Chapter 10

The Cohort-Component Population Projection: A Strange Attractor for Demographers

10.1 Introduction

It has been said that all Western philosophy is but a footnote to Plato. I feel as though anything I might say here risks being but a footnote to de Gans, *Population Forecasting, 1895–1945: The Transition to Modernity* (De Gans 1999), to *Frontiers of Population Forecasting*, a supplement to *Population Development Review* edited by Lutz *et al.* (1998), and to Bongaarts and Bulatao [eds.] *Beyond Six Billion: Forecasting the World's Population* (2000). Little in science is ever truly definitive. But taken together these works come close in their treatment of the history and current practice of population forecasting. They will frame discussion of the topic for some time to come, and will have major impact on new developments.¹

My footnote aims to place the cohort-component population projection algorithm in a broader perspective. I suggest viewing it, not just as a technique for population forecasting, but more fundamentally as a general theoretical model of population dynamics. In this perspective, population forecasting is just one among many analytic uses of the model – an important one, but only one (See Romaniuc 1990, and Chaps. 4 and 9 above).

de Gans chronicles the triumph of the ‘demographic’ – that is the cohort component – approach to population forecasting in The Netherlands, but also internationally, to the point where it became and has remained to this day the standard method, sanctioned by academic demography, by national governments, and by influential international organizations such as the United Nations and the World Bank. As the title suggests, I sometimes find it strange that its triumph should

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¹See also Cohen’s (1995) Part 3 on ‘Future Human Population Growth,’ especially Chap. 7, ‘Projection methods: the hazy crystal ball.’

have been so complete and so long lasting. I find it easy enough to understand why the cohort-component projection [hereafter CCP] model should have become so popular in the 1920s and 1930s, although even here I have some questions. I find it harder to understand why, with so little change in details of application, it has remained so popular, to the near-exclusion of other methods.

I have sometimes thought that the CCP approach to population forecasting is obsolescent if not obsolete. There is an element of truth in this. But on further reflection, I would put it differently. The CCP method *as currently described and practiced, and as a monopolistic method* is obsolete. But it will continue to be useful in many contexts. In addition, the CCP model contains a kernel of demographic truth that is permanently valid, and therefore will be retained at the core of many future, more elaborate forecasting models. Another, although unconventional, way of saying this is that the CCP is fundamentally a valuable theoretical model of population dynamics, not just a popular technique.

The CCP model remains an excellent tool for many purposes, regardless of its well-publicized failures to predict accurately. With growing sophistication in both scientific and policy analysis, and with the calculating power of the modern computer that makes the CCP projection computationally trivial, there is good reason to keep it our toolbox, along with other, perhaps newer and more powerful analytic tools. But as de Gans reminds us on more than one occasion, demography and statistics are human activities, subject to human foibles. The future of population forecasting will no doubt be influenced by disciplinary and other vested interests, by ego, and by ideology. Our best hope will be to contain these influences in the interests of good science and rational policy analysis.

This chapter touches on three questions, although not separately or systematically:

1. Why did the CCP model become the dominant tool for population forecasting?
2. Why has it remained dominant for so long, to the near exclusion of other methods?
3. What will be its future status?

By way of tentative and partial answer to these questions, I focus on: (a) the inherent strengths of the CCP algorithm, which are many; (b) its mathematical simplicity, involving little more than basic arithmetic; (c) some characteristics of the field of demography, broadly defined, including its relative lack of mathematical sophistication, (d) a general tendency towards parochialism, and (e) what I have come to think of as theoretical and methodological nonchalance. By the latter I mean relative inattention to theory-building and to the philosophy of science in favor of a preoccupation with data and technique.

10.2 The Cohort-Component Population Projection Model: An Overview

It is useful to begin with a reminder of the main features of the CCP algorithm:

1. It is mathematically easy, involving no more than addition, subtraction, multiplication and division, and knowledge of decimal fractions. Most of the individual relationships in the model are obvious after a little thought. It involves some complexity, but little inherent difficulty.
2. It is computationally intensive, especially if the projection is over a long period and uses small (for example, 5-year) age intervals. There are no shortcuts, in the sense that one cannot skip from t_0 to t_{75} without computing results for all the intervening years. Compare the stable population model, which more economically yields some information on long-term dynamics, or the exponential or logistic [or other formulaic] approaches, which easily evaluate the function $P[t]$ at any time. The high calculation costs of CCP projections in the early days, before computers, help explain why most projections were done by government agencies rather than by individual researchers.
3. Model interrelations are necessary relationships. Given a starting population structure and assumptions about fertility, mortality and migration, the outcomes follow with mathematical certainty and considerable precision.²
4. Behavioral inputs are strictly exogenous. Nothing in the model impacts on age-specific fertility, survival probabilities, or the amount (number or rates) of migration. More specifically, there are no feedbacks from population size and structure to the basic inputs. Size and structure interact with the rates, of course, to produce births and survivors (and perhaps migrants), but there is nothing in the model to change the rates themselves, even in the face of extreme developments.
5. The model has limited content; socio-economic determinants of population dynamics are excluded. It is thus a demographically self-contained population model. But it is limited even in demographic terms. For example, CCP projections often do not explicitly include marital/quasi-marital status and status-specific fertility as variables. In cases where it is included, it is introduced exogenously; for example, emerging age-sex structures, which might include distorted sex ratios, do not affect marital status. There are no feedbacks from structure to input rates.
6. The exogenous inputs of fertility, mortality and migration typically are not behaviorally modeled. The most common assumption is that they will exhibit continuity with the present or recent past. The continuity assumption is implemented by means of informal judgements: 'The total fertility rate,

²According to an increasingly influential view of science and scientific theory, this is a characteristic of all good explanatory models. See Giere (1999), Teller (2001), Burch (2003, and Chap. 2 above).

currently 1.6, might rise as high as 1.9 or fall to 1.3 by the year 2020,' or, increasingly, by means of formal methods of extrapolation.

7. Partly because of the computational burden noted above, official population projections became the norm and were considered and used as general-purpose projections. Interestingly, the notion of one set of projections for all purposes runs counter to a cardinal rule of mathematical modeling [found in virtually every book on mathematical modeling or simulation I have encountered], namely, that a good model must be customized for the purpose for which it is being constructed. This issue emerges in de Gans' account of the tension between national and local population forecasters in The Netherlands.

In short, the standard CCP algorithm is limited, linear, and 'open loop,' and assumes continuity in fertility, mortality and migration. Keyfitz (1998) has summarized the matter as follows:

Demographic models commonly used for analyzing and projecting population are mostly variants of a very simple equation that can be written as $y_t = A^t x$, where y_t the outcome is a vector...say the anticipated future population at time t distributed by five-year age intervals..., x is the corresponding vector for the initial period, the jumping off point in time, A is the square matrix of constants that in practice are usually derived from the fertility and mortality of the jumping-off point..., and depart little from the data of the jumping-off point.... It [the equation] is not only linear, but among linear systems, it is an open loop, i.e., the result in one period does not affect the parameters for the next period; it is assumed applicable unchanged for successive time periods.' (p. 1)

In discussing the CCP model, note the importance of distinguishing the following: the central algorithm, which is formally true and in that sense beyond criticism; assumptions regarding input components, that is, about levels and/or trends in fertility, mortality and migration; and the interpretation and use of results.

10.3 The Many Strengths of the CPP Model

The CCP model is limited, but within those limits it is a powerful and versatile analytic tool. Consider the following advantages:

1. *Accounting for the past.* With respect to the past, assuming historical inputs of fertility, mortality and migration, the CCP algorithm provides a complete account of past population dynamics, including size, growth rates, and changing age-sex composition. The actual historical dynamics, with due allowance for errors in basic data, follow logically from past inputs combined with the algorithm. There are not many social science models that can supply such a sense of closure on historical explanation, at any level of analysis.
2. *Contingent but confident prediction.* Given assumptions about future inputs, future population dynamics follow necessarily and with certainty. Over short prediction horizons, one can be confident of assumptions, so that the results are

nearly inevitable. Again, there is solidity in these predictions seldom encountered elsewhere in social science.

3. *Guide to future intervention.* Besides contingent prediction, the CCP model provides some guidance as to how future population dynamics might be controlled. To a limited degree, it deals with causal mechanisms of future population dynamics, and identifies fertility [and possibly nuptiality], mortality and migration as policy levers that can in principle be used to change those dynamics in a desired direction and to a desired degree. Compare this with the relative lack of any sense of control or policy options when dealing with exponential or logistic models of population growth as these usually are presented.

In what has become one of my favorite books on scientific methodology, Meehan (1968) makes a sharp distinction between prediction and explanation. He points out that the latter is both more demanding intellectually, requiring specification of why something will happen, and more valuable practically, helping us control the future, not just adjust to it. The CCP approach, compared with some other population forecasting models, scores well on these criteria – it can both explain, within its limited compass, and predict.

4. *Details of age-sex composition.* Used for population forecasting, the CCP algorithm can provide meaningful detail on age-sex composition, again in contrast to exponential or logistic forecasts of total population. The feature has made CCP projections particularly useful for sectoral planning, for example, dealing with school-age or labor-force entry sub-populations. The age-sex detail also provides a solid foundation for superimposed age-sex distributions, for example, of marital status or household status (as in the headship rate method of household forecasting).
5. *Continuity as a first approximation.* There is a sense in which an assumption of continuity in levels and trends in fertility, mortality and migration is a natural assumption, in the absence of anything better. Up until World War II, this assumption served demography rather well. It has taken the Baby Boom, the post-1960s rise in divorce rates, the advent of widespread cohabitation, recent mortality increases in some advanced societies (for example, the former Soviet sphere), and other massive demographic discontinuities to accustom us to the view that such discontinuities are not unlikely, even if continuity remains more likely.

It has also taken a gradual weaning from the idea that demography and other human sciences can or must aspire to the discovery of immutable laws of behavior, in the manner of ‘celestial mechanics,’ an idea that is a *leitmotiv* of de Gans’ book.³

³See his valuable discussion of George Herbert Mead’s ideas on time, notably, the notion that ‘the emergent event is conditioned, but not determined, by the causal chain,’ that is, by the past (1999, p. 231).

6. *A powerful and flexible abstract model.* In demographic texts and monographs, the CCP model invariably is presented as a technique for making population forecasts. Other uses certainly have appeared, but they generally have not been emphasized. Romaniuc (1990) was one of the first to describe systematically some of these other uses, placing them on an equal footing with forecasting. He features three main applications of population projections⁴:

1. prediction: What will be the future of population growth? This is based on the best possible assumptions of the future course of fertility, mortality and migration.
2. prospective analysis: What are some realistic scenarios for a given population, assuming, for example, major and successful changes in policy?
3. simulation: What would happen to population growth if...? This can be based on any assumptions whatever, even unrealistic assumptions.

These are presented as lying on a continuum with respect to the concrete future, from more to less realistic.

Romaniuc thus emphasizes the CCP algorithm as an abstract model of population dynamics. I would take the next step and call it a theoretical model or theory.

Compared with stable theory, for example, the CCP model is more comprehensive, more realistic, and more flexible. It can deal with both sexes, separately but simultaneously; it routinely includes migration flows; it describes ‘transient dynamics’ as well as the equilibrium situation, a powerful advantage since most of human life is lived amidst such transient dynamics.⁵ These virtues were harder to appreciate in the early days of CCP, since computation of projections was no small matter. The stable model, by contrast, provided relatively economical long-term ‘projections.’ With the advent of computers and spreadsheets, calculating multiple projections for long time horizons is easy and routine. Overall, the CCP algorithm has much to recommend it.

10.4 Easy Mathematics

Not included in the above list of advantages and often overlooked is the fact that the CCP method is mathematically easy. It involves only the arithmetical operations of addition, subtraction, multiplication, and division, and a working knowledge of proportions and decimal fractions – in short, elementary school arithmetic. One

⁴See also de Gans’s discussion of the different possible roles of the forecaster (De Gans 1999, Ch. 8).

⁵The term has its origin in engineering, particularly electronics, where it often is the case that early instabilities disappear rapidly and the system settles into some desirable steady state. The word transient sometimes connotes unimportant. For demographic forecasts, by contrast, early developments are the most important and the most securely known.

does not need to know calculus, differential equations, or linear algebra. de Gans notes ‘the relative simplicity of the methods involved’ (De Gans 1999, p. 9).

This has appeal both to analysts preparing CCP forecasts, and to non-scientists who use the result. Anyone with ordinary intelligence and a reasonable knowledge of arithmetic can make a projection – given time, patience, or a statistical clerk – or understand one.⁶

Or at least people think they can understand what is involved, although there is a difference between thinking one understands and understanding. de Gans refers to Kuczynski’s use of the net reproduction rate, and his conviction that it ‘could indicate which populations were to expect an imminent decrease in population’ (De Gans 1999, p. 95). We now understand that this is not the case. An NRR of less than one indicates that [neglecting migration] a population *would* begin to decline some time in the future *if* current age-specific fertility and mortality rates were to remain unchanged indefinitely. In some cases, the hypothetical decline may not occur for several decades. But the concept seems simple: above 1.0 means growth; below 1.0 means decline; 0 means replacement. And many people who become acquainted with the concept confused current versus equilibrium conditions, and prediction with abstract modelling. Frank Notestein used to say that the NRR was a troublesome measure precisely because it lent itself to so much confident misunderstanding. In Canada one regularly reads in the popular press that Canada’s below-replacement fertility is such that only net immigration is preventing current population decline, whereas in fact current natural increase is still positive.

Similarly, if the core algorithm of a CCP is easy to understand, the subtle questions surrounding its open-loop character, the nature and implications of its assumptions, and its status as a contingent prediction are not. In practice, the meaning of a CCP is often misunderstood by the user.

Many users think they understand the CCP because no unfamiliar mathematics is involved, no calculus or differential equations. Some expositions of the method use matrix algebra, but this can be avoided by using the more common ‘book-keeping’ approach. Compare this with the mathematics needed to work with the logistic equation or some of its more complex elaborations (Gotelli 2001), or with a dynamic model based on differential equations [note the relative inattention in demography to the Lotka-Volterra predator-prey and similar multi-population models]. It would be interesting to look more closely at the precise way the logistic has been treated since its application to humans early in the twentieth century. Was it routinely viewed as a solution to the corresponding differential equation? Or was it simply a function *ex machina*, which one fitted using some cookbook procedure? Was there concern with the mechanisms that might underlie the curve, for example, falling fertility and rising mortality (see Wilson and Bossert 1971, Ch. 3)? Or, was it just a ‘law’ that seemed to apply, and to provide a basis for prediction without an understanding of process or of mechanisms?

⁶This characteristic of the CCP model was well suited to an era in which calculation was done with mechanical calculators, which could only add, subtract, multiply, and, awkwardly, divide.

In their influential paper on the logistic model, Pearl and Reed (1920), clearly thought they had discovered the true law of human population growth. The word law appears a dozen times in their paper; at one point, they suggest that their fitted curve captures the ‘true law of population growth’ (p. 84). Their attention to process and behavior is limited – a brief reference to Malthus on checks from the means of subsistence, and a discussion of humans’ ability to transcend environmental limits and raise the maximum sustainable population, suggesting a different logistic curve for different demographic eras. Emphasis is on fitting a mathematical function, with its evaluation based on empirical data, with little attention to underlying mechanisms.⁷ Current texts and manuals in demography generally introduce the logistic simply as an alternative forecasting tool, often seen as outmoded, rather than as a theoretical model of population dynamics.

The apparent simplicity of the CCP model can also be contrasted with contemporary microsimulation methods. Many non-scientists and not a few social scientists view these procedures with some suspicion, feeling that the results are somehow ‘made up’ – in contrast with the ‘solid’ outcomes of a CCP. In fact, both types of procedures make up their outcomes, in the sense that what comes out depends strictly on the assumptions of what goes in. The key difference is that the microsimulation models make the sensible assumption that the inputs involve some stochastic elements. The two approaches do not differ in their fundamental epistemological character. But the CCP approach is more familiar, and is easier in the sense that one does not need even a basic understanding of micro-simulation. Yet one remains accepted, the other held at arm’s length.⁸

10.5 Demographers and Mathematics

The fact that the CCP model requires only basic arithmetic may help explain its popularity with demographers. I know of no systematic data on the point but I would hazard the guess that the average practicing demographer in twentieth century has had relatively weak mathematical background – relative to what we have been given credit for, relative to what might have been useful, and relative to the ordinary training in engineering and the natural sciences. From de Gans’ accounts of the disagreements between government and mathematical statisticians, I would gather the same could be said of many population scientists from

⁷Dorn (1950) gives an interesting quote from Pritchett, who did U.S. population forecasts around 1900 by fitting a third degree polynomial, confidently projecting population for ten centuries into the future: ‘...it does not in the least diminish the value of such a mathematical formula, for the purpose of prediction, that it is based on no knowledge of the real causes of the phenomena which it connects together’ (page 317).

⁸These remarks are less accurate than when first written, given the increasing use of probabilistic population projections. For an early description, see Lee (1998).

other backgrounds. Demographic analysis and projections typically involved extensive analysis of data and much quantification, but not much mathematics.

The validity of this point will obviously differ by time and place. My impressions relate mainly to North America and the international demographic community, and, disproportionately to English-language literature. The case may well be different in other areas – for example, in France, where demography is studied as a separate discipline, often in an engineering context, or in Italy, where it has close ties to mathematics and statistics. But I think the situation I describe has been widespread enough to influence the international practice of demography, including the codification of that practice by international agencies. de Gans mentions the point several times, notably with reference to the Dutch statistician Van Zanten, who was neither a mathematician nor a statistician by training, having studied law (1999, 36–37).

Systematic research on the point is needed, but consider the following:

1. Standard compendia on demography or demographic techniques (for example, Shryock and Siegel 1973; UN Determinants and Consequences 1973) contain little mathematics beyond basic algebra. Shryock and Siegel have only a short section on the use of matrix methods in demography. The sections on stable population theory contain the key integral equations and the ordinary approximations. But for the rest, one can follow the book without any knowledge of calculus, differential equations, linear algebra, or probability theory.
2. The mathematics required for entry into or completion of advanced degree programs in demography frequently has not been very advanced. In my experience at Princeton in the late 1950s, there were no special mathematical requirements for admission to the demography program as a Ph.D. student in sociology. And, one was not required to learn more mathematics to qualify for the degree.⁹ I believe the situation was and is similar at many North American university centers for graduate training in demography. The average demography Ph.D. knows less mathematics than the average upper-class undergraduate in engineering, physics, chemistry, and, increasingly, biology and other life sciences.
3. Since demography has not routinely trained demographers in mathematics, it has relied heavily for its development on persons trained outside the discipline – biology and mathematics (Lotka, Cohen), engineering (Henry, Bongaarts, Willekens, Rogers), physics and economics (Coale), mathematics and statistics (Keyfitz, Wachter) – to give a few examples that come readily to mind. The result has been a large intellectual gap between the average demographer and these specialists, whose work often has been viewed as esoteric by non-mathematical demographers.
4. What was viewed as high-level mathematical work in demography has often struck outsiders as less so. Coale used to say that much of early twentieth century

⁹The admission requirements and expectations after admission were more stringent for economics. Also, the lack of requirements for further study after admission must be seen in the context of the informality of the Ph.D. program, with no formal course credit requirements.

mathematical demography (notably Lotka's work) could have been done in a few years by a first-rate applied mathematician. When he sent his student, the late Alvaro Lopez, to show his work to Baumol (a mathematical economist) and to Feller (a statistician), neither reacted with great enthusiasm. What seemed like mathematical breakthroughs in demography struck them as routine.

Roger Revell, the oceanographer, soon after being appointed head of the new Harvard population center some years ago, commented undiplomatically that he couldn't see anything in technical demography that a physical scientist couldn't master in a few months. His remark was not well-received by establishment demographers, although it contained a kernel of truth.

Had the average demographer known more mathematics, it seems likely that less time would have been spent on small refinements of the standard CCP algorithm, and more on the exploration of other approaches. Had a working knowledge of differential equations been routine demographic equipment, for example, more dynamic approaches might have been pursued.¹⁰ There might have been a deeper investigation of the logistic model, and of a whole family of differential equations to which it belongs (including some versions of the demographic transition model), with more attention to underlying behavioral mechanisms. Population dynamics might have been viewed earlier in terms of compartment models or dynamical systems, perhaps with less attention to 5-year age detail. This, coupled with a widespread working knowledge of matrix algebra, might have led to an earlier discovery of multistate demography. In fact, the CCP algorithm has close links with differential or difference equations, but given the stylized use of the CCP, these links often go unrecognized.

It is hard, of course, to know what might have been. I do not know, for example, the state of the art in differential equations in the 1920s and 1930s, although much of the basic theory dates to the eighteenth century. And mathematical ability does not always translate into good insight into demographic or behavioral dynamics. I am puzzled by De Gans' account of 't Hooft, identified as an engineer. How could someone presumably familiar with basic concepts of function, first derivative and second derivative [as in position, velocity, acceleration] have confused the demographic implications of *declining* versus *low* mortality, as seems to have happened in his use of the 'conveyor-belt' metaphor?¹¹ As Cohen rightly comments, in his discussion of the systems dynamics modeling school of population forecasting

¹⁰Abbott (1988) argues that in sociology Coleman's differential equations approach lost out to Blalock's multiple regression approach, and attributes this to the 'commodification' of regression in statistical packages such as SPSS, BMDP and SAS. It also is relevant that, even with the solution of differential equations now similarly 'commodified' in programs like Mathcad, Maple, and Mathematica, the application of differential equations requires a higher level of mathematical sophistication than does the application of multiple regression.

¹¹This case particularly interests me because a similar misunderstanding, using a different metaphor [a river dam] recurred in the work of A. Zimmerman (1961), a Catholic theologian. He also argued that rapid population growth would cease naturally, when mortality stopped *declining*, even though fertility rates were to remain high.

(e.g., *The Limits to Growth*), solving equations numerically is now relatively easy. The hard part in science is finding equations that represent empirical reality well enough for some analytic or practical purpose. What would have been the result if the average demographer had had enough mathematical sophistication to look for those equations in day-to-day work, instead of leaving the job to a small group of mathematical demographers, and instead of assuming that, as Abbott and Keyfitz put it, we live in a linear world adequately represented by the general linear model?

10.6 Some Further Questions

In the periods covered by de Gans' monograph, why was there a felt need to choose among population forecasting techniques, and to elevate one to a position of dominance, to canonize it as the 'standard' technique? Why was population forecasting not seen as a generic problem, serving many different scientific and practical needs, such that a broad repertoire of tools was needed rather than just one?

Why did the CCP model become and remain that one technique, despite its many and well-publicized predictive failures, and relatively early criticisms of the continuity assumptions underlying the technique?

Why was there not more emphasis on synthesis and cross-fertilization of technique? Had the logistic model been pursued in depth, it would have led inevitably to questions of mechanism, to the causal dynamics underlying fertility decline or mortality increase (or levelling off) in the face of growing size and density – the same questions that underlie assumptions about future inputs to CCP forecasts.¹² It might have led to greater intellectual connections between human demography and population biology, with earlier appreciation of species similarities and differences, and with greater familiarity with a different but powerful tradition of population mathematics. How many demographers even today are familiar with the Allee effect (Gotelli 2001), whereby for some species an initial increase in population density allows it better to cope, resulting in higher fertility and lower mortality, at least for some period? This is but one modification of the basic logistic model, with plausible applications to human populations. But we continue to think in terms of the stereotypical logistic, involving fruit flies and rats, and often assume it has little relevance to humans.

Granted the importance of internationally comparable data, and the inevitability of conventions (often embodying elements of arbitrariness) in science, why has demography shown a certain narrowness and rigidity in its conventions, and resistance to new or different approaches?

¹²Work with standard projections led Whelpton to undertake social surveys of fertility in order to improve assumptions about fertility. But behavioral dynamics continued to be viewed as exogenous to the projection model, which itself remained basically unchanged.

de Gans gives many illustrations of these problems for the past, showing how disciplinary habits pointed in one direction to the exclusion of others, or how personal proprietary interests led to competition among different techniques rather than to synthesis and parallel analysis.

For the post-World War II period, I would again emphasize the limited mathematical sophistication of many demographers. One result has been the development of demographic techniques as a set of distinct procedures applied to different realms of demographic behavior, rather than specific applications of more general concepts. Thus, calculation of a life expectancy, of Hajnal's singulate mean age at marriage, and of the total fertility rate often are presented as three separate procedures, whereas mathematically they all involve the same basic concepts – the area under a curve, or an integral or finite approximation of an integral. Similarly, demographic texts present a vast array of different summary measures, most of which can be viewed as weighted sums or averages, or as vector dot products. But opportunities for this kind of generalization often are overlooked.¹³

Hakkert (1992) has noted demography's relative failure to take advantage of modern statistical and mathematical developments, and its tendency until now to use the computer to implement what he terms 'paper and pencil algorithms.' This relative isolation from mainstream statistics and mathematics has been combined with what I have come to think of as theoretical and methodological nonchalance, that is, a tendency to focus on data and on the elaboration of technique, while paying less attention to the overall structure of the scientific enterprise, including such questions as the logic of science and explanation, and the central role of theory in any discipline.¹⁴

One might speak of a bureaucratization of demography, with establishment of a canon of 'correct' techniques, some partly arbitrary but valued for their own sake as well as their service of some larger end. Failure to use these specific techniques becomes the basis for a judgement of non-competence.

As an example, the systems dynamics school at MIT [starting with *Dynamo* and spreading to other software such as *Stella*, *Berkeley Madonna*, and *Vensim*] developed a perfectly usable algorithm for projecting population that is largely ignored by demographers. But the language is 'strange' – the word *rate*, for example, is used in the calculus sense of change per unit of time rather than in the demographic sense of events/exposure. And age categories are not survived to the next highest age, but stand still as it were, with people coming in from the lower category (often called 'aging in') and leaving for the higher category ('aging out'),

¹³The search for and presentation of general concepts underlying specific techniques has been more common in the French school of demography than in the North American or English-language school.

¹⁴Demography is not alone in this respect. In a recent paper on 'modern human origins,' the author comments: 'The disciplines that contribute to the field (archaeology, human paleontology, and molecular biology) tend to be discovery-driven and focused on methodology. Following a strictly empirical approach ('the facts speak for themselves'), they often have little concern for the logic of inference underlying knowledge claims' (Clark 1999, p. 2020).

the proportions determined by the width of the age group (for example, one-fifth of a 5-year age group are assumed to enter the next age group each calendar year). Demographic rates of birth and death are termed ‘fractional rates,’ with the fractional death rate commonly defined as the reciprocal of life expectancy (which is strictly correct only in the stationary model).

The procedure strikes the average demographer as incorrect, and is likely to be dismissed. But the procedure works: with a few minor modifications, it can yield results that are substantially the same as those from a standard CPP projection using the same inputs. At the same time, it casts population dynamics in a difference equations context, with links to concepts of dynamical systems, using software designed to incorporate feedbacks. The model lends itself to expansion, with the core demographic variables linked to broader environmental, economic, social or cultural variables, as both cause and effect.

The general dismissal of systems dynamics by empirically oriented social scientists, including demographers, deserves further study. Granted a certain naiveté in some early work in this genre (see Berlinski 1976), it included sound elements, including emphasis on dynamics, nonlinearity, and feedback, all ideas that have gained currency, often without credit to early systems theorists.¹⁵

On a more concrete level, it is interesting to witness such contemporary phenomena as the worldwide depletion of fish stocks in light of analyses and forecasts contained in *The Limits to Growth* (Meadows *et al.* 1972), one of the best known and most maligned of systems dynamics studies. As scientific analysis it certainly had its flaws [which could have been dealt with in replications], but it seems to have been right about some important issues.¹⁶

In his chapter on population projections, Cohen comments, with perhaps unintended force, that ‘demographic projection techniques omit major factors that influence population change’ (p. 134), which is a rather heavy indictment of common practice. But he is not willing to opt for a systems approach: ‘Predictions based on systems models are too recent to evaluate in terms of their success, but the 20 years of experience with the World3 model gives grounds for serious doubt’ (1995, 134). If population projection is put in the broader context suggested above and seen as having many uses in addition to prediction, this judgement seems too harsh. It also seems to overlook the inherent capabilities of the approach – which is nothing more and nothing less than the application of systems of differential equations to specific issues – based on early shortcomings.

The tendency to fall back on the standard CPP approach, essentially unchanged, even when its limitations are recognized – as in Cohen’s discussion – is all the more interesting given the fact that predictive failures of the technique have been well publicized, and criticisms more or less continuous from the very beginning. As

¹⁵In his popularizing book on complexity and chaos, for example, Waldrop (1992) does not recognize the anticipation by systems dynamics theorists of many of the ideas he reviews. The word system does not appear in the index.

¹⁶For a recent, positive evaluation, see Bardi (2011).

early as 1938, just as the CCP approach was achieving its dominant position, Truesdell (1938) commented: 'There still remains a tendency to base forecasts of the future on past rates of increase, though where these rates of increase have been high, the very absurdity of the resulting forecast has brought with it some degree of caution....' (p. 377). He speaks of the 'falsity of the assumption of continued movement in the same direction, even let alone at the same velocity...' (p. 378), and concludes:

The way out of the difficulty seems to be, therefore, to devote more study to the underlying factors which tend to divert population ...from one area to another, and thus to speed up or retard the velocity of change in the elements for which the forecast is required.... [I]t would seem that large-scale, coordinated study would have more promise of success. (p. 379)

Barlowe (1952), commenting on one of Notestein's early statements of transition theory, notes that

Our demographers have made numerous predictions as to population trends during the past few decades and a high proportion of these predictions have been wrong. Like the economists and agricultural economists, they are discovering that it is not safe to base future predictions on the simple continuation of present or past trends. (p. 54)

Ascher (1978), assessing population forecasting from the broader perspective of social science forecasting of all types, gives the following summary view:

Thus, even though the modern methods are more sophisticated in their disaggregation of population growth, the forecaster still faces the dilemma whether current trends represent 'noise' or significant trends. Consequently, the real progress in population forecasting will come not in the further elaboration of technique, which is even now able to accurately and consistently trace out the implications of given fertility and mortality assumptions. It will come via studies of the social, economic, and technological determinants of fertility and mortality. (p. 57)

In the 40 years since Ascher wrote, there have been many studies of the determinants of fertility and mortality. But the results of these studies have not been systematically incorporated into the CCP projection model. They may inform judgements about future levels, but for the most part are still exogenous to the model.

Perhaps the underlying problem has been a failure among demographers and government statisticians to recognize that, when all is said and done, techniques are just tools. Assuming no blatant errors, no one measure or model is inherently better than another, despite much evaluative nomenclature – 'crude' birth rates, the 'true' rate of natural increase, etc. A tool is judged good or bad primarily by reference to the purpose for which it is used. The perfect hammer is no good for driving screws. The 'true' rate of natural increase may be and often is completely false as a description of current natural increase.

de Gans comments with respect to Rooy's 1921 forecast: 'The method is simple but satisfactory, given the task Rooy had set for himself. It is an example of everyday forecasting practice' (p. 128). One can ask why this pragmatic attitude did not become more common in the art and practice of population forecasting. A little later, de Gans continues: 'The incentives for innovation came not from the

needs of planning and decision making but from substantial social and scientific interest in the population issues' (p. 130). That which motivated interest – including ideology – also influenced choice of models.

The more pragmatic approach has re-surfaced recently in the new sub-discipline of applied demography. It leads to views somewhat at odds with traditional demographic practice. It leads Swanson and Tayman (1995), for example, to the idea that in some contexts, given time and cost constraints, the best or most practical population forecast may be a 'no cost' forecast, namely, the assumption that population size 3 years from now will be approximately the same as population size today. More generally, Swanson *et al.* (1996) have argued that the prime requirement of applied demographic analysis is that it support sound decision making, including decision making that is timely and within cost constraints. Whether the analysis is 'correct' and whether a prediction comes true are, strictly speaking, considerations of secondary importance. The best scientific analysis is not useful if it comes a year too late or requires resources that are not at hand.

Such an approach would ultimately lead to the heretical view that some good demographic analysis might be qualitative rather than quantitative. Puccia and Levins (1985) have argued that in intervening in complex natural systems, sometimes the most that one can know is that an intervention will push the system in the desired direction. They are speaking in the context of biological ecology, but their comment would seem to apply with even greater force to intervention in human systems, including demographic systems. The idea would be familiar to students of differential equations, who often value qualitative solutions, but foreign to many if not most demographers.

10.7 Conclusion

The fundamental merit of the CCP model is that it embodies sound theory of population dynamics – it is a good theoretical model. The drawbacks to the model relate to the way it was perceived and used, as an exclusively valid approach to population forecasting, often applied and interpreted in a mechanical way. The state of population forecasting in mid-to-late-twentieth century might well have been better had the CCP approach be allowed to take its proper place as one among a variety of approaches to future-oriented analyses of population dynamics. A more nuanced view of population forecasting could have resulted from the use of a well-rounded collection of forecasting tools instead of the elevation of one tool to canonical status. Recent work referred to in the opening paragraph suggests that demography has turned a corner in this regard.

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