman and Smith (1995) is a strong defense of using traditional data sources. Much of this argument is associated with the selection bias phenomenon (discussed in chapter 16) – people in an experimental program inevitably are not a random selection of all people, particularly with respect to their unmeasured attributes, and so results from the experiment are compromised. Friedman and Sunder (1994) is a primer on conducting economic experiments. Meyer (1995) discusses the attributes of "natural" experiments in economics.
- Mayer (1993, chapter 10), Summers (1991), Brunner (1973), Rubner (1970) and Streissler (1970) are good sources of cynical views of econometrics, summed up dramatically by McCloskey (1994, p. 359): "most allegedly empirical research in economics is unbelievable, uninteresting or both." More comments appear in this book in section 9.3 on errors in variables and chapter 19 on prediction. Fair (1973) and Fromm and Schink (1973) are examples of studies defending the use of sophisticated econometric techniques. The use of econometrics in the policy context has been hampered by the (inexplicable?) operation of "Goodhart's Law" (1978), namely that all econometric models break down when used for policy. The finding of Dewald et al. (1986), that there is a remarkably high incidence of inability to replicate empirical studies in economics, does not promote a favorable view of econometricians.
- What has been the contribution of econometrics to the development of economic science? Some would argue that empirical work frequently uncovers empirical regularities which inspire theoretical advances. For example, the difference between time-series and cross-sectional estimates of the MPC prompted development of the relative, permanent, and life-cycle consumption theories. But many others view econometrics with scorn, as evidenced by the following quotes:

> We don't genuinely take empirical work seriously in economics. It's not the source by which economists accumulate their opinions, by and large. (Leamer in Hendry et al., 1990, p. 182);
>
> The history of empirical work that has been persuasive – that has changed people's understanding of the facts in the data and which economic models understand those facts – looks a lot different than the statistical theory preached in econometrics textbooks. (Cochrane, 2001, p. 302);

> Very little of what economists will tell you they know, and almost none of the content of the elementary text, has been discovered by running regressions. Regressions on government-collected data have been used mainly to bolster one theoretical argument over another. But the bolstering they provide is weak, inconclusive, and easily countered by someone else's regressions. (Bergmann, 1987, p. 192);

> No economic theory was ever abandoned because it was rejected by some empirical econometric test, nor was a clear cut decision between competing theories made in light of the evidence of such a test. (Spanos, 1986, p. 660); and

> I invite the reader to try . . . to identify a meaningful hypothesis about economic behavior that has fallen into disrepute because of a formal statistical test. (Summers, 1991, p. 130)

This reflects the belief that economic data are not powerful enough to test and choose among theories, and that as a result econometrics has shifted from being a tool for testing theories to being a tool for exhibiting/displaying theories. Because economics is a non-experimental science, often the data are weak, and because of this empirical evidence provided by econometrics is frequently inconclusive; in such cases it should be qualified as such. Griliches (1986) comments at length on the role of data in econometrics, and notes that they are improving; Aigner (1988) stresses the potential role of improved data. This is summed up nicely by Samuelson (as quoted in Card and Krueger, 1995, p. 355): "In economics it takes a theory to kill a theory, facts can only dent a theorist's hide."

- Critics might choose to paraphrase the Malinvaud quote as "The art of drawing a crooked line from an unproved assumption to a foregone conclusion." The importance of a proper understanding of econometric techniques in the face of a potential inferiority of econometrics to inspired economic theorizing is captured nicely by Samuelson (1965, p. 9): "Even if a scientific regularity were less accurate than the intuitive hunches of a virtuoso, the fact that it can be put into operation by thousands of people who are not virtuosos gives it a transcendental importance." This guide is designed for those of us who are not virtuosos!
- Feminist economists have complained that traditional econometrics contains a male bias. They urge econometricians to broaden their teaching and research methodology to encompass the collection of primary data of different types, such as survey or interview data, and the use of qualitative studies which are not based on the exclusive use of "objective" data. See MacDonald (1995), Nelson (1995), and Bechtold (1999). King, Keohane, and Verba (1994) discuss how research using qualitative studies can meet traditional scientific standards. See also Helper (2000).

1.2 The Disturbance Term

- The error term associated with a relationship need not necessarily be additive, as it is in the example cited. For some nonlinear functions it is often convenient to specify the error term in a multiplicative form. In other instances it may be appropriate to build the stochastic element into the relationship by specifying the parameters to be random variables rather than constants. (This is called the random-coefficients model.)

- Some econometricians prefer to define the relationship between C and Y discussed earlier as "the mean of C conditional on Y is $f(Y)$," written as $E(C|Y) = f(Y)$. This spells out more explicitly what econometricians have in mind when using this specification. The conditional expectation interpretation can cause some confusion. Suppose wages are viewed as a function of education and marriage status. Consider an unmarried person with 12 years of education. The conditional expectation of such a person's income is the value of y averaged over all unmarried people with 12 years of education. This says nothing about what would happen to a particular individual's income if he or she were to get married. The coefficient on marriage status tells us what is the average difference between married and unmarried people, much of which may be due to unmeasured characteristics that differ between married and unmarried people. A positive coefficient on marriage status tells us that married people have different unmeasured characteristics that tend to cause higher earnings; it does not mean that getting married will increase one's income. On the other hand, it could be argued that getting married creates economies in organizing one's non-work life, which enhances earning capacity. This would suggest that getting married would lead to some increase in earnings, but in light of earlier comments, the coefficient on marriage status would surely be an overestimate of this effect.
- In terms of the throwing-darts-at-a-target analogy, characterizing disturbance terms refers to describing the nature of the misses: are the darts distributed uniformly around the bull's eye? Is the average miss large or small? Does the average miss depend on who is throwing the darts? Is a miss to the right likely to be followed by another miss to the right? In later chapters the statistical specification of these characteristics and the related terminology (such as "homoskedasticity" and "autocorrelated errors") are explained in considerable detail.

1.3 Estimates and Estimators

- An estimator is simply an algebraic function of a potential sample of data; once the sample is drawn, this function creates an actual numerical estimate.
- Chapter 2 discusses in detail the means whereby an estimator is "justified" and compared with alternative estimators. For example, an estimator may be described as "unbiased" or "efficient." Frequently estimates are described using the same terminology, so that reference might be made to an "unbiased" estimate. Technically this is incorrect because estimates are single numbers – it is the estimating formula, the estimator, that is unbiased, not the estimate. This technical error has become so commonplace that it is now generally understood that when one refers to an "unbiased" estimate one merely means that it has been produced by an estimator that is unbiased.

1.4 Good and Preferred Estimators

- The terminology "preferred" estimator is used instead of the term "best" estimator because the latter has a specific meaning in econometrics. This is explained in chapter 2.

- Estimation of parameter values is not the only purpose of econometrics. Two other major themes can be identified: testing of hypotheses and economic forecasting. Because both these problems are intimately related to the estimation of parameter values, it is not misleading to characterize econometrics as being primarily concerned with parameter estimation.

TECHNICAL NOTES

1.1 What is Econometrics?

- In the macroeconomic context, in particular in research on real business cycles, a computational simulation procedure called *calibration* is often employed as an alternative to traditional econometric analysis. In this procedure economic theory plays a much more prominent role than usual. Indeed, Pagan (1998, p. 611) claims that "it is this belief in the pre-eminence of theory that distinguishes a calibrator from a non-calibrator." This theory supplies ingredients to a general equilibrium model designed to address a specific economic question. This model is then "calibrated" by setting parameter values equal to average values of economic ratios known not to have changed much over time or equal to empirical estimates from microeconomic studies. A computer simulation produces output from the model, with adjustments to model and parameters made until the output from these simulations has qualitative characteristics (such as correlations between variables of interest) matching those of the real world. Once this qualitative matching is achieved the model is simulated to address the primary question of interest. Kydland and Prescott (1996) is a good exposition of this approach. Note that in contrast to traditional econometrics, no real estimation is involved, and no measures of uncertainty, such as confidence intervals, are produced.

  Econometricians have not viewed this technique with favor, primarily because there is so little emphasis on evaluating the quality of the output using traditional testing/assessment procedures. Hansen and Heckman (1996), a cogent critique, note (p. 90) that "Such models are often elegant, and the discussions produced from using them are frequently stimulating and provocative, but their empirical foundations are not secure. What credibility should we attach to numbers produced from their 'computational experiments,' and why should we use their 'calibrated models' as a basis for serious quantitative policy evaluation?" Pagan (1998, p. 612) is more direct: "The idea that a model should be used just because the 'theory is strong,' without a demonstration that it provides a fit to an actual economy, is mind-boggling."

  Dawkins, Srinivasan, and Whalley (2001) is an excellent summary of calibration and the debates that surround it. Despite all this controversy, calibration exercises are useful supplements to traditional econometric analyses because they widen the range of empirical information used to study a problem.