PSC Discussion Papers Series

Volume 15 | Issue 2 Article 1

1-29-2001

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ISSN 1183-7284

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Discussion Paper no. 01-2

January 2001

On the web in PDF format: http://www.ssc.uwo.ca/sociology/popstudies/dp/dp01-2.pdf

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Teaching the Fundamentals of Demography:
A Models-Based Approach to Family and Fertility[1]

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[Draft, 29 January 2001]

Introduction

This paper sketches some guidelines for teaching the fundamentals of demography, and gives several illustrations of their application to the demography of fertility. The principles are based on: a] forty years of experience in teaching demography; b] some practices exemplified in a leading introductory physics text; and c] recent work in the philosophy of science, notably by two representatives of the so-called *semantic* school, Ronald Giere [1988, 1999] and Nancy Cartwright [1983, 1999].

The focus is on demography viewed as a science, a body of valid scientific knowledge, and on providing students of all kinds with an understanding of and ability to use this knowledge for a variety of purposes. From this perspective, the collection of demographic data by means of censuses, registers, and sample surveys, although clearly important, is seen as an ancillary activity, not part of the unique core of demographic knowledge and more a matter of applied general statistics. It is what we know about how populations work that makes demography unique.

Much of our best knowledge of how populations work is to be found in the sub-area of formal demography, often labelled with the misleading term *techniques.* The argument here is that much of formal demography, while technical in some respects, can also be viewed as substantive [theoretical] knowledge. By the same token, in a *model-based* view of science [this term is from Giere [1999], who prefers it to the term *semantic*], behavioural demography can be seen to contain, among other things, formal models whose structure is not fundamentally different from that of formal demographic models. The distinctions between technical and substantive demography, and between formal and behavioural demography are blurred. In the model-based view of science, all models or theories are formal. Since this is a highly unconventional view of demography [but see Keyfitz, 1975], it will be necessary to present it at some length.

The principles for demographic teaching are meant to apply to almost any context. Fundamental principles of a science do not change depending on who is learning them. There will be differences in depth and detail, but not in the core knowledge.

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[1] This paper has been prepared for the Seminar on Demographic Training in the Third Millennium, Rabat, Morocco, 15-18 May 2001, organised by the IUSSP Working Group on the Teaching of Demography. The research on which it is based has been supported by a grant from the Social Sciences and Humanities Research Council of Canada.

I do not know whether or to what extent contemporary practice in the teaching of demography exemplifies these principles or the view of science on which they are based. My impression is that demographic instruction in North America does not closely correspond, and could be greatly improved. Teaching in Italy or in the French school probably comes closer to what I view as ideal.[2]

Pedagogical Approaches in a Popular Physics Text

The text is *Fundamentals of Physics* by Halliday, Resnick, and Walker [1997]. Now in its 5th edition , the work is available in a number of different formats, the largest, the so-called 'extended' edition running to forty-five chapters. The version considered here contains thirty-eight chapters, covering approximately one thousand pages. The choice of text is not crucial; other physics texts, or perhaps texts from other disciplines, would have served as well.

I expect the general pedagogical quality of physics texts to be high, partly because it is such a well-developed science, and partly because it has been so widely taught for so long. The modern text is the result of a strong evolutionary process. Economics texts might also be useful in this regard. In demography, as we well know, the number of students taught and the level at which they are taught [seldom in first year of university] are such that textbooks are not economically attractive to publishers, and there have been correspondingly few.

This approach assumes that physics, properly interpreted, can serve as a valid model of good science for demography. Not all would accept this assumption.

Some noteworthy features of the above text include the following:

1] Emphasis on fundamental principles, including classical mechanics [Newtonian] and simple abstract models. Despite a popular impression to the contrary, physicists do not reject the older ideas as outmoded by relativity and quantum theory. The unreal models of classical mechanics [straight line motion, no friction or air-resistance, constant acceleration, etc.] are presented as valid knowledge when applied to appropriate parts of the real world.

2] Emphasis on developing the student's ability to reason; an active approach to the subject matter. '…[W]e have enhanced the applications that help students forge a bridge between concepts and reasoning. We not only *tell* students how physics works, we *show* them, and we give them the opportunity to show us what they have learned by testing their understanding of the concepts and applying them to real-world scenarios' [p.vii]. The aim is '…to establish a connections between conceptual theories and applications,' and to 'force a bridge between concepts and reasoning and to marry theory with practice' [p.vii]. To this end, the text contains 1,000 'checkpoints' and questions, and approximately 3,400 exercises. The checkpoint questions '…require decision making and reasoning on the part of the student;

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2 Book titles over the years suggest an underlying difference in attitude and approach. Lotka, writing in French, included in the title of his masterwork the phrase *théorie analytique*. Pressat's well-known text is called *Analyse Démographique*. . English-language works on 'formal' demography characteristically use the words *techniques* or *methods*. The latter set of words connotes an instrumental approach, the former, notions of substantive insight.

they ask the student to organize the physics concepts rather than just plug numbers into equations' [p.viii]. One is reminded of the adage: 'I hear and I forget; I see and I remember; I do and I understand.' [3]

3] Frequent use of illustrations. The authors write: 'Because the illustrations in a physics textbook are so important to an understanding of the concepts, we have altered nearly 30 percent of the illustrations to improve their clarity' [p.viii]. The number of illustrations is large, both in expository text and in problems and exercises. Chapter 2, for example, on straight-line motion, contains 31 illustrations in 25 pages, more than one per page. A few are photographs and a few are graphs of functions, but many are visual representations of objects or processes. Compare this with the infrequent use of visual representation and diagrams in demography, other than those used to graph data.

4] Relatively brief expository text. In many chapters, the expository text occupies only a fraction of the overall space. In the chapter on motion mentioned above, problems and exercises occupy nine of the 25 pages; in the remaining 16 or so, the basic text occupies at most 2/3 of the space, with the rest devoted to checkpoints, sample problems, illustrations, problem-solving suggestions, etc.

One way to summarise the above is that in each chapter *a few basic concepts and principles* are clearly stated and then *applied* to a wide variety of subject matters. In a sense, the amount of subject matter introduced is small. Emphasis is on the power of its application. By contrast, many 'population texts' [notably in North America] cover an enormous range of topics but in less depth and with less rigour.

A Model-Based View of Science

The logical positivist view of science has dominated social science, including demography, in the latter half of the 20th century. According to this view, theory – a propositional summary of what is known in a field – must be based on valid empirical generalisations or laws. Explanation, in this perspective, consists of subsuming some fact under a broader general proposition, which in turn is subsumed under a still broader generalisation, etc. – the so-called 'covering law' approach to explanation. Laws are subject to empirical test, to be 'proven,' or, in keeping with the widespread Popperian view, to survive efforts at falsification.

Contemporary philosophy of science has increasingly challenged this view, arguing that the classic logical positivist view of Nagel [1961] or of Hempel [1965] is neither an accurate description of what scientists actually do nor a good guide to what they should do for their work to be fruitful. [4] In this newer view, scientific laws are seldom if ever true representations of reality, but at best idealisations of certain features of an indefinitely complex real world. Nor are they so much 'discovered' in nature as constructed by the human mind. Cartwright [1983, 1999] speaks of *nomological machines*: models created by the scientist generate laws rather than vice-versa.

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3 This quote is from the first edition of *An Introduction to Computer Simulation Methods* by Harvey Gould and Jan Tobochnik. I no longer have the exact reference, and it is not repeated in the second edition [1996].

4 For a fascinating adumbration of this approach by a political scientist, see Meehan [1968].

Giere [1999] notes that most scientific laws are not universal, and that they are in fact not even true: '…understood as general claims about the world, most purported laws of nature are in fact false. So we need a portrait of science that captures our everyday understanding of success without invoking laws of nature understood as true, universal generalizations' [p.24]. The reason is that any law of nature contains '…only a few physical quantities, whereas nature contains many quantities which often interact one with another, and there are few if any isolated systems. So there cannot be many systems in the real world that exactly satisfy any purported law of nature' [p.24].

For Giere, the primary representational device in science is not the law but the *model* , of which there are three main types: physical models; visual models; and theoretical models. Models are inherently abstract constructions that attempt to represent only certain features of the real world. They are true only in the sense that definitions are true. The question of whether they are empirically true is irrelevant, since they cannot be. The relevant question is whether they correspond to some part of the real world in a] some respects b] to a sufficient degree of accuracy for c] certain well-defined purposes. Giere gives the example of the model for the earth-moon system, which is adequate to describe and account for the moon's orbit and perhaps for putting a rocket on the moon, but is inadequate to describe the Venus-earth system, and says nothing about whether, as the nursery rhymes would have it, the moon is made of cheese. The prototype of scientific knowledge is not the empirical law, but a model plus a list of real-world systems to which it applies.

A model explains some real-world phenomenon if a] the model is appropriate to the real-world system in the three respects noted above, and b] if the model logically implies the phenomenon, in other words, if the phenomenon follows logically from the model as specified to fit a particular part of the real world. It would never occur to most physical scientists to add the second condition. But in social science, including demography, we are so used to loose inference that its explicit statement is necessary.[5]

Note that in this account of science, all models are *formally* true [assuming, of course, no logical errors or internal contradictions], that is, true by definition. The empirical question then becomes one not of empirical truth or validity, but whether a valid model applies to a particular empirical case.

Of course some models are more widely applicable than others, and, other things equal, science will prefer the model with the widest applicability. In demography, for example, the fundamental demographic equation is true by definition and applicable to every well-defined real population [neglecting error in data]. The exponential growth formula is true by definition, and, with respect to calculation of the average annual growth rate over a period is also applicable to every real-world population. With respect to describing a population's growth trajectory, however, the exponential growth formula applies more or less to some populations, but is not at all applicable to others.

5 The notion of explanation as logical inference from a model is central to Meehan's *Explanation in Social Science* [1968].

A behavioural model such as the theory of demographic transition can be stated in such a way that it is formally true. Its applicability to the real-world has been a matter of debate for over fifty years. But it is worth noting, in terms of Giere's criteria of applicability, that it correctly represents a large number of actual cases of mortality/fertility decline, at least in qualitative terms.[6]

In my reading of Giere's and Cartwright's accounts of science, they come close to the what has long been the standard approach in the literature on mathematical modelling, and more recently of computer modelling. A model is an abstract construct that may or may not be useful for a certain purpose. In science, that purpose often will be explanation or prediction as opposed to practice. And in some schools of computer modelling, the emphasis is on less abstract models, trying to capture more of the complexity of the real world. But the central ideas are the same.

The model-based approach to science described above prefers not to make a sharp distinction between a model and a theory. Some authors distinguish the two on a general/specific axis; but then differences are in degree only not in kind. Giere speaks of 'theoretical models,' and sometimes describes a 'theory' as a collection of such models.

Note that this position does not agree with the view that science is totally a social construction. A good model is good precisely because it captures some important aspects of the real world. In Giere's words, there is 'realism without truth.'

Demographers have seldom written on general scientific methodology. An interesting exception is a 1975 paper by Keyfitz, which comes close to the model-based view of science in some important respects. In answer to the title question 'How do we know the facts of demography?', Keyfitz comments 'Many readers will be surprised to learn that in a science thought of as empirical, often criticized for its lack of theory, the most important relations cannot be established by direct observation, which tends to provide enigmatic and inconsistent reports' [p.267].

To illustrate his point, he first looks at the issues of the interrelations among growth and proportion of elderly, and of the relative impact of fertility and mortality on age structure, both of which are best answered using populations models. In a section entitled 'No model, no understanding,' he notes that statistical observations of differential incidence of breast cancer remain largely unexplained, and comments 'Here is just one more question that is unlikely to be solved by any volume of statistics by themselves' [p.276].

He then considers the issue of the effect of marriage delay on completed fertility, that of promotion in organisations, and the effects of development on population growth – all questions involving behavioural models on which there is less consensus than on the stable model used to solve the problems on age structure.

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[6] An interesting point about transition theory is that there has been a tendency to dismiss it as not fitting all cases or as not providing details of timing, pace, etc. There seems to have been relatively little effort to accept it as a valid model and work towards a more precise specification by defining functional forms for fertility or mortality decline as functions of 'development,' and parameters representing size of lags, slopes, etc.

The important point is that Keyfitz does not make a sharp distinction between formal models [e.g., the stable model] and behavioural models [e.g., transition theory]. The logical procedures involved in the statement and use of the two sorts of models are seen to be much the same. The spirit is very much that of Giere, as described above. In a final section entitled 'The psychology of research,' he comments

> 'The model is much more than a mnemonic device, however; it is a machine with causal linkages. Insofar as it reflects the real world, it suggests how levers can be moved to alter direction in accord with policy requirements. The question is always how closely this constructed machine resembles the one operated by nature. As the investigator concentrates on its degree of realism, he more and more persuades himself that his model is a theory of how the world operates' [p.285].

Reference to a model as a 'machine' reminds one of Cartwright's 'nomological machine'; the phrase 'degree of realism' resonates with Giere. Finally, note the equation of model and theory in the closing sentence of the quoted passage.

Pedagogical Principles for Demography

In light of the above, here are some guidelines for the teaching of fundamental demography.

1] Teach the basic principles of formal demography at the very beginning. Do not relegate them to an appendix or to a separate course on 'demographic techniques.' They represent a solid core on which behavioural demography must build.

2] Focus on general principles that apply to a wide variety of measures and models. Elaborate on the general notion of balancing equations [including the basic demographic equation as a special case], on the notion of events as a product of rates and population structure or exposure, and on the notion of exposure itself. Since these are absolutely central notions, they require thorough treatment, even if students find it somewhat abstract [But see point 7 below; students will feel differently about abstract principles when they see that they can use them to do something]. Recognise that most demographic summary measures are weighted sums or averages. Give the student the tools to recognise later that the life expectancy at birth and Hajnal's singulate mean age at first marriage are of essentially the same form; they are not two totally different concepts. The French school of demography scores higher on this criterion than does North America.

3] Recognise that much of formal demography ['techniques'] is concerned with substantive models of how population processes work. Many of the tools of formal demography are measurement tools; but they are not just that.

4] Honour the validity of some of older, simpler models, many of which have tended to be neglected because 'they don't fit all the data.' If physicists treated classical mechanics the way demography treats some of its older models, they would throw away the first half of the standard introductory text. Examples of good models that often are considered outmoded included gravity and intervening-opportunities models in migration, demographic transition theory, and microeconomic models of fertility [especially with the newfound emphasis on culture, diffusion, and social interaction in fertility theory].

5] Treat the distinction between formal and behavioural demography as one of degree not of kind.

6] Increase the use of visual devices to communicate demographic ideas. That is, do not limit visual representation to the representation of data, as in age pyramids, age-profiles of behaviour, and time series. The common diagram of a typical demographic transition, for example, should be taken much more seriously than it often is, and certainly not dismissed as 'only a schematic diagram.'

7] After teaching basic analytic tools, set a large number of problems or exercises which they can be used to solve. In other words, emphasise active and critical thinking on the part of the student, not just passive learning. It is my impression that in many techniques courses and texts, students are required to learn the life-table concept and calculate a life-table, with no further analytic challenges. This may explain why many beginning students find the whole procedure anti-climactic: 'Why all this fuss just to arrive at an age-standardised measure of current mortality, e_0?' And in truth, some kind of sum or average of age-specific death rates might serve that purpose as well. Given the computer, calculating a life table is now a trivial matter. Once the student has done it, emphasis should be on experimentation and problem-solving using the life table as a tool.[7]

8] Some of the problems and exercises should try to lead students to face the limitations of the analytic tools they have just learned. There should be problems that suggest the need to add other variables to the models or to relax one or more of the simplifying assumptions.

Some Concrete Examples of Abstract Fertility Models

How might these guidelines be implemented in introducing students to the demographic study of fertility?

As a first example, let's consider the *total fertility rate*. This concept typically is introduced as a summary measure of age-specific fertility rates, most commonly period rates, calculated as the unweighted sum [or evenly weighted, that is, multiplied by 5] of the rates. The student may or may not have been introduced to the concept of *exposure* at this point. A synthetic cohort interpretation will often used to introduce the statistical calculation, or added afterwards to give more meaning to the result. Depending on level and context of teaching, it may be noted that the same procedure can be applied to a set of age-specific rates for a real cohort, observed over time.

This approach does not begin at the beginning. The most fundamental concept is that of a cohort of women surviving over their lifetimes and producing children. Even the distinction between real and synthetic cohort is less fundamental. And treatment of fertility behaviour of a real cohort immediately raises issues of data availability, incomplete experience, differential survival, etc. The most fundamental concept is that of any cohort.

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[7] The best examples of this approach that I am aware of in English-language literature are in Hinde [1998] and Pollard, Yasuf, and Pollard [1990].

An alternative approach would start with an abstract model of the lifetime fertility behaviour of a cohort, and, in the manner of physics, spend a chapter or at least a long section setting forth the basic concepts. The concepts would be represented visually to the extent possible, and used to solve a number of problems or carry out a number of 'experiments.' Initially, the only reference to data would be to a set of age-specific rates [plausible but not necessarily real] without reference to a temporal dimension other than age.

Thus:

1] Let's look at the births of a well-defined group of women [say, 1,000 women at age 15] during their reproductive period, roughly ages 15 through 49. We assume for the sake of simplicity that none dies during this period, and that they do not lack sexual partners or other means of conceiving. These are unreal assumptions, but then so is the assumption of no air-resistance or friction in beginning classical mechanics. Later we will make them more realistic. It might be worthwhile to show a graph of the number of women alive at each age, admittedly only a horizontal line. But then so is the position / time graph in a physics text showing a stationary object [zero straight-line velocity].

2] At each age, the women bear children at a given rate – births per woman in each year of age. We start with individual years of age – 15, 16, etc. Later we'll deal with five-year age intervals. Note that for this model, the student needs only to grasp the notion of a rate as a relative number; the distinction between probability and central rate is not yet relevant since all 1,000 women survive throughout. But the student is presumed to know one of the fundamental principles of demography: events = rate[s] times structure [exposure, population at risk].

3] The calculation of births during a given year of age is now straightforward, as is the calculation of total births over the reproductive period, and the calculation of average births per woman over the reproductive period.

4] The rates can be graphed and total births over the reproductive period viewed as the area under the curve. The typical shape of the age-specific fertility curve can be noted. It would be useful at this point, even for students without much calculus, to associate total fertility with the definite integral of the fertility-age function over all ages [or over 15-49], and to contrast this with the finite sum typically used in practice. It can be noted that there is no 'law of fertility' represented by a particular mathematical function, although total fertility can be calculated by integration of an approximating function fit to an empirical data set.

5] After introducing [or assuming] the notions of weighted sum and weighted average, one can define the mean age of fertility and indicate it on the graph. The same could be done for the median age, although this measure is seldom used.

6] The basic concepts can then be modified to deal with data in five-year intervals.

7] The notion of sex-ratio at birth can be introduced, and a calculation made of the number of daughters born as opposed to total births. This can be done over all, or, age-by-age, introducing the notion that the sex ratio at birth differs slightly [but only slightly] by age or order.

At this point, the student will have learned [or reviewed] a number of primitive concepts in demography: relative rate; exposure; events as the product of rate[s] times population at risk; weighted or unweighted sums as summary measures of rates; sums as area under an age-curve of demographic rates; areas as integrals or finite sums; 'laws' of demographic behaviour and approximating functions; the sex ratio at birth; five-year versus single-year data. Note there has be no mention of period versus real cohort data, with all the complications involved.

Still, the student can do many things with the basic concepts. They can reverse the order of some or all of the rates to convince themselves that order does not matter for total fertility, but does matter for average age. They can calculate how much difference it would make to total fertility if there were no births before age 20 or after age 35 or both. This exercise could be introduced as relevant to the frequent policy aim of eliminating teen-age fertility. They can calculate incomplete fertility, e.g., up to age 30, and compare it with total fertility. These exercises can be done using both finite sums and integration, as mentioned above. They can experiment with radical changes in the sex ratio at birth, such as might accompany social fads relating to gender preferences. In short, they can use the simple tools provided to gain greater understanding of how human reproduction works or might work.

This is demography is slow-motion. An extremely simple abstract concept has been developed at length and in detail, and is then used to answer a number of substantive questions about human fertility.

Some next steps are obvious, but note they are next steps, not the first steps. The basic notions presented above can be applied to two radically different temporal contexts: the lifetime fertility experience of a real birth cohort; the cross-sectional experience in a calendar year of many different birth cohorts at different ages. Each would be treated in a separate section. Now, the basic concept developed above would be seen as leading to the ordinary total fertility rate as a measure of current fertility. But it is now placed in a proper context.

This approach – developing a general concept and then applying it to two different temporal contexts [observation plans] -- would by its explicitness help avoid the frequent confusion of cohort versus period data and measures. And it would be repeated, with appropriate changes, in dealing with mortality, marriage, divorce, migration, and other demographic behaviours.

The first example takes what is usually presented as a demographic measure or technique and treats it like a substantive model of demographic behaviour, a summary of important knowledge of population dynamics. It is a simple model, involving unreal assumptions. But it is a good starting point.

The second example is Easterlin's socio-economic model of marital fertility, a behavioural model which many consider invalid or oversimplified. It is here treated as a formally valid abstract model of fertility and fertility control. It is taken to be true by definition, valuable for giving students insight into fertility decision processes, and for clarifying important behavioural issues relating to fertility. Why does fertility remain high in some developing nations? Why is it so low in the Europe and North America? How might policy interventions raise or lower it? Can family planning help?

For these purposes the early, simple statement of the model [Easterlin, 1975] will suffice, using equations only, or, depending on the economics background of the students, some of the indifference curves found in the original article. And again, in order to develop the model and present it to students, one need not have real data for all the variables. Plausible data will do. One can admit that some of the concepts and variables are difficult or even impossible to measure [e.g., some would say this is so of the *costs of fertility control*]. But this does not prevent the student from gaining insight from learning and applying the model. One of the main barriers to theory development in demography has been the requirement of a one-to-one correspondence between theoretical ideas and successful, or even easy, measurement.

The Easterlin model can be summarised as follows:

Definitions:

F = marital fertility [the total marital fertility rate]
N = natural marital fertility, the number of births that a couple would have if they did nothing to limit births
s = the probability of surviving from birth to adulthood, defined as age 20
C_n = the number of surviving children a couple would have if they did nothing to limit births
C_d = demand for children, the number of surviving children a couple wants; the number they would have if fertility control were costless
RC = the costs of fertility control, both economic and 'psychic' costs

Propositions:

1] The level of marital fertility is a function of the extent of effective fertility control.

2] Motivation to control fertility is a function of a comparison of potential surviving children C_n and demand for children C_d. The simplest functional specification is $C_n - C_d$ but others are possible [e.g., addition of parameter, use of ratio rather than a difference, etc.].

3] The extent of effective fertility control is a function of motivation and of costs of control RC. Limitation will occur when motivation > costs. A simple functional specification would be

$$\text{fertility control} = k\,[\text{motivation} - \text{RC}] \quad \text{if motivation} - \text{RC} > 0,$$
$$\text{else, fertility control} = 0$$

that is, fertility control is proportional to the difference between motivation and costs.

4] C_n is a function of natural fertility N and the probability of surviving from birth to age 20: $C_n = N * s$.

5] C_d is function of income, prices of children and other goods, and tastes or preferences for children – taken directly from elementary microeconomics.

6] Natural fertility N is a function of coital frequency, fecundity, and fetal mortality [excluding induced abortion, which is considered a form of fertility control].

7] Fecundity is a function of many variables, notably lactation.

8] Costs of fertility control RC include money costs, time and effort, and psychic costs [guilt, annoyance, fear of side effects, etc.].

As stated above, this is a simple behavioural model, which can be written, with suitable shorthand, on half a sheet of paper. It is easily grasped by most students. A full quantitative specification is much more difficult, but again that can come later. Even this simple model provides students with a powerful tool to help them begin thinking analytically about complex real-world problems. In my undergraduate classes, after presenting the model, I typically ask students [in discussion or exams] to use it to deal with the following questions:[8] a] Why is Canadian fertility so low? [causal analysis]; b] Do you expect it to rise appreciably over the next ten to twenty years? [prediction].

Later in the course, I ask them to use the same model to deal with the policy question: If the Canadian government were to decide to try to raise fertility levels, what specific measures would you advise? [policy analysis]. This leads to some interesting dead-ends, e.g., lower motivation for fertility control by reducing natural marital fertility, or substantially increasing the costs of fertility control [this leads to a brief discussion of the infamous Rumanian case]. After considering all the possibilities, students tend to focus on the notion of raising C_d by reducing the costs of children [notably through subsidised daycare].

The important point about the exercise is not that they reach the correct answer, if there is one, but that they have had the experience of analytic thinking about important demographic problems, using as an analytic tool a logically [if not yet quantitatively] rigorous model. There is active discussion, but it is disciplined active discussion, with the discipline supplied by the model.

Towards More Complex Models

The models discussed above are abstract and simple – some would say oversimplified. But so is the introductory physics of straight-line motion or of a body falling in a vacuum under the influence of gravity. But these simple models provide an introduction to analytic thinking, as opposed to passive learning, and are the foundations of more complex models to come. A recent review of a book on migration and microevolution [Lahr, 2000] includes the following as one of the book's three major conclusions: 'The frequent violation of the

8 By this point, the notion of overall fertility as a function of marital fertility and marriage patterns would have been presented, and the Easterlin model put in this context.

assumptions underlying classic population genetic models call for the development of more complex models, for which computer simulations are the main tool' [p.2057].

Of course, more complex models will have to be developed in demography as well [Burch, 1996]. The assumption of no mortality in the model underlying the total fertility rate clearly is unrealistic, more so for some populations than others. Easterlin's assumptions, for example, of a one-time fertility decision to maximise lifetime utility, are unrealistic in many, perhaps most, contexts. But that does not mean that one should start with these more complex models in the teaching of demography. This would be justified only if the simpler, often older, models were judged to be worthless. But they are not if they are viewed from an appropriate methodological perspective.

The simple Easterlin model can serve as a starting point for greater complexity in different ways. It can be elaborated on as a microeconomic model of fertility decision making, and there is a vast economic literature doing just that. Or it can be placed in a broader context. With the assumption that mortality or desired number of children or costs of fertility control -- or any and all combinations of these, or other variables in the Easterlin model -- are inversely related to 'development,' it can provide a behavioural underpinning to a model of demographic transition.

If development leads to lower mortality, given constant fertility, the number of children surviving to adulthood [Cn] will rise, perhaps exceeding the number wanted [Cd]. By definition, this creates motivation for fertility control. Assuming Cd also declines with development, motivation will be increased even more. Unless fertility control is very costly in the broad sense defined by Easterlin, deliberate fertility control will begin and fertility will tend to decline.

Note again that this scenario is 'true' by definition – it follows inevitably from the Easterlin model and the assumptions about relationships between development and key model variables, and it is logically coherent. Cartwright might say that it is 'true' in that it correctly captures the 'nature' of aggregate human behaviour over time: we do not generally persist in accepting what we clearly do not want unless the costs of avoidance are too high. The Easterlin model can be seen as a 'nomological machine,' generating the 'law' of the classic demographic transition.

Even in its simplified form – or perhaps especially in its simplified form – the Easterlin model provides students with a tool for analytic thinking about complex behavioural issues. As students work with the model to deal with various problems and exercises, it will not take long before they begin to raise questions about timing. Does the inevitable fertility decline occur immediately, in concert with mortality decline, or is there some delay or lag? Students will have no difficulty in introducing the notion of reaction time. And, depending on the level of instruction, this notion can be introduced explicitly into the model in the form of a delay.

The empirical question, as always, is whether the model can be usefully applied to one or more observed fertility transitions, whether, in Giere's words, it fits sufficiently closely in certain respects to provide an explanation, or perhaps a prediction. There is ample evidence that it does: strong empirical associations between development, mortality, and fertility; observation of the mortality/fertility lead/lag pattern in most historical transitions; etc.

But is it the best model, in general or to explain a particular case [for example, early fertility decline in France]? Or is it the only good model? Of course not. And in due time the student will have to learn other, more complex models that emphasise culture, social interaction, wealth transfers, and other classes of variables not included or highlighted in the Easterlin model or in classic transition theory.

In short, the Easterlin model and classic transition theory are not taught as the 'truth' about fertility decision-making and long-term transitions, but as sensible models that can serve as useful tools for the analysis of some but not all problems. Given their simplicity, they are particularly appropriate for students in the early stages of learning demography. Our physics text spends the best part of one chapter dealing with the case of motion in a straight line in the case of constant acceleration. This material is simplified, and unrealistic for almost all but laboratory settings – but appropriate for students to learn to understand simple systems before moving on more complex systems.

It is not that much teaching in current demography doesn't present the full panoply of models found in the literature. But it is my impression that they are often presented in fairly broad conceptual terms and passed over quickly. Older models are often presented as outmoded and of historical interest only. My suggestion is that all sensible models be taken more seriously, presented in greater detail and rigour, and then used to deal with important real-world problems.

Concluding Comments

There is little under the sun that is brand new. Most of the ideas outlined above can be found somewhere in the literature and practice of social science and demography. Mathematical demographers will be comfortable with the application of these ideas to formal demography. Economists will respond with a 'ho-hum' to the emphasis on teaching students to think analytically using oversimplified models, as will some sociologists who remember discussions of 'abstract analytic theory.' Many social demographers will feel comfortable with the emphasis on a multiplicity of theories, with no one singled out as best.

But other ideas are apt to evoke puzzlement or resistance. One is the notion that the models of formal and behavioural demography have the same fundamental epistemological status, as abstract models of some part of the real world, true by definition. Another, closely related, is the abandonment of logical positivist notions of proving or disproving scientific laws. In this view, the 'underdetermination of theory by empirical data' is not some passing flaw in our science, but a central feature of all scientific knowledge, one we simply have to learn to live with and to help our students live with.

Some will wonder where this approach leaves our disciplinary penchant for multivariate analyses of census or survey data. This issue needs further study, and cannot be dealt with here. It is likely, however, that in the approach sketched above, descriptive studies using the general linear model may indeed play a smaller role, notably in teaching, giving way to more emphasis on theoretical thinking, often involving non-linear models. But statistics clearly is needed to test how closely a theoretical model fits some particular empirical case, which will be partly described using statistics. Historical demographers may rally against such total reliance on abstract models, preferring a more personal notion of knowledge, an ‘understanding’ of or ‘feeling for’ concrete historical cases, acquired by immersion in historical detail.

Each of these and other possible objections has its merits. And not all of them are diametrically opposed to the ideas sketched above; some are complimentary. But there are strong arguments for the suggested re-orientation of demographic teaching. The thinking of a growing number of philosophers of science points in that direction, providing an alternative to the frustrating dead-ends of logical positivism and its search for universal laws. Pointing in the same direction is the pedagogy of some of the strongest sciences, tried and proven in the teaching of multitudes of students that we demographers could only dream of. I have focussed on physics text, but other disciplines provide similar examples, notably in biology [see, for example, Gotelli, 1998].

My suggestions are made in the context of a growing concern that demography risks losing its status as a distinct scientific field unless it pulls up its scientific – specifically theoretical – socks. In many quarters, demography is seen as a purely descriptive field, the sort of descriptive work done by government statistical agencies; one often hears the terms *human bookkeeping* or *demographic accounting*. Demography is often seen as narrowly technical, concerned only with ‘data grubbing.’ Economists often find little in demography that they think cannot be subsumed under their discipline. In some sociological circles, demography is being surreptitiously replaced by the *sociology of population*, the notion being that a social gerontologist, for example, can teach demography while being innocent of the details of cohort analysis, life-table construction, or the stable population model.

My suggestions point toward a stronger demography, a discipline or sub-discipline that is unique, based on a distinctive blending of formal and behavioural models, and an unusual wealth of descriptive data. It is this discipline that we should present to our students – all of our students.

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