Long-Range Forecasts of Society and Culture: Four Quantitative Methods from Cultural Anthropology[1]

Trevor Denton *Brandon University*

Abstract: Cultural Anthropology occupies a position of strategic importance for those wishing to forecast the future. Hundreds of long-range trends in culture are known to exist going back thousands of years. These trends, along with some theoretical models fitted to past societies, seem intuitively to be extrapolatable into the future. Worldwide archaeological chronologies are increasingly available to facilitate construction of time series. Four long-range quantitative forecast methods are developed for extrapolation of: (1) universals of culture; (2) atheoretical long-range time series models; (3) directional long-range trends; and (4) theoretical models. Examples are given.

Résumé: L'anthropologie culturelle occupe une position stratégique pour ceux et celles qui veulent prédire l'avenir. On reconnaît que des centaines de tendances de longue portée remontent à des milliers d'années. Ces tendances, associées à des modèles théoriques pertinents pour les sociétés antérieures, paraissent pouvoir être intuitivement extrapolées dans le futur. Des chronologies archéologiques à l'étendue du globe sont de plus en plus accessibles et permettent la construction de séquences temporelles. Quatre méthodes quantitatives pour les prédictions à long terme sont développées dans cette perspective : 1) les universels des cultures; 2) des modèles non-théoriques de séries chronologiques étendues; 3) des tendances à long terme orientées dans une direction donnée; 4) des modèles théoriques. On présente des exemples.

Introduction and Preamble

Cultural Anthropology occupies a position of strategic importance for those wishing to forecast the future. Hundreds of long-range trends in culture are known to exist going back thousands of years. These trends, along with some theoretical models fitted to past societies, seem intuitively to be extrapolatable into the future. Worldwide archaeological chronologies are increasingly available to facilitate construction of long-range time series. Four quantitative methods are developed for making long-range anthropological forecasts of culture and society. The four methods are extrapolation of: (1) universals of culture; (2) atheoretical long-range time series models generated by the ongoing, underlying process of social/cultural differentiation; (3) directional long-range trends; and (4) causal models. While there may be more ways to forecast than these, the four forecast methods are widely applicable.

This paper is intended to be "reader" friendly to all readers whether they use quantitative methods or not. Throughout the paper, ideas are developed in plain English understandable to all. Where, at times, it is possible to distill results into mathematical form such mathematics are set off in rectangles or shunted to footnotes. Readers who so wish may skip over these rectangles or footnotes without loss of continuity.

Before we start, we need to consider several matters which set the stage for the forecast methods, and the forecasts themselves, which follow. A "long-range" forecast is defined here to be a forecast to a point in time 10 years or more ahead. Such a definition is admittedly arbitrary. Long-range forecast methods may also at times be used to make short-range forecasts. Our forecasts will be for times up to 2050 AD inclusive. Reasons for this will be stated below.

Forecasts are defined here to be unconditional predictions of what will happen in the future. Extrapolations are defined to be conditional predictions of what will happen in the future, provided certain assumptions are made. In the case of some extrapolations, for example the United Nations (1998) population extrapolations to 2150 AD, the extrapolator leaves unanswered the question of which of several different extrapolations will actually occur. This will not be the case here. In the present paper we will make extrapolations contingent on only a few premises which seem justifiable to the writer. These premises are:

A. The theory and data used to make the forecasts are valid.
B. Up to 2050 AD there will be:
   1. no major disasters eliminating a large proportion of the world population, i.e., no devastating epidemics, no collision with large extraterrestrial objects, no devastating nuclear war;
   2. no major genetic changes to our species, no major elongation of the human life span beyond the fourscore years of the United Nations (1998) long-range population projections.

There will be considerable concensus in Cultural Anthropology for the theory and data to be used here. Hence, assumption A seems as justifiable for Cultural Anthropology as for other disciplines where forecasts are made. Assumptions B, 1 and 2 are also reasonable. The writer is unwilling, at the moment, to make extrapolations beyond 2050 AD. The rapid rate at which discoveries in biotechnology are being made creates uncertainties which are difficult to fathom.

Finally, the perspective of this paper is that no serious forecast from Cultural Anthropology ought to be made unless demands of rigour are made on it. Any theory and data used ought to be replicable. Narrative, verbal ideas ought to be put into quantitative form. Probabilities ought to be replicable among forecasters and hence objective from the point of view of mathematical probability theory (Mood, Graybill and Boes, 1974; Roberts, 1979), if not from that of Kuhn (1962).

Extrapolation of Universals of Culture

The construct "universal of culture" is defined here to be a single object of culture which, to the best of our knowledge, has always existed everywhere in the modern, post-35 000 BC form of our species. In practice, such universal objects of culture are either sets of complex, multivariable behavioural relations or single traits of culture. There are many theoretical models of multivariable behavioural relations which are posited by their formulators to be universals. For example, psychodynamic functioning of the mind, many cognitive models of thinking, many features of language are all considered to be universals although some cross-cultural psychologists (Berry, Poortinga, Segal and Dasen, 1992) might disagree. In a circumstance where there is significant concensus that a set of complex, multivariable behavioural relations, i.e., a theory, is applicable everywhere, then it is reasonable to extrapolate the theory into the foreseeable future. All the universalizing conceptualization in Cultural Anthropology for which there is widespread consensus as to how society works may be extrapolated into the future. Such extrapolation gives us a firm foundation on which to build.

While there may be dissensus about the validity of many middle-range theories hypothesized to be universals, we are on safer ground with single traits of culture. Many universal culture traits (Brown, 1991; Brown and Witkowski, 1980; Lonner, 1980) are known to exist, the best-known of which are the universal traits of culture of Murdock (1945) and the universal needs and analytic categories of Malinowski (1944, 1988). Murdock's (1945) universals are the ubiquitous presence of some 50 culture traits such as age grading, athletic sports, bodily adornment, fire, study of weather, marriage and family. Examples of Malinowski's (1944, 1988; Piddington, 1957) universals are the presence of culture traits meeting basic zoological needs for food, shelter, mobility, safety, health, rest, sex. That all societies meet these basic needs makes cultural responses to them universal even though how people meet these basic needs may vary from one society to another. Malinowski (1944, 1988) also posits universal analytic categories of culture such as group, bases of group formation, renewal of resources (economics), organization of power and authority (politics) and organization of training (education) which are universals in the sense that they are found everywhere even though their form may vary from one society to another. While Malinowski (1944, 1988) thought of economics, politics and education as derived needs emergent from responses to basic needs, today they are thought of as analytic categories. Since they exist everywhere they are universals.

For methods as to how to detect cultural universals see Brown (1991). In plain words, if something is universal up to 2050 AD, it will exist everywhere up to 2050 AD, which is a forecast.

FORECASTS EXTRAPOLATING A UNIVERSAL. By definition, if an event E is a universal, then it is a certainty at time t, so the probability that event E will occur at time t is 1, i.e., $P(E_t) = 1$, present time $< t \leq 2050$ AD.□

From a probability point of view this is a point forecast with zero variance and a 100% confidence interval of zero. Probabilities for single trait universals of Probability Model 1 are replicable and hence objective from the point of view of probability theory (Mood et al., 1974; Roberts, 1979). They are obtained primarily from ethnographies. Tests of complex, multivariable narrative theories asserted by their formulators (Brown, 1991) to be universals are generally replicable.

So much for making forecasts by extrapolating universals of culture and society. The second of the four forecast methods developed in this paper is extrapolation of long-range time series models.

Extrapolation of an Atheoretical Model of a Univariate Time Series Generated by an Ongoing, Underlying Process

A "time series" may be defined as a set of observations indexed by time (Chatfield, 1996: 1). We will arbitrarily define a "long-range" time series of some facet of culture to be a time series which goes back at least 250 years. For example, suppose we have reason to believe that the proportion of the world population living in class-based societies at 7000 BC, 6000 BC,..., 2000 AD is 0.40, 0.52, 0.64, 0.73, 0.83, 0.87, 0.87, 0.92, 0.95, 1.00 (Denton, 1993). This is a time series since each observation is indexed by time. It is a long-range time series since it goes back 9000 years.

We must always clearly have in mind the distinction between a time series of observations, i.e., a data set, versus a model of a time series of observations. A time series of observations may be continuous over time (e.g., a record of air temperature throughout a day) or at discrete points in time (e.g., the social class time series of the preceding paragraph where observations are at 1000-year intervals). The intervals of time between observations in a time series need not necessarily be equal, but if they are not equal this information must be factored into calculations.

One of the first things to do with a time series of observations is to plot a graph of it. Brockwell and Davis (1996) and Chatfield (1996) give examples of data sets of time series observations drawn from various disciplines and graphs of such time series of observations. A point process is a process where an event E reoccurs over time. For example, a count of war starts in nation states from 1720 to 1985 (Kaye, Grant and Emond, 1985; see also Singer and Small, 1972) is a point process. A binary process is a process where a random variable X (e.g., predominant family type) is in either of two states over time (e.g., independent family or extended family; see Ember and Ember, 1999). Cartesian $x-y$ co-ordinate graphs are customarily used to display how the amount of some univariate object y (shown on the vertical y-axis) varies over time (shown of the horizontal x-axis). Depending on the nature of the time series of observations graphed such $x-y$ co-ordinate graphs may show long-range trend, seasonal and other cycle, and other irregular components.

The graph of a time series of observations may appear to show long memory (where the value of an observation at a particular time t appears to be determined in part by much earlier observations) or short memory (where the value of an observation at time t appears to be determined only by recent predecessor observations). Space demands preclude reproducing the graphs of time series of observations commonly found in books of time series analysis. The reader wishing to see examples of such graphs (and their data sets) is referred to Chatfield (1996) and Brockwell and Davis (1996). Gottman (1981) is a nonmathematical treatment of time series analysis written for social scientists. There are more approaches to the study of process than time series analysis (e.g., Arminger, Clogg and Sobel, 1995; Gottman and Roy, 1990; Ross, 1997). Books of time series analysis usually assume that the reader has a command of calculus-based probability, mathematical statistics and linear algebra. Examples of such books are, in decreasing order of such demands, Brockwell and Davis (1991, 1996) and Chatfield (1996). In the writer's opinion there is nothing unique, from a modeling point of view, about social science time series of observations pertinent to this paper. Other books the reader may wish to examine for special purposes include Armstrong (1985) technology and Makridakis et al. (1998) for a general compendium of forecast methods written from a business perspective.

There are at least three different questions to answer in regard to time series forecasts: how to construct a time series of observations, how to model the time series of observations constructed and how to justify extrapolating the model into the future. We will consider each.

How to Construct a Time Series of Observations.

There are several matters to consider when deciding how to construct a time series of observations. First of all, the constructor of the time series of observations must make decisions about the constructs to observe over time, the unit of analysis, time depth, number of observations, unit of observation and population to which the time series is to apply. For example, Carneiro (1978) identifies a crude but viable time series of the number of independent political units in the world from the upper paleolithic to present time. Dupuy (1984) presents a crude but viable time series of the greatest amount of weapon lethality in the world from the upper paleolithic to present time. Denton (1993; 1994; 1995a; 1995b; n.d.), using quantitative ethnographic analogy, devised an indirect method for constructing archaeologically unobservable time series from 8000 BC to the present. Such time series are for the proportion of individuals in the world living in societies where a categorical random variable $X = x$. Here, X might be any of many theoretical constructs (e.g., predominant family type) and x one particular variety of X (e.g., the independent family).

The crucial matter in regard to the number of observations is the accuracy of chronological dating which, at present, means the accuracy of ^{14}C dating. Denton (1993) constructed from archaeological ^{14}C dates the proportion of the world population living in band forager, horticultural and pre-industrial intensive agricultural societies from 7000 BC to 1000 AD. ^{14}C dates for these constructs are vital ingredients of his indirect method of constructing archaeologically unobservable time series. He felt that observations more closely spaced than at 1 000-year intervals would be unreasonable since such observations would be spurious duplicates of what at best might be a single possible observation in any 1 000-year interval of time. Depending on the subject matter, observations at 500-year intervals seem within reach today. Soon, some worldwide observations at 250-year intervals may be possible. If so, then for the era 7000 BC to present, 40 observations may soon be possible. In general, the greater the number of observations the more satisfying the statistical models which may be constructed of them.

The constructor of a time series of observations to be used for forecasting must determine the population which the time series of observations is to portray. We shall see that it is the process of increasing cultural complexity with which most changes in culture over the last 10 000 years are correlated. Changes in cultural complexity appear to have been triggered by changes in subsistence (Denton, 1996). Hence, if the purpose is to make a forecast up to 2050 AD, many time series of observations will be in regard to a population which is either the entire world or the most culturally complex portions of the world.

If a time series of observations for the worldwide mean $\overline{X}$ of some variable X is to be constructed then it may be necessary to work up from regions of the world. For example, suppose the constructor of a time series of observations wishes to portray the proportion of the world population living in societies where X (e.g., local community) is predominantly of variety x (e.g., sedentary). The easiest way to calculate such proportion is to define, say, 10 regions of the world, calculate the number of individuals coded $X = x$ in each region at time t, then sum the numbers of such individuals over all regions at time t and divide by the total world population at time t. Sherratt (1980) gives one of several possible partitions of the world into regions. Biraben (1980; see also Livi-Bacci, 1997) is the best long-range demographic history of the world currently available.

It is increasingly possible to construct long-range time series of observations. Excellent worldwide archaeological chronologies such as those of Ehrich (1992) and Taylor and Meighan (1978) are increasingly available. Such chronologies will facilitate direct construction of worldwide long-range time series from archaeological data even though these chronologies have seldom been used for this purpose. Over the past several decades Archaeology has taken significant steps in developing new methods for reconstructing prehistory (Fagan, 1997; Renfrew, 1996). In turn, archaeological reconstruction of prehistory has grown at an explosive rate (Fagan, 1998; Wenke, 1999). In principle, it is now possible directly to construct many long-range time series from archaeological data. Major secondary data bases of prehistory will soon appear (Ember and Peregrine, in press; HRAF, 1999). There are many subject matters where it ought now to be possible to reconstruct $P(X_t = x)$, the worldwide probability (proportion of individuals) at time t of living in a society where categorical random variable X (e.g., predominant dwelling type) is in state x (e.g., circular), directly from archaeological data at 1 000-year intervals, or smaller intervals, from 30 000 BC to present day. If such a direct time series is of a concept of Cultural Anthropology then cultural anthropologists are just as able as archaeologists to model such a time series, perhaps even to construct the time series, especially if ethnographic analogy (Ember and Ember, 1995) is used in the construction of the time series. Culture change conceptualized via concepts of Cultural Anthropology, whether unearthed by archaeologists or not, is valid subject matter for Cultural Anthropology.

We may distinguish between direct versus indirect construction of long-range time series. By merging theory and quantitative ethnographic data from Cultural Anthropology with archaeological chronologies it has become possible indirectly to construct long-range time series of many subject matters which are not directly archaeologically observable (Denton, 1993, n.d.). Such indirect reconstructions by quantitative ethnographic analogy stand in contrast to direct reconstruction from archaeological data only. While the extent of subject matters which may be reconstructed by this indirect method are still in the process of being determined it appears that there are indeed many subject matters which may be so reconstructed (Denton, n.d, 1993, 1994, 1995a, 1995b). For methodological reasons (Denton, n.d.), such indirect time series are currently justifiable only back to the start of the Holocene, say back to 8000 or 9000 BC long-range time series, no matter how they are constructed nor who constructs them, are legitimate subject matter for Cultural Anthropology.

How to Make an Atheoretical Time Series Forecast

Making a time series forecast is easy. There are two steps: (1) construct a model of the time series of observations; (2) extrapolate the model to some future time. Of course, in order to justify extrapolating the model into the future we must be able to assume that there is an underlying process generating the time series of observations and that the process will continue into the future.

We will limit our consideration to time series which are atheoretical in the sense that we have no prior theory that we might bring to a time series of observations to explain the shape of its graph. For example, we will not consider time series such as population growth where we might have reason to believe that an exponential or logistic process determines the shape of the graph of time series observations. We will also limit our consideration to univariate time series.

Suppose we have constructed an atheoretical, univariate time series of observations. If we wish to make a forecast we must construct a model of the time series observations from the observations themselves. The forecast is made by extrapolating the model into the future. The first step is to graph the time series observations. Outlying (extreme) observations which are the result of measurement error ought to be cleaned. Sharp breaks in the time series at two or more points in time may indicate that different models may be needed for different segments of the time series. For example, eras before and after food producing may require different models. The graph of the time series may suggest the presence or absence of trend, cycle, etc.

Many time series analysts approach an atheoretical time series as if the graph of the time series of observations might consist at any particular time t of Trend $T(t)$ which is trend T at time t, Seasonality $S(t)$, Cycle(s) $C(t)$ plus irregular remainder $R(t)$. Hence, the model of any particular time series of observations $Y(t)$ at time t may be written as the sum of the components $Y(t) = T(t) + S(t) + C(t) + R(t)$. The trend component $T(t)$ of the time series is defined to be a slowly moving function of time t (Chatfield, 1996: 10). If there is a single Trend $T(t)$ which applies to the entire span of observations then this is known as a global trend. If Trend $T(t)$ is different over different segments of time then this is known as local trend. For long-range time series of the subject matter of Cultural Anthropology we will seldom be able to construct time series of observations of such precision as to show seasonality. As for cycle, the writer knows of no subject area in Cultural Anthropology where we might have reason to expect worldwide cycle $C(t)$ nor has the writer seen any such long-range time series where cycle is present (Carneiro, 1978; Denton, 1993; 1994; 1995a; 1995b; n.d.; Dupuy, 1984). Until we are able to construct better time series than the writer is able to construct at the moment, or until we find occasion where we need to model cycle, most long-range time series of the subject matter of Cultural Anthropology will show only trend $T(t)$ plus an irregular component $R(t)$.

How is a forecaster to decide which of several candidate models of a time series of observations to extrapolate? There are at least three strategies for constructing a forecast model. The first strategy is to use an heuristic forecast method simply because it seems to work. For example, exponential smoothing such as the Holt-Winters algorithm (Brockwell and Davis, 1996: 315; Chatfield, 1993; 1996: 68-71; Chatfield and Yar, 1988) appears to be a generally reliable, easy to understand, all-purpose method which is fully automatic in the sense that the forecaster does not need to impose judgment on how the model is constructed. The Holt-Winters algorithm is a variant of exponential smoothing and places more emphasis on recent observations than on those at more remote times.

Curve fitting is a second strategy for constructing a forecast model. Here, one scans the graph of a time series of observations and attempts to fit a curve which follows the graph of the time series of observations. For example, the modeler may find that a straight line or a parabolic, logistic or exponential curve fits the graph of a time series of observations, provided we allow for possible irregular deviation of the data set from the curve (Chatfield, 1996: 13; Daniel and Wood, 1980; Gilchrist, 1976; Harrison and Pierce, 1972). The problem with curve fitting is that several different curves may each fit a single time series of observations yet result in different forecasts (Chatfield, 1996: 68).

A third strategy for constructing a forecast model is to construct an atheoretical time series model from the time series of observations. While time series models may incorporate mathematical theory they are atheoretical in the sense that no theory from Cultural Anthropology is used in their construction. Models for point and binary processes may be found in books of stochastic processes such as Ross (1997). Brockwell and Davis (1991: 14-25; 1996: 13-14, 22-34) review methods for constructing time series models. One method (Brockwell and Davis 1991: 14-25; 1996: 13-14, 22-24) which is easy to apply to a time series showing only trend is to remove trend from the time series in the hope ultimately of finding Remainders $R(t)$ which are stationary. In such a case a forecast is made by calculating trend to some future time t, then adding to it a forecast of the Remainder $(R)t$ with a prediction interval. Remainders $R(t) = (Y(t) - T(t))$ are stationary if there is constant mean and constant variance over time and strictly periodic variations have been removed (Chatfield, 1996: 10, 28-30). Trend may be removed in one or more of three ways: by fitting a least squares polynomial trend $T(t) = a_0 + a_1 + a_2t^2$ so $Y(t) = T(t) + R(t)$, or by a technique known as smoothing, or by a technique known as differencing (Brockwell and Davis, 1996: 13-22; 1991: 14-20). Data transformations may be used in the effort to attain stationary residuals. If, when trend is removed from a time series, the Remainders are stationary and serially independent then modelling is completed. If they are stationary and serially dependent then a more complicated stationary time series model of the Remainders must be sought (ibid.: 34).

Chatfield (1988) reviews criteria for deciding which one or ones from among several different forecast models to extrapolate. Intuitively, it seems that the criterion of forecast accuracy is most important but there are other criteria to consider such as cost, availability of software, time and repertoire of the forecaster. One may estimate the accuracy of a forecast model by using it at past points in time to make forecasts ahead to other past or present points in time in the time series. There have been several competitions which have assessed the abilities of competing forecast models retroactively to forecast elements of a single time series. The best known of these competitions is the M-competition (Makridakis et al., 1984) in which several different forecast models were applied to a variety of short-range economic time series. The results of the M-competition seem to favour heuristic methods such as the Holt-Winters algorithm (Chatfield, 1996: 315). The justification for favouring heuristic methods over formal time series models (e.g., Brockwell and Davis, 1991, 1996; Chatfield, 1996) is that data may deviate from the time series data set at times beyond those of the data set. In such a case, the mathematical properties of a model extracted from the past time series of observations may not hold at future times.

Which forecast method or methods ought to be applied to long-range time series data sets of interest to Cultural Anthropology? An heuristic method such as the Holt-Winters trend algorithm (Brockwell and Davis, 1996: 315; Chatfield, 1993; 1996, 68-71; Chatfield and Yar, 1988) seems a reasonable method to consider for atheoretical time series. However, we do not know whether this method will produce the same types of results for anthropological data sets as it has produced for business data sets (Chatfield, 1988, 1996: 79-84; Makridakis et al., 1984). When anthropological time series data sets of, say, 20 to 40 observations become available we may get answers to this question. With data sets of 20 to 40 observations it will be easier to estimate forecast accuracy. Extrapolation of a formal time series model (Brockwell and Davis, 1996, 1991; Chatfield, 1996) also seems reasonable in the case of a long-range anthropological time series to extrapolate. What makes this latter method appear reasonable is that there is an ongoing, underlying process generating such time series. Here also, when anthropological long-range time series data sets of 20 to 40 observations become available we will be better able to test the forecast accuracy of this method. That a single, ongoing, underlying process appears to be generating virtually all long-range time series of culture is also a justification for considering extrapolating a model constructed by curve fitting in a circumstance where only a single standard curve (Daniel and Wood, 1980) seems to fit the time series of observations.

Example

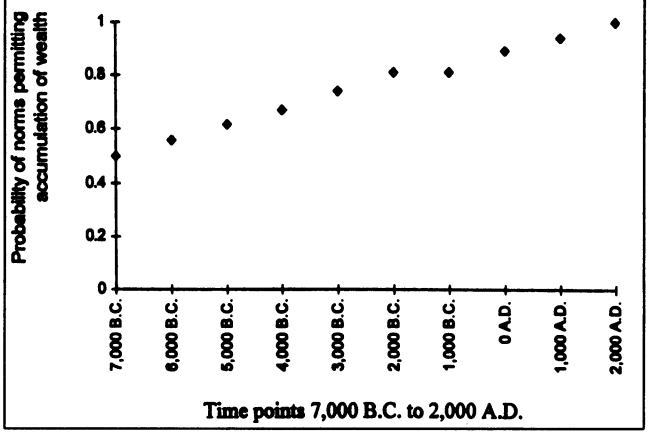
At the moment, there are few long-range worldwide time series in Cultural Anthropology going back thousands of years. There are some directly constructed from the observable archaeological record. For example, rudimentary time series of number of independent political units in the world (Carneiro, 1978) and weapon lethality (Dupuy, 1984) have been mentioned. Using a recently devised method Denton (1993, 1994, 1995a, 1995b, n.d.) indirectly constructs some 23 worldwide long-range time series of subject matters which are in large part not directly archaeologically observable. These time series are in subject areas such as social class, number of political jurisdictions per independent political unit, family, religion, war and literacy. Many more such time series will be constructed. In Archaeology, Wenke (1999) states several tentative time series while Scarre (1995), Sherratt (1980) and others contain various figures and graphs which approximate long-range time series directly constructed from the archaeologically observable record by synthesizers of prehistory.

Figure 1 shows a previously unreported long-range time series 7000 BC to 2000 BC of the probability of living in a society where norms permit individuals to accumulate wealth.[2] It will be asserted below that the time series of observations of Figure 1 is directly or indirectly generated by an underlying process which will continue to 2050 AD. We shall see, below, that this is the process of social/cultural differentiation. That the structure of the past data set will, by assumption, continue into the future allows us to consider using forecast methods such as the Holt-Winters algorithm or time series analysis to model the data. We might even consider curve fitting if a simple curve adequately fits the data set. Any forecast model we construct is atheoretical in the sense that we have no narrative theory by which to model the form of the time series of Figure 1. We will construct an atheoretical time series model by using the formal time series methods of Brockwell and Davis (1991: 14-25; 1996: 13-14, 22-34) cited above. Application of the Holt-Winters algorithm (Brockwell and Davis, 1996: 315) to the data set of Figure 1 produces equivalent results. The graph of the time series of Figure 1 appears to show only trend which appears to be global trend. Using Brockwell and Davis (1991: 14-25; 1996: 13-14, 22-34) we might use any of three methods to eliminate trend. For reasons to be stated in a moment we will seek to eliminate trend by fitting a quadratic least squares $Y(t) = T(t) + e(t)$, Trend $T(t) = a_0 + a_1 t + a_2 t^2$ (Brockwell and Davis, 1996: 28), to the time series of observations of Figure 1. Here, the Remainder $R(t)$ is denoted $e(t)$ to emphasize the random error deviation $e(t)$ from the model $Y(t) = T(t)$ at time t. It turns out that a_2 of trend $T(t) = a_0 + a_1 t + a_2 t^2$ is equal to zero for the data set of Figure 1 in the sense that the residuals $e(t) = (Y(t) - a_0 - a_1 t)$ fit the assumptions of a model of residual errors $e(t)$ which are identically and independently distributed Normal with mean zero and a variance σ^2 shown in Figure 1. With 10 observations spaced at 1 000-year intervals in the time series of Figure 1 the residuals are independently distributed. For a time series at smaller intervals than 250 years over the 7000 BC to 2000 AD time span of Figure 1 the residuals might be serially dependent but would, the writer conjectures, be easily modeled by one of the time series methods of Brockwell and Davis (1996) for modeling serially dependent residuals.

A straight line fits the time series of Figure 1 in the sense that when we eliminate Trend $T(t)$ using the methods of Brockwell and Davis (1991; 1996) the assumptions placed on the remainder error term of the model $Y(t) = a_0 + a_1 + e(t), e(t) \sim iiN(0, \sigma^{2)}$ are (or at least appear to be, given only 10 data points) met by the time series observations. We make a forecast as follows. The time series of observations of Figure 1 has 10 time points which we denote as 1, 2,..., 10. Time point 2050 AD becomes 10.05. The Trend $T(t)$ at time point 10.05 is $a_0 + a_1(10.05)$ to which we the add residual $e(t) \sim iiN(0, \sigma^2)$. We calculate $a_{0,}$ a_1 and σ^2 by methods of least squares (Mendenhall et al., 1986). The forecast for 2050 AD is shown in Figure 1 as a point estimate located in a prediction interval for the residual error $e(t)$. The probability—interpreted as proportion of individuals in the world—of living in a society at 2050 AD where individuals are permitted to accumulate wealth is 1 with a 90% prediction interval [0.79, 1].[3] Over the next few years it is likely that the indirect method used to reconstruct

Figure 1
Probability of Living in a Society Having Norms Permitting Individuals to Accumulate Wealth

7000 B.C.	0.50	
6000 B.C.	0.56	
5000 B.C.	0.62	
4000 B.C.	0.67	
3000 B.C.	0.74	
2000 B.C.	0.81	
1000 B.C.	0.81	
0 A.D.	0.89	
1000 A.D.	0.94	
2000 A.D.	1.00	preindustrial expectation, writer's estimate



Note: Rescaling the time points of the 10 observations to create 10 equally spaced time points 7000 BC to 2000AD, $t = 1, 2, \ldots, 10$, unit time jumps of 1 000 years, $Y(t) = 0.454 + 0.0545455t + e(t)$, $e(t) \sim ii(0, \sigma^{2)} \sigma^2 = 0.00026$, t = 1, 2,..., 10. At 2050 AD with unit spacing $t = 10.05$, $\hat{Y}(10.05) = 1.002$ which, since probabilities cannot exceed 1, becomes 1. Calculating a prediction interval[3] (Mendenhall, Scheaffer, Wackerly, 1986).
$P(0.79 \leq Y[10.05] \leq 1) = 0.90$.

time series observations such that of Figure 1 will permit narrower confidence intervals (Denton, n.d.).

The forecast of Figure 1 may seem trivial but it is not trivial if we agree to make no predictions of the future unless they are quantified and rooted in replicable theory and data. If we wish to make a principled forecast to 2050 AD, or indeed to any future time, we must have a principled method for making the forecast. "Principled" in this context denotes a quantified, replicable method for making forecasts where only objective probabilities are used in forecast models. The method of extrapolating an atheoretical, long-range time series model, where the time series is generated by the underlying, ongoing process of social/cultural differentiation, is a principled method. Figure 1 may have policy implications. Individuals in the foreseeable future will be permitted to accumulate wealth even though governments may redistribute wealth.

The only reason that relatively few long-range time series forecasts have been made to date is that relatively few long-range time series of observations have been constructed to date. With the advances in archaeological chronology and reconstruction of prehistory cited above, this circumstance will change. Whether we attempt to construct time series of observations directly from archaeological data or indirectly by means of quantitative ethnographic analogy (Denton, 1993, n.d.) the range of subject matters we might consider forecasting is virtually unlimited. After extrapolation of universals, extrapolation of a model of a long-range time series is the surest forecast method available to those wishing to use the resources of Cultural Anthropology. Thousands of such long-range time series await construction.

How to Justify Extrapolation of an Atheoretical Time Series Model into the Future

There are at least three basic questions in regard to making a forecast by extrapolating a model of a long-range time series. We have considered the first two questions which are how to construct a time series of observations and how to model an "already constructed" time series of observations. The third question is this. Suppose we have a model of a time series of past and present observations. How are we to justify extrapolating the model into the future? Some time series analysts use the rule of thumb that a model of a time series may safely be extrapolated 1/10 the length of time of the time series into the future. We will only extrapolate our time series models 50 years into the future which, for a 9 000-year time series such as that of Figure 1, is 1/180 the length of time of the time series. Beyond using the practice of time series analysts to justify extrapolation of a time series model a short distance into the future, there is a conceptual justification which will now be stated.

There is reason to believe that all holocene (9000 BC to present) long-range time series which might be constructed of the worldwide mean of a univariate trait of culture are driven by an ongoing, underlying process which will continue into the foreseeable future. The only exceptions to this statement appear to be fluctuations in items of culture caused by fluctuations in temperature or other physical matters such as humidity and habitable land. Temperature and other physical properties of the holocene have varied considerably over some regions of the world but have been relatively uniform worldwide (Roberts, 1989; Stahl, 1996). It seems safe to ignore relatively small changes in temperature and other physical matters except in subject areas where conceptual knowledge demands that such small changes be considered. The crux of the matter is this. Since there is a single, underlying process which gives shape to the graph of a long-range univariate time series, and since the underlying process will continue into the foreseeable future, a model of the graph may be extrapolated a short distance into the future. This ongoing, underlying process is the process of social/cultural differentiation. It is true that many behavioural processes have been triggered by changes in social/cultural differentiation but it is the process of social/cultural differentiation which is the force driving the shape of long-range time series.

The process of social/cultural differentiation is the process whereby most societies have changed from homogeneous, independent parts in simple societies to differentiated, interdependent parts in complex societies. In a "simple" society such as the forager Ju, for example, most day-to-day activities occur in the context of kinship roles, age/gender roles and local community roles. Few specialized occupations exist beyond those of gender. In a complex society such as contemporary Canada there are more than 25 000 specialized occupations (Denton, 1998) with an attendant burst of knowledge in many subject areas, such as technology. While the process of social/cultural differentiation may be observed in individual societies (Denton, 1996; 1998) it is changes in worldwide long-range mean social-cultural complexity which will enable us to make forecasts.

It was Herbert Spencer (1900, formulated prior to 1859) who first stated the idea of differentiation of interdependent parts. Durkheim (1933) elaborated the construct. From 1956 to 1980 some six scales purporting to measure cultural complexity proved highly intercorrelated giving construct validity to the concept (Chick, 1997; Levinson and Malone, 1980, 31-37). Hundreds of correlates of cultural complexity are known to exist (Levinson and Malone, 1980: 28, 32, 37- 44, 296). It seems doubtful that such correlates are due to any modest, worldwide holocene (Roberts, 1989; Stahl, 1996) climate fluctuations although the correlates and the process generating them may or may not have been triggered by climate changes at the end of the pleistocene. Denton (1996) gives a culture-based explanation for the process of social/cultural differentiation.

The rationale for extrapolating a long-range model 50 years into the future may be developed via notions of nested functions. If a subject matter such as that of Figure 1 is a function of social/cultural complexity which itself is a function of time then the result is that the subject matter such as that of Figure 1 is what is called a nested function of time.[4]

The probabilities used in an extrapolated model of an atheoretical time series of observations such as that of Figure 1 are generally frequentist (Hoel, 1984; Mood et al., 1974). They are replicable and hence objective from the point of view of probability theory (Mood et al., 1974; Roberts, 1979). Such probabilities are obtained using empirical observations from ethnographies and from archaeological chronologies and are therefore replicable. There have been various tests replicating narrative theory both that all changes in worldwide mean frequencies of culture traits are correlated with social differentiation (Denton, n.d.; see also Levinson and Malone, 1980) and that social differentiation is primarily occupational differentiation (Denton, 1996, 1998; Durkheim, 1933).

Extrapolation of a Long-Range Trend Generated by an Ongoing, Underlying Process

It has long been recognized by anthropologists that there are many long-range trends in culture going back thousands of years. Levinson and Malone (1980: 28, 32, 37-44, 296), Ember and Ember (1999: 377), Carneiro (1970) and others review these trends. The crux of the matter from the point of view of the present paper is that all these trends are really trends $T(t)$ of an unobserved time series model of an unobserved time series of observations.

We have seen that a model of a time series of observations may be thought of as consisting of four elements—trend $T(t)$, cycle(s) $C(t)$, seasonality $S(t)$ and an irregular remainder $R(t)$.

$$Y(t) = T(t) + S(t) + C(t) + R(t)$$

Most constructors of time series observations will be unable at the moment to construct an anthropological long-range time series of observations having a seasonal component $S(t)$. While there is no presently known empirical nor conceptual reason to expect the presence of cycle(s) $C(t)$ in a long-range time series of observations what will be said would hold also for the trend component $T(t)$ of a time series where cycle is present since trend is, or will be assumed to be, independent of cycle. We will start by focussing only on trend $T(t)$ and remainder $R(t)$.

If we exclude the remainder $R(t)$ from a time series model $Y(t) = T(t) + R(t)$ we are left with trend which is simply slow change—or no change—in the mean value of $Y(t)$ over time. This is not how cultural anthropologists have written of long-range trends in culture. The phrase "long-range trend in culture" has been used to denote a strictly increasing (or strictly decreasing) change over time going back thousands of years. A trend $T(t)$ is strictly increasing (or decreasing) if, for all points t and all intervals of time of length Δt no matter how small Δt is but always greater than zero, then the difference in trend $T(t + \Delta t) - T(t)$ between the end of the interval and the beginning of the interval is greater than (less than) zero. For example, Levinson and Malone (1980: 28, 32, 37-44, 296), Ember and Ember (1999: 377), Carneiro (1970) and others have catalogued many long-range trends in subject areas as diverse as exchange (from only reciprocity to reciprocity, redistribution and monetary exchange), social inequalities (from relatively egalitarian societies to class-based societies), settlement size (from smaller to larger settlements), regional unification (from independent local communities to large scale regional unification) and numerous other sectors of culture including, but not restricted to, harnessing of energy, bureaucratization and reduction in the mass and volume of objects used as money. Every one of these long-range trends is stated in a loose, narrative, verbal way. As with long-range time series, every one of these long-range trends may be considered (Levinson and Malone, 1980) to be correlated with the process of social/cultural differentiation. As with long-range time series, the chain of causation that causes any given trend correlated with social/cultural complexity may be unknown. It is known, however, that the long-range mean worldwide value of some object Y changes directionally with the ongoing, underlying process of social/cultural differentiation.

With a long-range time series model $\hat{Y} = T(t)$, where $\hat{Y}(t)$ denotes $Y(t)$ excluding $R(t)$, we may find that $\hat{Y}(t) = T(t)$ changes over time or that $\hat{Y}(t)$ is a constant

k. In the latter case Trend $T(t)$ is zero and the covariance COV[$\hat{Y}, t$] is zero so the univariate trait of culture is independent of time t although still a constant function of it and the expectation $T(t)$ at 2000 AD is equal to the expectation $T(t)$ at, say, 10 000 BC. Wife beating appears to be an example of this (Denton, 1994).

Those who have defined long-range culture trends have had in mind something different from invariance over time. Consider, for example, the long-range trend in settlement size which is stated by Levinson and Malone (1980: 296). They state that there is a trend from "small, lightly populated" in "simple" societies to "large, densely populated" in "complex" societies. Levinson and Malone (1980: 55) state data which might be used to quantify this trend although they do not attempt quantification. What does Levinson and Malone's (1980: 296) wording of the trend denote? The most obvious denotation is trend in the arithmetic mean of all communities in the world at time T. However, other interpretations might be made. Their statement of this trend, indeed statements of all the long-range trends of Levinson and Malone (1980), Ember and Ember (1999) and Carneiro (1970) are so imprecisely stated that each must be more rigorously worded. However, every one of these trends—whether of settlement size or of any other construct—has the same implied geometric form. Each such trend $\hat{Y}(t) = T(t)$ either a single, monotonic, strictly increasing (or strictly decreasing) curve or may be made so by dividing the process into two sequential, monotonic trend curves—from strictly increasing to strictly decreasing, or strictly decreasing to strictly increasing. Examples of the latter sequence of two adjacent monotonic trend curves of different direction are trends in the frequency of the extended family (Blumberg and Winch, 1972; Denton, 1994; Nimkoff and Middleton, 1960)—from lesser in simple societies, to greater in sedentary horticultural societies, to lesser in industrial societies.

We are at the crux of the matter in regard to trends. It has not always been recognized that every known (i.e., defined or cited by Carneiro, 1970; Ember and Ember, 1996: 377; Levinson and Malone, 1980: 28, 32, 37-44, 296) long-range trend of a culture trait in Cultural Anthropology implies not only a monotonic function $\hat{Y} = T(t)$ of time t but also implies a model (i.e., $T(t)$) of a possibly conceptual time series of observations underlying the trend. These time series models and the time series observations on which they are based may await construction but they are implied. These results themselves imply a viable long-range forecast method. First, however, we need to construct some of the mathematical properties of long-range culture trends.

DEFINITIONS. 1. A function $\hat{Y} = T(t)$ is a single-valued deterministic function of time t if for every time t in the domain of t for which $T(t)$ is defined there is one and only one y in the range of $\hat{Y}(t)$.
2. A long-range culture trend, as this phrase has been used in Cultural Anthropology by Levinson and Malone (1980), Ember and Ember (1999), Carneiro (1970), is the monotonicity of a (possibly conceptual) graph of a (possibly unknown) single-valued deterministic function of time $\hat{Y} = T(t)$ of a univariate object of culture Y going back thousands of years, where the graph is strictly increasing (decreasing) or may be made into a sequence of two such trend curves from strictly increasing to strictly decreasing (strictly decreasing to strictly increasing). The function $T(t)$ is continuous and left open twice differentiable at all times t in a continuous domain of time t. The second derivative $f^{11}(t)$ is continuous.□

The preceding definition of long-range trend may seem artificial but is exactly what is implied by those who have, in narrative verbal form (e.g., Carneiro, 1970; Ember and Ember, 1999; Levinson and Malone, 1980), asserted long-range trends. For virtually all such trends known in Cultural Anthropology the deterministic function of time $T(t)$ is unknown at the moment. Indeed, a function $T(t)$ which is in fact a trend would be discovered by constructing and modeling a time series of observations using one of the time series forecast methods mentioned above. Some properties of mathematical interest in regard to trends may now be stated.

LEMMAS. *(1) Every long-range trend of Definition 2 implies a monotonic deterministic function of time* $\hat{Y} = T(t)$.
(2) Every monotonic deterministic function of time from (1) is continuous and left open twice differentiable. The first derivative is continuous and of constant sign. The second derivative is continuous and may be positive, negative, zero or a sequence of any or all of these.

PROOF. (1) From Definition 2, for any variable Y for which there is a long-range trend there is a deterministic function of time $T(t)$ such that $\hat{Y} = T(t)$. The function $T(t)$ may be unknown but is stated in the definition. Also from Definition 2, $T(t)$ is monotonic.

(2) That $T(t)$ is left open twice differentiable is stated in Definition 2. Continuity of $T(t)$ and $T^1(t)$ is stated in Definition 2 and follows from the differentiability of $T(t)$ and $T^1(t)$. Continuity of $T^{11}(t)$ is stated in Definition 2. The proof for the rest of Lemma (2) uses elementary principles of calculus (e.g., Loomis, 1982). We will prove the result for strictly increasing trends. The proof for strictly decreasing trends follows easily. For a strictly increasing left open differentiable function $\hat{Y} = T(t)$, by definition $\hat{Y}(t)$ is defined all $t \geq 0$ and $[\hat{Y}(t + \Delta t) - \hat{Y}(t)] > 0, t \geq 0$. Also, the limit as $\Delta t \to 0$ $\frac{T(t + \Delta t) - T(t)}{\Delta t} = T^1(t) > 0$, all $t > 0$. Since no restrictions are placed on the sign of $T^{11}(t)$, $T^{11}(t)$ may be positive and/or negative and/or zero.□

There are no readings known to the writer dealing with how to construct a long-range trend. Most such trends known today have been known to Cultural Anthropology for decades. These are summarized by or cited by Levinson and Malone (1980), Ember and Ember (1996) and Carneiro (1970). If all available archaeological and ethnographic evidence support the notion of a long-range directional trend then the assumption of such a trend is reasonable. Most such trends in the readings cited are sloppily stated—the exact starting time is not stated, no precise population is stated, data presented for the modern extreme of the trend is from preindustrial complex societies even though the trend seems assumed by the writers to be applicable to contemporary complex societies. Once such defects are corrected then the forecast method for extrapolation of the trend is simply that the value of a strictly increasing trend $T(t)$ is greater (lesser) at future time $(T + \Delta t)$ than at present time t. This statement says nothing about the irregular remainder $R(t)$ in $Y(t) = T(t) + R(t)$ nor any cycle(s) $C(t)$ but there will be many instances where only a trend forecast will be considered worthwhile. Indeed, unless there is conceptual or empirical reason to the contrary, it seems reasonable to assume that there is no cycle(s) $C(t)$ at work. The forecast method may be put into mathematical form as follows.

FORECASTS BY EXTRAPOLATION OF A LONG-RANGE TREND

Suppose we have a long-range trend of an object of culture Y where long-range trend is defined as in Definition 2, above. Then, assuming that no seasonality nor cycle is present, $\hat{Y}(t) = T(t), T(t)$ may be unknown, $t \geq 0, T(t)$ is monotonic.

By hypothesis, the trend is correlated in some possibly unknown way with the underlying process of social/cultural differentiation which is ongoing and will continue into the foreseeable future. Then, we may make a trend forecast of expectations that $E[\hat{Y}(t)] = \hat{Y}(t); E[\hat{Y}(t + \Delta t)] = \hat{Y}(t + \Delta t)]$ $E[\hat{Y}(t + \Delta t)] > (<) E[\hat{Y}(t)]$ for an increasing (decreasing) function.

Here, the error deviation $e(t)$ in $Y(t) = T(t) + e(t)$ (or $Y(t) = T(t)e(t)$) is unknown but if we are willing to assume the errors $e(t)$ are independently and identically distributed Normal at time intervals of sufficient length to attain serial independence then $e(t), e(t + \Delta t)$ are unknown but are $\sim iiN(0, \sigma_1^2(t))$ and $(0, \sigma_1^2(t + \Delta t))$ at times $t, t + \Delta t$, or $\sim iiN(1, \sigma_2^2(t))$ and $(1, \sigma_2^2(t + \Delta t))$, provided Δt is of magnitude sufficient to attain independence. Also, $E[\hat{Y}(t)] = T(t)$, $E[Y(t + \Delta t)] = T(t + \Delta t), E[Y(t + \Delta t)] > (<) E[Y(t)]$.□

In words, we may use long-range trends of Definition 2 to forecast the trend component $T(t)$ of unknown functions. If we are able to assume, for time jumps of sufficient magnitude, independently and identically distributed adjacent errors which are normally distributed with mean zero or 1 and unknown variance in the real world then we are able to forecast expectations $E[Y(t + \Delta t)]$ which are equal to the trend component $T(t + \Delta t)$ at some future time $(t + \Delta t)$. The justification for assuming normally distributed errors is the Central Limit Theorem (Taylor and Karlin, 1984: 27-28) which says that if errors $e(t)$ are serially independent and are the result of many sets of factors no one of which is dominant then the errors $e(t)$ will be Normally distributed. Variances and prediction intervals for point forecasts are unattainable at the moment for extrapolation of long-range trends. However, there will be many circumstances where a forecast which is simply an expectation, or even simply a trend component, will be considered worthwhile.

Technically, the directional trends of Definition 2 are only one variety of long-range trend if trend is defined to be a slowly changing mean $T(t)$. Trends which only increase or decrease are easier to detect by non-quantitative methods than more complicated changes in mean.

This is the reason cultural anthropologists have used the word "trend" as "directional trend" of Definition 2. More complicated trend forms will be discovered only by first constructing time series of observations. It is important to note that the forecast method of extrapolation of directional trends based on Definition 2 is applicable only to directional trends, which limits the method to directional trends such as those noted by Levinson and Malone (1980: 28, 32, 37-44, 296), Ember and Ember (1999: 377) and Carneiro (1970).

Replicable, objective evidence of the existence of directional trends may be obtained in various ways, for example from sound but qualitative interpretations of the archaeological record, or by equating directional change with correlates of cultural complexity in recent preindustrial societies of the 19th and 20th centuries. Provided one exercises caution (Denton, n.d.; Ember and Ember, 1995), such latter data of the recent ethnographic present generally constitute ethnographic analogical indicators of correlates of cultural complexity in prehistoric societies. There is one *caveat*. While Levinson and Malone (1980) and other cultural anthropologists have defined many long-range directional trends, these trends are usually defined up to complex preindustrial societies (inclusive) and assumed to exist up to complex industrial societies (inclusive). In order to be extrapolated beyond 2000 AD such a trend must be valid up to complex industrial societies at 2000 AD.

It has been shown that the second derivative of the unknown function $T(t)$ implied by a long-range trend of Definition 2, exists (is finite) at all $t > 0$, and is continuous. Also, the second derivative is positive or negative or zero or a continuous sequence of any or all of these. This fact implies that the unknown, strictly increasing (decreasing) function $T(t)$ underlying the trend may be concave up, concave down, a non-vertical straight line or any continuous sequence of these.

Extrapolation of a Theoretical Model

The last forecast method to be considered in this paper is extrapolation of theoretical models. Anthropologists and others wishing to make long-range forecasts will use whatever methods they find useful. Some methods such as demographic forecasts, simulation, scenario, stochastic processes such as Markov chains and counts and the probability models underlying them may be useful for purposes of making a forecast but may not be especially tied to Anthropological theory and data from pre-industrial societies. Such methods will not be considered here. There are, however, two classes of theoretical models which not only use Anthropological theory and data from pre-industrial societies but which will also be applicable to some concrete forecast situations. These are theoretical forecasts made by extrapolating deterministic functions of time or by extrapolating causal models. Considerations of space demand that we only sketch the contours of these methods.

Extrapolation of a Theoretically Constructed Deterministic Function of Time

Suppose that narrative theory for a particular subject matter posits a deterministic function of time with possible random error in the real world. At the moment, there is little narrative theory in Cultural Anthropology for such processes but there is some (Denton, 1996). It is likely that many such processes await construction. With only a few exceptions all long-range trends and time series currently known to Cultural Anthropology are atheoretical, deterministic functions of time correlated in various ways with the underlying, ongoing process of social/cultural differentiation (Denton, 1995a, 1996, 1998, n.d.; Levinson and Malone, 1980). If we had decent narrative theory for such processes we ought to be able to use the theory to construct models $y = g(\bar{w})$, $\bar{w} = h(t), y = g(h(t)) = f(t)$, which is a nested deterministic function of time, $\bar{w}$ is a variable of social and/or cultural complexity.[5] If we are able to use theory to construct $f(t)$ we do not need to construct $g(\bar{w})$ nor $h(t)$. We make a forecast by extrapolating either $y = g(h(t))$ or $y = f(t)$ depending on what narrative theory leads us to construct. Probability models for random error of such functions ought to be relatively easy to construct.

Extrapolation of a Causal Model

Suppose we have a fully specified causal model purporting to define the causes $Z_1, Z_2, \ldots,$ of a result X at time t. Suppose we know the states of the causal variables $Z_1, Z_2, \ldots,$ at some future time $(t + \Delta t)$ or probabilities for these states. Then, intuitively, we ought to be able to forecast X at time $(t + \Delta t)$.

Causality is a deep construct with lengthy philosophical roots. It is also an unsettled subject area where lively development is ongoing (Eells, 1991; Seltiz, Wrightsman and Cook, 1976: 114-115; Shafer, 1996). The notion of a "fully specified causal model" is relative to the information demands of the causal model. Sobel (1995) is a recent review of causal modelling in the social sciences. The notion of causality permeates Cultural Anthropology.

We are limited in our construction of causal models not only by data but also to subject areas where there is sufficient conceptual knowledge to enable causal modelling. There are few subject areas where such theory exists at the moment but there are some. What makes causal modelling a potentially useful method of forecasting is the possibility of using time series forecasts to forecast the states of causal variables in a fully specified causal model. While space constraints preclude pursuing the subject further, causal models are likely to make viable forecasts in some subject areas (Denton, n.d.).

Conclusion

At the outset only two assumptions were made. These are important assumptions to make but are reasonable (in the writer's opinion) up to 2050 AD. Astronomers use the theory and data currently available to them to forecast the motion of objects in the universe. It is reasonable to use the theory and data currently available to Anthropologists to make forecasts, provided such theory and data have significant peer support. That the writer has been able to cite supportive readings throughout this paper is evidence of such peer support. Making only the two assumptions it is possible to make hundreds, perhaps thousands, of forecasts of the future. The reader may consider these "forecasts" to be either extrapolations based on reasonable assumptions or forecasts since the assumptions on which the extrapolations rest are reasonable. Throughout this paper "forecast" has been used in either sense.

In this paper hard forecast methods have been formulated. The forecasts made by the methods of this paper are replicable in the sense that construction of the elements of forecast models may be replicated by others. From the perspective of probability theory, it is objective (rather than subjective) probabilities (Mood et al., 1974) which both enter into the forecast methods and result from them. In forecast models for universals, time series, a deterministic function of time and causal models replicable, objective confidence intervals may be calculated although space has precluded consideration of such matters here. For forecasts made by extrapolating trends only expectations are currently possible.

Of the forecast methods considered those for universals and time series are currently the most powerful. From the method of forecasting universals we are able to extrapolate into the future all the current basic conceptual apparatus of Cultural Anthropology as to how societies work. This gives Cultural Anthropology a solid foundation on which to build. It is forecasts made by extrapolating time series models which gives Cultural Anthropology exceptional strategic positioning for making long-range forecasts. Thousands of forecasts await construction by extrapolating atheoretical models of long-range time series. Narrative theory and ethnographic analogical data make such subject matter as much the purview of Cultural Anthropology as of Archaeology, although chronologies of the latter are generally essential. Probability models for extrapolating deterministic functions of time and causal models will generally be mathematically sound but of lesser applicability than extrapolation of time series models in the sense that knowledge permitting use of the former is likely to be less readily available than for use of the latter.

It is useful to put the results of this paper in the general context of forecasts of society and culture. First, all the forecast methods of this paper are made possible by focussing on behaviours which are deterministic functions of time with possibly some irregular element. Even the causal models method will need to use ingredients which are deterministic functions of time. Time series forecasts may be used to forecast the state(s) of a causal variable(s) in a causal model. Indeed, if there is an invariant behavioural relation between a cause X (e.g., mobility) and result Y (e.g., family type), then the invariant behavioural relation is a function of time, namely, a constant.

The second way in which this paper bears on forecasting is to show that it is possible to make forecasts of society and culture—in this case long-range forecasts. We may not often be able to predict which of several alternative events will actually happen but we are able to make point forecasts located within confidence intervals. Of course, there is more to forecasting society than the methods of this paper. For short-range forecasts non-time deterministic methods may be more appropriate. Some forecasters in business and elsewhere are reluctant to work with forecasts, preferring instead to work with non-quantitative branching scenarios which, once constructed, may be selectively activated according to which branches actually occur. Confidence interval methods applied to the results of this paper may be used to generate probabilities for branches.

That long-range forecast models may be used to generate short- to mid-range forecasts is a third way in which this paper impacts on forecasts of society and culture. This is a technical matter which will not be considered here. Confidence intervals for such forecasts will be especially useful in circumstances where no other viable forecast methods are available.

Fourthly, more needs to be said about what subject matters are worth forecasting. The methods of this paper may be used to forecast idiosyncratic matters of interest to individuals, governments or businesses. For example, if we are able to forecast many facets of how people will live in 2020 AD or 2050 AD—which we are—then we may be able to forecast economic demand for products consumed. If we have a theory of how society works then we ought also be able to use the methods of this paper to forecast elements of such a model of society.

While this paper carves out a niche for Cultural Anthropology in regard to forecasting there is much to be done. There is a need for secondary data bases of worldwide prehistory back to 9000 BC and beyond. HRAF (1999 and after) and Ember and Peregrine (n.d.) appear to be a start in this direction. In regard to worldwide time series back to 9000 BC there is a need for more observations at intervals spaced at 500 years and, over time, at 250 years. When such time series of observations appear it will be possible to construct forecasting competitions where the forecast accuracy of curve fitting (Chatfield, 1996: 13), heuristic methods such as Holt-Winters (Brockwell and Davis, 1996: 315) and time series models (Brockwell and Davis, 1996) are compared. There is a need to clarify the role of ethnographic analogy in reconstruction of prehistory (Denton, n.d.; Ember and Ember, 1995).

While the results of this paper have been informed by theory from Cultural Anthropology the results might be used to inform theory from Cultural Anthropology. The form of an atheoretical time series model might be examined as an object from which to extract grounded theory. Hypotheses might be tested using time series of observations.

In many ways life in the foreseeable future will be much as it has been for the past 37 000 years. From the method of extrapolating universals we may say with certainty that groups such as the family and local community will continue to exist. Systems for co-ordinating power, renewal of resources, education and recreation will exist. Individuals will have basic needs for food, clothing, shelter, mobility, relaxation, safety, sex and health (Denton, 1998). They will meet these basic needs in part by themselves but largely by entering into exchanges with other people (or machines). This will create a variety of interdependencies. From extrapolation of a theoretically constructed deterministic function of time (Denton, 1996 which forecasts more interdependent, differentiated occupations) interdependence in the future will be even more massive than today. Women will have children (a universal) although the number of children per mother will decrease in developing nations (United Nations, 1998). From extrapolation of causal models (Ember and Ember, 1999) men and women will marry and nurture children although fewer children per marriage and mechanization of work will send women to work outside the home even more than today. This will reduce the need for marriage which is, to a large extent, to nurture children and to pool the results of division of labour by gender. Marriages as they have existed to date (Ember and Ember, 1999) will be fewer and more fragile since there will be fewer children. From extrapolation of time series models bilateral kinship will predominate to 2050 AD as will neolocal residence and the independent family (Denton, 1994). Wife beating will be more than rare and people will be able to pick their own spouse (Denton, 1994). Social inequalities arising from age, gender, natural ability, property ownership, specialized training, ethnicity and geographical location will exist although it is uncertain to what extent government redistribution will redress inequalities. The frequency of war will decrease (Denton, 1995a) and where war occurs one of its purposes will be to attain political objectives—to control the vanquished (ibid.). It seems likely that there will be widespread belief that a single order permeates the universe, which single order—now the subject of study of Physics and related scientific disciplines—itself may be considered a variety of monotheism (Denton, 1995b). The number of political jurisdictions in political hierarchies will increase, which is an implied trend toward a single, world nation-state (Denton, 1993). Government will become even more bureaucratic. People at 2050 AD might find people of 2050 BC incomprehensible from the point of view of clothing, smell, violence, and the like. In fact, societies at both times may be considered identical in the sense that both are organized in such a way as to enable the individuals in them to meet their basic needs via interdependence (Denton, 1998). We may extrapolate all the universals and virtually all the long-range trends, properly formulated and valid to 2000 AD, known to Cultural Anthropology.

The theory and data of Cultural Anthropology enable us to make principled forecasts of the future. Here, a principled forecast denotes a quantified, replicable forecast where objective probabilities are used. Whatever may be approached as universals, long-range time series, long-range trends or deterministic functions of time ought to be forecastable although common sense must always be used. In some cases causal models may be extrapolated. Subject matters which cannot be approached from these vantage points will require different forecast methods. If we have no quantitative method for forecasting a particular item X, no replicable theory nor data for making a forecast, then we cannot—or in the writer's opinion should not—construct what we claim to be a rigorous forecast of it. Thus, volatile subject matters such as clothing styles and winners of sports events would presumably be outside the long-range forecast methods of this paper. Such subject matters necessitate forecast methods—or at least better long-range data and better narrative theory—beyond those considered in this paper. Even limiting ourselves to the results of this paper Cultural Anthropology, with a grasp which reaches deep into the past, enables us to forecast deep into the future.

Notes

1 The writer gratefully acknowledges the constructive suggestions of two reviewers of this journal.

2 Technically, each observation of the time series of Figure 1 is the proportion of individuals in the world, at the time of the observation, living in societies where norms permit individuals to accumulate wealth. Each proportion is interpreted as a probability. The time series of observations shown in Figure 1 is constructed using an indirect method for constructing time series of behaviour not directly observable from the Archaeological record. The method developed by Denton (1993; 1995a) is sound when applied to subject matter within the ambit of the method (Denton, n.d.). Examples of such time series are also given in Denton (1994; 1995b). For the purpose of the present paper we will not digress to state how the time series of Figure 1 is constructed but rather will simply assume that the time series of Figure 1 is valid in order to use Figure 1 as an example of a forecast made by extrapolating a time series model of an atheoretical long-range time series of observations.

For those wishing to relate the time series of Figure 1 to the method of Denton (1993; 1995a; n.d.) here is relevant technical information. Figure 1 describes a time series based on the Human Relations Area Files Quality Control Sample (Naroll, 1967), QCS Variable 45 (Levinson and Wagner, 1986: 28). Figure 1 graphs the probability $P(X_t = 1)$ of living in a society where norms permit accumulation of wealth by some or all individuals. Its opposite, $P(X_t = 0)$ would denote norms of resentment making significant accumulation of wealth difficult, unlikely or dangerous; or norms of redistribution preventing accumulation of wealth. Thus, Figure 1 graphs the probability $P(X_t = 1)$ of living in a society coded as QCS Variable 45 codes $2 \cup 3$. Figure 1 is based on codes for 34 societies of which 10 are coded $Y = 1$, 18 are coded $Y = 2$, 6 are coded $Y = 3$. Of the 10 QCS (Levinson and Wagner, 1986: 28) societies coded $Y = 1$, 5 have QCS V45 codes $2 \cup 3$. Of the 18 QCS societies coded $Y = 2$, 13 have QCS V45 codes $2 \cup 3$. Of the 6 QCS societies coded $Y = 3$, all have QCS V45 codes of $2 \cup 3$. For the meaning of the symbols $Y = 1, Y = 2, Y = 3$, see Denton (1993; 1995a). For readers unfamiliar with use of coded data from worldwide cross-cultural ethnographic databases, Levinson and Malone (1980: 5-7) give fair assessment. Technically, Figure 1 graphs the probability that a Bernoulli random variable $X_t = 1$ at time t,

$$X_t = \begin{cases} 1 \text{ the event that QCS Variable 45 codes} = 2 \cup 3 \text{ at time } t \\ 0 \text{ otherwise} \end{cases}$$

The symbol $P(X_t = 1)$ denotes the proportion of individuals in the world at time t living in a society where individuals are permitted to accumulate wealth. This proportion is treated as the probability of living in such a society at time t.

3 The prediction interval for Y (2050 AD) in Figure 1 is calculated using the method of least squares (Mendenhall et al., 1986). The OLS variance of $e(t)$ shown in Figure 1 must be adjusted to take into consideration the way in which the Figure 1 long-range time series by conditioning (Denton, 1993) is constructed. The variance used in calculation (Mendenhall, et al., 1986) of the prediction interval for y (10.05) shown in Figure 1 includes this adjustment using the variance adjustment of Denton (n.d.). While the variance adjustment of Denton (n.d.) results in slightly larger adjusted variances than would result from the variance adjustment of Denton (1995a) the adjustment of Denton (n.d.) is more accurate. It is assumed that the form of the graph of Figure 1 is created by the underlying process of social/cultural differentiation which will continue into the foreseeable future. This assumption, justified in the text of the present paper, justifies extrapolating the 7000 BC to 2000 AD variance to 2050 AD.

4 Consider Figure 1. Let us denote the worldwide probability $P(X_t = 1)$ of Figure 1 as y. Here, y is a function f of time t so $y = f(t)$. However, what is really going on is that y is evolving as worldwide mean cultural complexity which we will note as $\bar{w}$ which is itself a function h of time t. Here, y is a function g of worldwide mean cultural complexity $\bar{w}$. All in all, we have the nested function $y = f(t) = g(h(t))$, where $y = g(\bar{w})$ and $(\bar{w}) = h(t)$.

5 As established in note 4.

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