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A SYSTEM OF HEALTH STATISTICS
TOWARD A NEW CONCEPTUAL FRAMEWORK FOR INTEGRATING HEALTH DATA

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In this paper the author outlines a broad new conceptual approach to the organization of health statistics data for Canada. It represents the initial thinking in a longer term project directed towards the review of the basic form and content of Statistics Canada's program of health statistics. Two major concerns have given rise to the project. First is the general lack of coherence in health data, as compared for example to the System of National Accounts. Second is a widely perceived imbalance in data collection efforts that places too much weight on the resources devoted to provision of health care and not enough on the health status of the population—both in terms of distribution and temporal trends. These concerns are reviewed, and then a new conceptual framework within which these concerns could be met is suggested.

> "Her account of the voyage was considerably more interesting than the account of expenses incurred; but she was asked to account for spending so much of the voyage visiting minor satellites rather than seeking a broad overview of the entire system."
>
> Anon.

1. BACKGROUND AND CONTEXT

The purpose of this paper is to suggest a conceptual framework for a possible System of Health Statistics (SHS) for Canada. The genesis of this effort is the Research and Analysis Advisory Committee to Statistics Canada. This committee was concerned about a general lack of coherence in a number of areas of social statistics on the one hand, and the wide acceptance and coherence of economic statistics on the other, particularly as represented by the System of National Accounts (SNA).

Initial discussions revolved around the idea of creating "satellite accounts," a terminology inspired by the French national accounting experience (e.g. Pommier, 1981; Teillet, 1988). The advisory committee recommended that the health sector be considered in a first trial effort in the development of a series of satellite accounts. Health was felt to be an important as well as a challenging subject matter area.

This paper has been developed in response.[1] We begin first by suggesting that the effort should be conceived differently, as a discussion of a possible "System of Health Statistics" (SHS). The phrase "satellite account" suggests that

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[1]In fact, this is a substantially revised version of a draft working paper circulated in the Fall of 1987. That paper was generally accepted, so work has proceeded, focusing first on the health outcomes portion of the framework.

the subject matter of the account is of lesser importance than, and subordinate to, the System of National Accounts (SNA)—a view we reject. The health of the Canadian population and the associated system of health-related institutions is of sufficient importance to merit a system of statistics developed primarily for health related considerations, though it is obviously desirable that links with the SNA should be included where appropriate.

A further nuance relates to the word "account." In an economic context, accounts have the connotations of money as the unit of measure, and of double entry bookkeeping. In common parlance, however, "account" often has a much broader meaning referring to a story or travelogue wherein a careful, detailed and systematic description of a region is given. In order to avoid the problem of this ambiguity in the meaning of "account," we have chosen to refer to a System of Health Statistics rather than health accounts.

The basic objective of an SHS is to provide a systematic set of data on health matters where the data are synoptic yet comprehensive, and have some coherence or "adding up" properties. (Note that "adding up" is here taken to include multiplication and other mathematical operations, not only addition.) The various bits of health data should have more in common than mere juxtaposition and the fact that they pertain in some way to the subject matter of health.

Why bother to strive for coherence or systematic data? First, coherence or a systematic framework assures completeness; the architects of the framework have to think explicitly of the domain and scope of the system of statistics to be assembled. In turn, this allows the statistical agency to spot and assess data gaps and data collection priorities. Second, constructing a systematic data framework encourages explicit consideration of the theories that either underlie the data or the analysis for which the data will be used. Finally, as Wilk (1987) has suggested, systems of statistics like the SHS discussed here offer a major potential for statistical agencies to begin to tackle in a rigorous and effective way problems of non-sampling error. This possibility arises because the coherence that results from having a system of statistics means that constituent chunks of data from different sources must confront one another and have some consistency.

This coherence and "adding up" applies to the SNA via a combination of well-defined and consistent concepts, arithmetic identities as in the equality between income and expenditure, redundancy as in the separate data feeder systems used to estimate income and expenditure (an example of Wilk's data confrontation), and theory as in the widely accepted (but loose) connections between the rate of inflation and rates of interest, or between employment and output. Such coherence also applies to demographic data with the fundamental identity that population next year equals population this year plus births plus net in-migration minus deaths. A fundamental issue, therefore, in the development of an SHS is to define a basic set of concepts, identities, data feeder systems, and theories.[2]

It is useful to recall that in the case of the SNA, the theory preceded the major development of the accounts. Indeed the theory in this case, Keynesian macroeconomics, was developed in the wake of the Great Depression, and the

[2]As in economics, some of the underlying relationships may be stochastic and/or non-linear.

first National Accounts saw their major development during and immediately following World War II. Since the level of "crisis" in the health area today is nothing like the economic and political circumstances of the 1930s, and there are no grand theories of health, it would seem prudent to expect that the development of any SHS will proceed slowly and will require concerted effort by its proponents. Still, there is increasing general and public policy interest in such areas as expenditure control, efficacy of new treatment technologies, and the impact of aging on health care costs. As well, the managers of the various components of the health care delivery system have assembled a vast wealth of computerized administrative data. These generally untapped data represent a major potential advantage for the SHS compared to the situation at the inception of the SNA.

The idea of systematic accounts in the area of social data is certainly not new, nor is it couched exclusively in terms of satellite accounts. One strand derives from the seminal work of Sir Richard Stone with his "system of social and demographic statistics." This framework was grounded in the idea of transition matrices. The population was divided into groups by age and status, where status could include such things as being in school or the labour force or retired or in hospital. This framework clearly has a multitude of "adding up" conditions and allows both stocks (e.g. numbers of students and patients of various sorts) and flows (e.g. graduation, entering hospital) to be coherently represented. It also has the capability of linking demographic data to economic data in an integrated accounting framework, as sketched by Richard Stone (1981, p. 355) for health services.

In the late 1960s, this framework was given a great deal of attention in international statistical circles, culminating in a UN publication, *Towards a System of Social and Demographic Statistics* (1975) authored by Richard Stone. It is useful to understand why this grand statistical effort has failed to generate any following. Several reasons have been offered (based on personal conversations with Hans Adler, Tom Juster, Jean-Pierre Poullier, Richard Ruggles, and Leroy Stone). It appears that the conceptual framework was so highly refined and detailed that when asked to begin implementing it, all national statistical agencies balked because of the very high costs of establishing the required data feeder systems. Another view was that the system of accounts was too closely tied to transition matrices and the Markov model. For sophisticated users, this framework was too limiting, while in an international context it was seen as too complex. Among the lessons to be drawn from this experience is that we are well advised to develop a conceptual framework that can begin with a simple prototype that will itself be useful. However, this prototype should build upon a conceptual base that is more general than Markov transition matrices, and is sufficiently robust in structure that it can be incrementally upgraded.

A second strand in the previous work on systematic accounts of social activity can be associated with the time-use studies, for example as reported by Juster (1985) and discussed by Juster *et al.* (1981). Here, the basic focus is on individuals, and how they spend their time each day. This framework clearly "adds up" just as minutes add up to hours since the basic numeraire is the amount of time spent in various activities. While this framework has some conceptual attractions, its major weaknesses would appear to lie first in its empirical basis. There continues to be skepticism as to the reliability of the responses to household surveys of time-use. Second, it is not clear that time-use data offer any particular advantage in tying health status information to other kinds of data relevant to the health sector.

Within Statistics Canada, there has been previous work on health accounting, particularly the Sunga and Swinamer (1986) health care accounts developed on a prototype basis using Ontario data. This work is very much in the SNA and French satellite accounting style, using dollars as the basic numeraire and the SNA type of financial accounting structure. The focus is on health care rather than health, and the perspective is that of economic production. While this work has been welcomed, it has not inspired any ground swell of support.

Another strand of work, not as broad in scope as a complete system of health statistics, is the literature on the costs of illness (e.g. see Cooper and Rice, 1976, Hartunian *et al.*, 1980, and Rice *et al.*, 1985). This literature distinguishes both the direct and indirect costs of an illness—the immediate costs incurred by the health care delivery system when someone is treated, and the economic value of the lost output when a person is too sick to work or dies prematurely, as well as the non-market costs that may be imposed on family members who help care for the ill person. From our point of view, the most interesting feature of this work is that it goes beyond the SNA style institutions and dollars type of accounting by integrating individual level information on disease progression and non-market impacts. As well, the cost of illness literature clearly recognizes the need to examine the impacts of disease on individuals in a life-cycle framework.

Further emphasis for going beyond only financial accounting comes from the Owen report (1984), an evaluation of the health status program components of the Health Division of Statistics Canada. One of its central recommendations was that more attention should be paid by Statistics Canada to health outcomes, as compared to the resource consumption of the health sector. A similar perspective is evident in the terms of reference of the new National Health Information Council (1989), a committee of senior federal and provincial officials established to develop concensus and set priorities regarding health data and information systems.

Outcomes are more difficult to measure than inputs, but they represent the proverbial "bottom line" of the health sector. There is increasing recognition that information on the costs of the health system is of only limited use if such information cannot be linked to outcomes—the impacts these health care interventions have on the health of the Canadian population. Perhaps it was the exclusive focus on costs in the Sunga and Swinamer (1986) account, without any data on outcomes, that explains the general interest, but lack of enthusiasm for their work.

Examples of global indices of health outcomes are provided by Wilkins and Adams (1983) and Peron and Strohmenger (1985). These indices are based on generalizations of the concept of longevity—essentially the idea of full health equivalent life expectancy, or quality adjusted life years (QALYs). These measures assume that every person-year of life can be assigned a scalar value, say in the range from zero to one corresponding to a range in health status from dead to full of vim and vigour. Given such a weighting system, and appropriate sample surveys of the population, weighted life expectancy or "population health expectancy" (PHE) can readily be calculated.

In turn, this kind of measure, along with related measures of (hypothetical) cause-eliminated life and population health expectancy, include as special cases some of the key statistical indicators that have been suggested by the OECD (1981) for their social indicator framework, and by WHO (1981) in the context of monitoring progress toward "health for all by the year 2000." Thus, an ability to provide the foundation for computing the health expectancy of the Canadian population each year would be a very desirable part of any SHS framework.

2. Proposed Basic Premises

As the starting point in the development of an SHS, it seems most appropriate to be explicit about the basic premises. Agreement with or changes to these premises at an early stage of the developmental effort is relatively easy, and can assure that subsequent efforts are not wasted. As well, a number of the premises proposed may represent fairly substantial departures from usual practice for Statistics Canada. These premises begin with the foci of the SHS, then turn to the main objectives, and finally make explicit a number of corollary or subsidiary objectives.

The first premise is that *one major focus of the SHS should be people and their healthfulness.* In other words, health outcomes should have primary emphasis. In terms of statistics, this means that there should be an overall indicator of the average or median healthfulness of the Canadian population published each year. This could be a statistic like the "population health expectancy" (PHE) measure. PHE would then become for the SHS the analog of the CPI or GDP in the SNA. There would be a single annual statistic that is at least as comprehensible to the average Canadian as the inflation rate or the rate of economic growth (not that these concepts are actually that well understood by the public), and this single measure would give a reasonable indication of how we are doing as a nation in regard to health status.

It is recognized that this is a very ambitious objective given the profound problems in measuring health status (e.g. Brooks, 1986, and Loomes and McKenzie, 1989). Any single-valued indicator for an individual will have to be an index defined over a vector of health status attributes. In turn, each attribute will raise substantial measurement issues, and any aggregate index will embody important matters of judgement. Nevertheless, let us assert that measurement and conceptual problems of similar depth have not prevented Statistics Canada from producing a Consumer Price Index and a set of Low Income Cut-Offs (our "semi-official" poverty lines), or even GDP statistics.

In addition to this overall measure, the "CPI or GDP of Health," the measure of health outcomes or *health status should be tied to a family of outcome measures* that give various *breakdowns across the population,* for example by age, province, family composition, and income. Furthermore, within any of these groups or for the entire population, the outcome measure should be capable of disaggregation such that the *dispersion or degree of inequality* in health status across individuals can be indicated. Insofar as the summary health status measure ("health expectancy") is an index or aggregation based on a vector of more narrowly defined health attributes (e.g. physical mobility, cardiovascular disease), distributions of these individual attributes should also be available.

Given that one major focus of the SHS should be on health outcomes, *the other major focus should be on economic costs.* As in the case of measures of outcomes, these *costs should be able to be disaggregated,* for example by jurisdiction (e.g. province, municipality), type of institution (e.g. teaching hospital, pharmacy), purpose (e.g. cure, care), financing arrangement (e.g. publicly paid, publicly insured), and type of resource used (e.g. nurse, hotel, or diagnostic services). Costs should also be understood to be more general than the direct costs incurred in the health care delivery system. (We use the phrase "health care" because it is conventional; a more accurate phrase would be sickness care and health restoration.) Economic costs include indirect costs such as foregone income, and non-market transfers such as care given by family members (e.g. Cooper and Rice, 1976).

Given these two major foci for the SHS, we turn next to a set of objectives. Some of these objectives may appear trivial or self-evident; nevertheless it is still useful to attempt at this stage to be explicit and comprehensive. There are essentially three principal objectives:

- the SHS should include the *maintenance of a database*;
- the statistical data should be *coherent and consistent*;
- the database should be *associated with analytical frameworks and mechanisms.*

We turn now to an elaboration of these objectives and a discussion of their implications.

To begin, the idea of the SHS as a database immediately locates the effort in the post-computer era, unlike the original development of the SNA. This has a range of profound implications. The ultimate realization of the SHS should not be a publication containing many tables of numbers. Such publications should certainly be one manifestation of the SHS, but not its totality. Instead, the SHS should be fully realized as a *computerized database plus associated retrieval and analytical software.* As a database, the SHS should be portable (across computer architectures), well organized, flexible, well documented, and easily accessible. Subject only to the constraints of the Statistics Act and other relevant legislation, *all the data and associated software should be in the public domain.* The database should be designed with a view towards facilitating research and analysis by individuals across the country and internationally.

Of course, the SHS should be accessible to the public generally and to a wide range of groups, the large majority of whom will not own a computer. Thus, an *annual series of print publications* should be part of the SHS. These publications should contain a set of *standard tables* carefully designed to meet a broad range of general interests and to result in consistent time series. To give the SHS popular appeal, the standard tables should include the major summary indicators such as "health expectancy" and direct dollar costs.

To have coherent and consistent data requires that the data are based on *clear and uniform concepts, definitions, and categories.* Given the breadth of the major foci, the data should cover the spectrum from population health status and disease incidence through the resources and institutions involved in health restoration processes to the dollar costs. In addition, *coherence requires a set of identities* so that variables "add up" (or can be related by mathematical operations). Different series of statistics should be related by more than mere juxtaposition.

A corollary objective related to the idea of a database is that *the SHS should be built upon a strong microdata foundation.* This means that any totals or aggregates should simply be the sum of the constituent figures for all (or a statistically representative sample) of the relevant individual entities (e.g. people, hospitals, health care providers). Such an explicit microdata foundation would represent a major improvement over the SNA. It is only feasible with the use of computers. However, it is far more flexible than table or cell-based statistical accounts. As well, with the potentially infinite variety of tables that can be imagined, and the falling relative price of computing, it is more compact and more efficient to store data in a microdata framework. Finally, as will be discussed below, it is only within a microdata framework that both PHE indicators and economic costs can be sensibly connected.

Finally, the third principal objective above was that the SHS should include analytical frameworks and mechanisms. In the first instance, these are simply database retrieval and cross-tabulation software packages. But this objective has deeper implications. A major type of analysis consists of posing "what if" questions. For example what if cancer incidence were halved, or the average hospital obstetric stay was reduced by one day? *The SHS should allow derivation of the impacts of hypothetical scenarios* like these on both the health expectancy summary outcome measures and on economic costs (clearly in association with a stringent set of related *ceteris paribus* assumptions). In the parlance of information theory, the SHS should be not only a database, but also a decision support system (in the gross sense—i.e. for longer term health system planning, not for individual clinical interventions).

Initial efforts to construct such an SHS will encounter all sorts of data gaps. By starting with a complete framework, however, all the myriad cubby-holes waiting for pieces of data will be explicit, and hence so will all the data gaps. In the first instance, these gaps could be filled with "guesstimates." Then a set of sensitivity analyses with respect to these data gaps could be used to guide data development priorities. To turn this around, one of the corollary objectives is that *the conceptual framework of an SHS should aid in the identification and prioritization of data gaps.*

A final objective for *the SHS should be "upgradability."* The database and conceptual framework should be designed on the assumption that new and better data and theory will continue to become available. As this new information arrives, it should be relatively easy to incorporate it into the SHS. Such information could include improved medical knowledge of disease progression, the development of new treatment techniques, more detailed longitudinal administrative microdata on patients, more clearly explicated links between environmental and workplace risk factors and disease onset and progression, and changes to the institutional environment within which health care is financed.

3. A Conceptual Framework

Our task is to suggest a conceptual framework for a system of health statistics that will hopefully meet all of the objectives just described. The starting point is a broad spectrum of interests ranging from population health outcomes to dollar resource costs. We also begin in the context of diverse and fragmentary data, for example:

- population surveys of health status,
- differential disease prevalence across occupations and income groups,
- clinical studies of disease progression/etiology,
- stocks of hospital bed-day capacity,
- numbers of health care professionals,
- pharmaceutical consumption,
- financial statements of various health care providers,
- treatment protocols by disease type,
- high variance in the use of various surgical procedures, and
- clear gradients in health by socio-economic status.

The latter two types of data are disturbing in and of themselves; they and others of these data fragments are also problematic for conventional aggregative national accounting strategies. The challenge is thus to knit these data and interests together in a way that transcends juxtaposition, in a way that makes an explicit step-by-step connection between health outcomes and costs, both direct and indirect.

To begin, it is important to emphasize that we shall proceed on the basis of data that *in principle* can be obtained given current knowledge and methodology (and not at unduly high costs). In the first instance, actual data availability is ignored. Subsequently, the available data will be surveyed to assess the extent and nature of data gaps.

We recognize that this is a very ambitious (even daunting) endeavor. One fundamental problem is that in the health literature, one can find arguments or evidence to the effect that virtually everything affects everything else. One very promising example of a broad framework for understanding the determinants of health is shown in Figure 1 adapted from Evans and Stoddart (1989). Conventional health statistics have focused on health care and on diseases, principally as defined by physicians and codified by the WHO International Classification of Disease.

However, there has been increasing recognition of the role of lifestyle and environmental factors, for example as emphasized by the Federal Minister of Health and Welfare in the Lalonde Report (1974). More recently still, there has been some reaction to the individualistic, "blame the victim," connotation of lifestyle variables (e.g. smoking, obesity, fitness). The various boxes and arrows in Figure 1 thus seek to identify lifestyle factors as a mix of social environment factors (e.g. peer pressure re smoking, cultural differences that affect when symptoms or conditions are considered medical problems) and individual responses. In addition, human biological factors are identified in Figure 1 as a mix of genetic factors, diseases, and the concept of individual or host response. This latter concept stems from recent research in areas such as psycho-neuro-

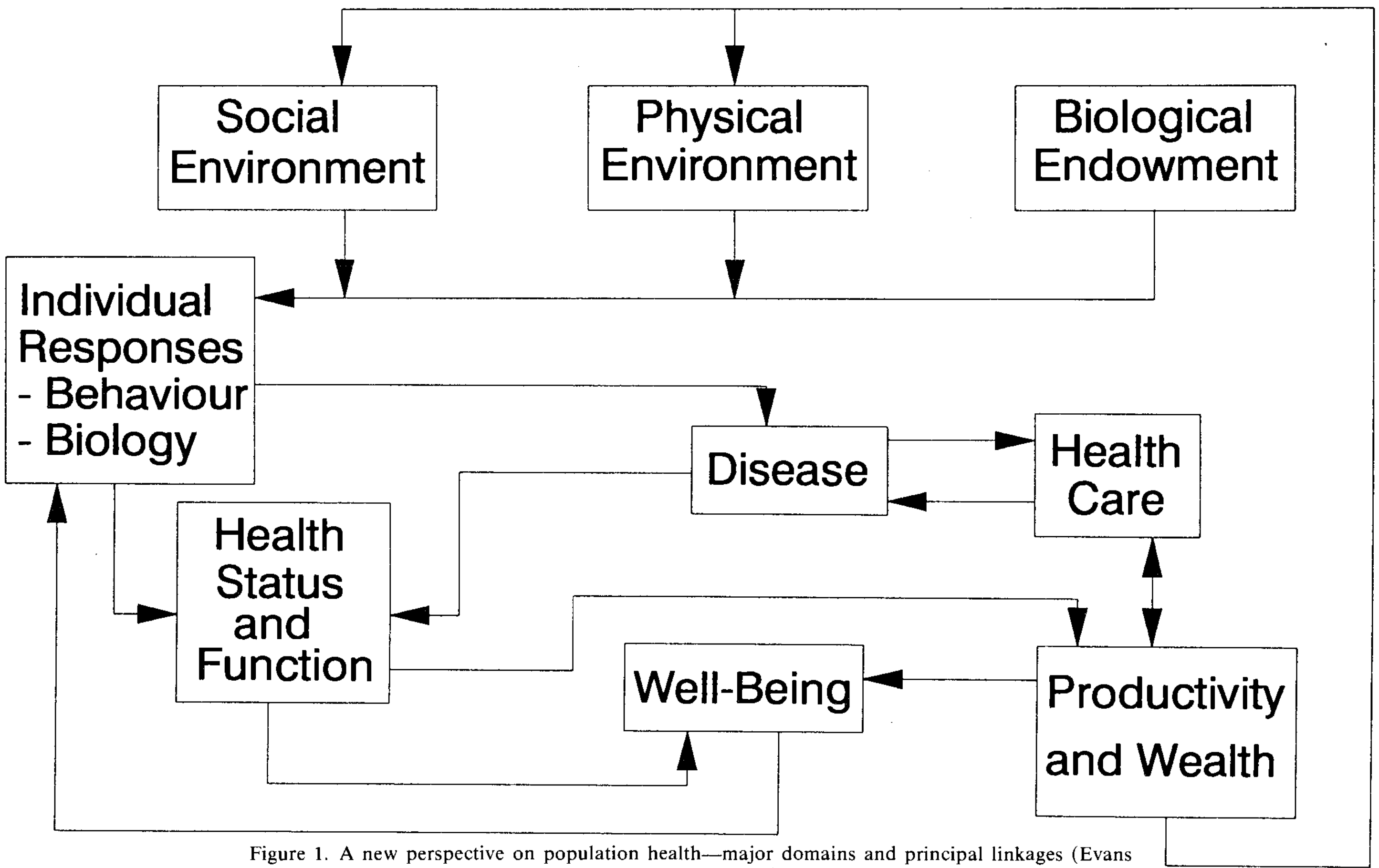

Figure 1. A new perspective on population health—major domains and principal linkages (Evans and Stoddart, 1989)

immunology where the existence of biochemical linkages from mental states to immune system responses have been established. Finally, Figure 1 shows the effect of health and health care on the general economy and several general ways by which the state of the economy can affect health.

This is clearly a complex and highly interrelated system. Any relatively simple conceptual framework for the SHS must necessarily abstract from and ignore important areas of interest. In the context of Figure 1, it would seem most reasonable to ignore the "Prosperity" and "Well-being" boxes, since they are either already covered by other statistical systems, or pose fundamental measurement problems. As well, the more biochemical aspects of the determinants of health are generally beyond the scope of a national statistical agency.

Another basic question concerns the level of detail. Although it is possible to imagine trying to keep track of tens of thousands of different diseases—their prevalence, treatments and etiology, this could be overwhelming. Practicality implies some limit to the level of detail kept at the national level, just as Statistics Canada tends never to produce data classified by more than a few hundred occupations or industries.

On the other hand, it would be most useful if the SHS framework could be applied at various levels of geographic aggregation such as province or municipality—to correspond to the jurisdictions with direct responsibility for health. Thus, in the first instance, the SHS should be national in scope and should support a moderate amount of disaggregation by health attributes. At the same time, the conceptual framework should be capable of finer levels of disaggregation, especially geographic and categories of health problems and health care interventions.

Fortunately, we do not have to start from scratch in developing a conceptual framework for the SHS. There are three existing conceptual frameworks upon which we can build: life tables, input-output matrices, and the SNA. The first of these, the life table, originally provided the basis for the concept of longevity or life expectancy. More recently, the life table concept has been generalized to allow multiple states. In the health context, multiple states can be associated with varying degrees of disease, a weighted average of which were used to generate the Wilkins and Adams (1983) measures of healthful equivalent life expectancy, or health expectancy.

This life table-based health outcome oriented conceptual framework would appear to be a natural starting point for the SHS. It would provide some of the kinds of indicators suggested by WHO (1981) and OECD (1981), as well as providing an aggregate index of population health status as suggested in the literature (e.g. Rosser, 1979, Chiang and Cohen, 1973, Chen, 1979, and Hall *et al.*, 1984).

Unfortunately, multi-state life tables suffer from a fundamental limitation—they focus on states rather than individual life paths or biographies. This in turn creates two major problems. First, multi-state life tables become cumbersome and ultimately intractable as the number of states is increased. For example, if disease incidence data were available for 10 different diseases each of which had at least 2 or 3 distinct forms or degrees of severity; if the progression of at least some of these diseases depended on 10 or more health, demographic and risk factor histories each with at least 2 or 3 different states and going back 10 years; and if multiple diseases were possible simultaneously or the diseases were interdependent; then an individual could have reached a given age via any one of millions of possible paths.

This scenario is not an unreasonable characterization. Yet millions of states would be required if one attempted to generalize the life table to represent all the possible paths. This level of detail in a multi-state life table is clearly impractical, if not computationally infeasible.

Second, by focusing on states rather than individual life paths, multi-state life tables track only groups of individuals. However, information on distinct individuals is essential to absorb data on disease incidence and treatment efficacy. Furthermore, path information is absolutely necessary to allow calculation of the distribution of population health expectancy (PHE) measures within a group of individuals.

Fortunately, the generalization of multi-state life tables based on microsimulation solves both of these problems. As noted by Wolf (1986) and Vaupel and Yashin (1986), Monte Carlo microsimulation is a more practical and flexible method. Wolfson (1989b) gives an example of the generalization of the multi-state life table methodology using microsimulation.

These limitations of multi-state life tables and their resolution with microsimulation parallel a discussion of the transition matrix approach to demographic accounting developed by Stone. Both life tables and the Stone-style demographic accounts rely on a set of transition matrices or transition probabilities. Land and Juster (1981, p. 15) in an overview suggest that "the underlying conceptual bases of the (life table and microsimulation) models are identical. The main difference lies in the use of matrix representations of the transition regime in the demographic accounting models as compared to Monte Carlo representations in the microanalytic simulation models." Monte Carlo microsimulation is thus generalization of life tables, with various social or biological phenomenon represented by more general multi-variate stochastic processes rather than by transition matrices.

The idea of including some sort of modeling, microsimulation or otherwise, at the core of a system of statistical accounts may be jarring to some readers. Thus, it is helpful to consider the relationship between modeling and accounting. In the words of Land and Juster (1981, p. 9) "accounting and modeling are distinct, though reinforcing, strategies . . . accounting refers to modes of organizing data, whereas modeling is concerned with measuring and explaining outcomes. But these activities should not proceed independently. That is, data bases need to be built in the context of certain organizing concepts, and models cannot be empirically grounded in the absence of data bases."

Thus it is appropriate for a national statistical agency not only to develop and maintain systems of statistical accounts, but also to explicate the underlying theoretical premises and to work with prospective users in the construction of modeling software based on the data in the statistical accounts. Furthermore, if there is a popular demand for summary statistical indicators whose production requires the use of a model—as is the case at present (albeit unknown to most users) with the conventional demographic life expectancy statistic, and would be the case with PHE summary outcome measures—then it is clearly reasonable for a national statistical agency to develop such modeling software.

As a result, the portion of the SHS focusing on health outcomes, including a family of PHE indicators, can build on the life table concept as generalized using microsimulation. The basic numeraire or unit of account would be person-years in different states of health (or "illth"). In turn, these person-years would be associated with a sample of individuals, each of whom would have a complete lifecycle history of health as well as socio-economic status.

An initial version of such a microsimulation framework, DEMOGEN, has already been developed for socio-economic status variables and has been applied to demographic and pension policy analysis (Wolfson, 1988, 1989a, b). DEMOGEN is an example of longitudinal Monte Carlo microsimulation, as described by Hain and Helberger (1986). For convenience, we can refer to a version of this framework which has been augmented with a set of descriptions of health status variables such as risk factors and disease onset and progression as SES/HS, for socio-economic status and health status.

Any representative sample of individual SES/HS lifecycle histories, when viewed from a cross-sectional rather than a longitudinal perspective, will provide a set of diseases and other health attributes distributed over the population. Depending on the richness of detail in the SES/HS life histories, diseases can be disaggregated by age, sex, and disease history. In turn, with a set of take-up or utilization rates (leaving aside where these rates come from), these instances of disease can be transformed into a set of demands on the health care system. This forms the link with the next major portion of the SHS, an I/O table (or generalization thereof) relating resource consumption to disease treatments in the health care sector.

In the context of the SNA, the I/O table is essentially a disaggregation of financial flows. However, conceptually, the input/output framework represents physical transformations. Each input and output can be measured in distinct physical units. Correspondingly, in the health context, resource inputs can be viewed in terms of heterogeneous physical units, i.e. as an activity or column vector representing a technique of production or "treatment technique" (e.g. see Evans, 1984, p. 304). The output would be a treatment for a given kind of "disease." (We leave aside for now the question of what effect this health care sector output—a "treatment"—has on the patient's health.) For example, a serious automobile accident or a birth is usually associated with a hospital visit. In turn, this visit entails the consumption of a given volume of bed-days, nurse-hours, doctor-hours, operating room-hours, etc. These "techniques of production" for various treatments can be naturally represented as a column vector in an I/O table format. (Of course, we recognize that many expectant parents view the health care system as being seriously flawed precisely because it tends to treat births in the same way as diseases.)

To extend this childbirth example, a set of alternative treatment techniques could be estimated to highlight inter-provincial differences in average practice, most versus least resource intensive practice (based on either domestic or international data), ordinary versus high risk practice, and doctor versus mid-wife oriented practice. These treatment techniques would then correspond to a set of column vectors in an I/O table format. Important variations in techniques of producing health care (not necessarily health), can be captured by allowing multiple techniques in the I/O table for each treatment, or sub-matrices in the parlance of demographic accounting.

Of course, the I/O table representation of techniques of production suffers from several obvious limitations such as an assumption of constant returns to scale and a simplistic notion of capacity constraints imposed by fixed capital. However, in the context of a computerized system as is envisaged for the SHS, much richer algorithmic characterizations of treatment techniques are feasible.

Furthermore, just as existing Canadian I/O tables are disaggregated by industry and province, the set of treatment techniques can be similarly disaggregated in the SHS context—by province, institution (e.g. large city teaching hospital versus rural hospital), funding agency, and level of technology. (It is important to distinguish current resource consumption flows from capital service flows in order subsequently to distinguish marginal from average costs. This in turn requires separate accounting for capital stocks.)

Of course, as emphasized by Evans and others, the technology of health care is substantially discretionary, quite varied across the country, and continually evolving. However, these characteristics make it all the more important for the SHS to bring together such data. Furthermore, even though these techniques of production may seem like moving targets, at any point in history, some specific mixture of resources will have been utilized by the health care delivery system. Thus, an "account" of that point in time will have no ambiguity.

The third major conceptual framework is the SNA. Here, the numeraire is dollars and the major focus is on production and its associated financial flows. It is essential that a part of the SHS should tie into the SNA, and it is clearly desirable that a part of the SHS should address the same concerns—costs and financial flows measured in a common unit of account (i.e. dollars), and breakdown by type of institution, type of factor input, sources of revenue, and purpose. In these areas, the SHS can and should build on the concepts and definitions already developed for the SNA.

Such SNA-style financial accounts can be largely derived from the treatment technique and utilization data. Continuing in the sense of an historical account, a simple multiplication of the numbers of treatment visits by the treatment technique vector will give total direct resource consumption in heterogeneous physical units. (In practice, the treatment technique vectors can be "observed" or derived by an inverse process—dividing total resources consumed by the number of treatments performed over the same time period.) Finally, multiplication by a corresponding price vector converts this resource consumption measured in physical units to resource consumption in financial terms. Provided the treatment techniques have been suitably disaggregated, the result is then a set of financial costs by type of input, province, and type of health care delivery institution. Such a set of detailed financial costs would provide the basis for a major portion of the Sunga and Swinamer (1986) SNA style account.

We have now completed a sketch of a conceptual framework that covers the spectrum from health outcomes to financial costs by building on a linkage of three main groups of concepts—life tables as generalized by the use of microsimulation, I/O concepts especially related to techniques of production, and SNA concepts of factor inputs, purposes of expenditures, and sectors.

4. A Formal Structure

To fix ideas and to be more precise, Table 1 sets out the matrices that represent the basic structure of an SHS along the lines developed above. Fairly simple transformations can be used to link all the matrices together in a set of identities. In particular,

Health Status (HS) = Socio-Economic Status (SES) × Prevalence Rates (PR);
Treatment Demand (TD) = HS × Treatment Rates (TR);
Resource Consumption (RC) = TD × Treatment Technique (TT); and
Total Costs = RC × Prices (P).

These matrices and identies are a summary structure. All the variables in Table 1 can be observed for a point in time more or less directly. For example, socio-economic status (SES) can be observed directly by a series of annual cross-sectional sample surveys, while risk factor, disease, and functional limitation prevalences (hence HS, and then PR by taking ratios) could be derived from a similar series of population health status surveys. Similarly, the mix of resources consumed in treatment (TT—measured in heterogeneous physical units) can be derived as a set of averages, for example within hosptial emergency or obstetric departments over the past year.

However, these identities are very mechanical and reflect no understanding of the underlying processes for the determinants of health, disease progression or the economic behaviour of health care providers, for example. They would *not* provide a reasonable basis for answering "what if" questions; nor would the SES/HS matrices derived in this way support the calculation of health expectancy summary outcome measures, nor related indicators such as cause-deleted health and life expectancy.

As an alternative, it is equally possible for the various matrices in Table 1 to be derived from more complex representations of the underlying processes. In particular, the SES and HS matrices can be summary tables derived from a sample of complete (albeit synthetic) household life histories generated by a microsimulation model.

The major reason for creating these synthetic life histories is to support the estimation of summary outcome measures such as PHE. In turn, the life histories are synthetic due to the absence of actual longitudinal microdata of sufficient detail, and little prospect that such data will become available in the forseeable future. In effect, the SES and HS matrices provide a set of marginal control totals, and the microsimulation modeling then creates a sample of life histories that when cross-tabulated match (to the extent possible) these control totals. (If this effort is successful, arguably it will also be much less expensive and much less invasive of personal privacy than direct longitudinal data collection.) Another major reason for synthesizing these data is to begin to understand the processes well enough to pose "what if" questions.

Data on demographic transitions (e.g. marriage, fertility, divorce) can be used to generate SES attributes. Clinical, biological, and epidemiological data

TABLE 1

THE BASIC MATRICES AND/OR MICRODATA SETS IN A SYSTEM OF HEALTH STATISTICS

Matrix	Main data structures Description	Numeraire
SES (t, p, i, j)	Socio-Economic Status	person-years
PR (t, p, j, k, m)	Prevalence Rates	dimensionless
HS (t, p, i, k)	Health Status	person-years
TR (t, p, j, k, m)	Treatment Rate	dimensionless
TD (t, p, k, l, m)	Treatment Demand	numbers of treatments
TT (t, p, k, l, m)	Treatment Technique	heterogeneous physical units
RC (t, p, j, k, l)	Resource Consumption	heterogeneous physical units
K (t, p, l)	Resource Stocks	heterogeneous physical units
P (t, p, j, k, l, m)	Prices/Unit costs	dollars per physical unit
TC (t, p, j, k, l, m, n)	Total Costs	dollars

Note: Illustrative subscript definitions:

t • calendar year

p • province (or geography more generally, e.g. urban/rural)

i • household (including all constituent individuals)

j • attributes of socio-economic status, e.g.
- demographic—age, sex, marital status, fertility, geography
- education/labour market—educational attainment, labour force participation, industry, occupation, employment income
- savings/housing—tenure, dwelling characteristics, equity in owner-occupied housing, private pension plan accruals, other private saving

k • attributes of health status/type of disease
- risk factors, e.g.
  - genetic predisposition, innate "coping skills"
  - individual lifestyle—smoking, exercise, diet, alcohol, seat-belt use, substance abuse, sexual behaviour, health awareness
  - physical environment—toxins, work place hazards
  - social environment—community attitudes, social support networks, prosperity, tolerance for disability
  - biological markers—body mass index, blood pressure, pregnancy, serum cholesterol, fitness, diabetes, immune status
  - iatrogenesis—drug side-effects, nosocomial infection

    diseases—CVD, cancers, dementias, arthritis/rheumatism, accidents

    activity limitations—mobility, dexterity, hearing, seeing, communicating, cognitive, emotion, pain
- overall index of health status

l • type of resource consumed in treatment
- health care professional services (in person-hours, e.g., specialists, physicians, nurses, dentists)
- buildings and land (hospitals, offices)
- equipment (e.g. surgical, diagnostic)
- semi-durable (e.g. bedding)
- non-durable (e.g. food, electricity)
- pharmaceutical

m • health care institution
- physician visit (office, clinic, hospital)
- hospital (teaching, urban, rural, chronic care)
- nursing home
- community clinic/comprehensive health organization
- diagnostic lab
- pharmacy

n • source of funding (e.g. governments, individuals, businesses, insurers) can be assembled to describe the determinants of susceptibility and the evolution of risk factors, and processes of disease onset and progression, disease by disease, to generate a corresponding set of health status attributes for each individual in the synthetic sample of household life histories. The PR matrix could then be derived simply as the ratio of the HS to the SES matrices, just as it would be with directly observed data, but this time it would be a reflection of much richer and explicit underlying data.

Similarly, underlying the TT matrix could be sets of alternative treatment techniques for each disease or health problem, where the treatment technique may be characterized by processes that are more complex than fixed coefficients I/O style column vectors.

The matrices in Table 1 would cohere and be linked together in this "model-based" situation as well, but this time by means of a more complex and rich set of explicit underlying processes, each represented in turn by detailed health-related data and well-defined mathematical algorithms (some stochastic, others deterministic).

However, to the extent that the SES and HS matrices are generated by a microsimulation model, there will be some tension between the SHS as a set of models, with these latter kinds of algorithmic/process foundations, and the SHS as an account of what actually happened in a given year. For example, it will generally not give identical results to a census or sample survey of the current population. Similarly, if the treatment technique matrix was built up as a weighted average of techniques observed from various clinical or micro-level studies of a sample of procedures at various kinds of health care institutions, the results would probably not be in accord with an aggregate I/O table style derivation.

Indeed, it will probably be a long time before our theoretical understanding of Canadian society is sufficiently refined and accurate that simulated and observed results are essentially identical. Thus, for the foreseeable future, we shall have to accept a tension between model results and observations in this proposed conceptual framework for an SHS.

Is such a tension a bad thing? We think not. First, achieving such an identity between simulations and observations would reflect success in gaining a fundamental understanding of the processes in question. Such understanding has been achieved, for example, in the case of the motion of planetary bodies. Second, this tension is the price to be paid for explicitly incorporating modeling into the framework of the SHS; one of the corresponding benefits is the potential of systematically tying in a wealth of micro level data and information in the health area—for example, clinical results on disease progression and treatment efficacy, and case study data on different institutions' treatment techniques and costs. As well, a model-oriented structure is essential for computing PHE outcome measures. Third, by developing more detailed data in a framework that is oriented toward understanding the underlying processes, it is much easier to ask "what if" questions in a realistic way. Finally, this tension can be viewed as a creative pressure. It provides a major potential source of redundancy in the data, the possibility of "data confrontation" in Wilk's (1987) terms, and thus a continuing force to improve the quality of the data and process representations.

5. A Process Outline of the System of Health Statistics

Given that the matrices in Table 1 can be derived essentially from direct observation, we turn now to a more detailed description of how they might be derived instead from a set of models that incorporate explicit representations of various underlying processes.

Quantitative algorithmic representations of various social processes would appear to be a new kind of "data" for a national statistical agency to collect. However, there already exist simple examples of such data collection—for example the age-specific divorce propensities published with and used in marital status life tables, and input/output table based models (both making very stringent *ceteris paribus* assumptions). As well, if the SHS is to go beyond collecting data on dollars and institutions to include people and their healthfulness, some format must be found in which to collect and systematize clinical and biological information.

In the health area, the idea of collecting and refining such statistical process representations—the outputs of population-based epidemiological and biostatistical analyses—seems more natural than compiling bibliographic lists of clinical research or collecting biological data. The following sketch shows how the matrices in Table 1 can be derived by a mixture of modeling and much more detailed rather than direct observation. This presumes not only the collection of much more detailed and varied data, but also their being analyzed to derive stochastic or other representations of the underlying processes.

One major objective in this description relates to theories and paradigms. There are a variety of contending views about how the health care system functions, and the most important determinants of healthfulness. For example, the conventional "medical" model can be caricatured as people getting sick "out of the blue," going to the health care delivery system, and then getting "fixed." Similarly, some view disease progression as primarily determined by biological factors, and health care based on a relatively straightforward "one cause, one treatment" procedure.

Alternative views emphasize the extent to which numbers of doctors rather than the prevalence of illness might influence the demand for medical services, the importance of socio-economic and environmental risk factors in disease onset and progression, and the pervasiveness of multiple-cause ailments requiring a mix of interventions—many non-medical—to restore health. A broad framework for understanding the determinants of population health was set out in Figure 1.

One objective in sketching the processes underlying the matrices in the SHS is to show that the proposed framework is compatible with any of these alternative theories or paradigms. This is evidently a very ambitious objective. However, it is important for a national statistical agency not to prejudge the outcome of scientific inquiry in an area of intellectual ferment. To the extent possible, a broad range of concepts and data should be included.

Figure 2 provides an overview of this process oriented or dynamic view of the SHS framework. The SES and HS matrices are somewhat renamed in the large block in the upper-left. The vertical axis covers the variables comprising socio-economic and health status; the horizontal axis is time; and the third dimension represents different members of the population.

This block can thus be thought of as a flat computer file representation of a massive longitudinal microdata set. Each record represents an individual in a given year (a single column vector), and the vertical axis represents the record layout. A slice through this block parallel to the X-Y plane thus represents an individual's life history. (More appropriately, the file should be heirarchical, so that adjacent individuals may be members of the same family, or more generally there are pointers and list structures to capture family and neighbourhood relationships.)

The large block at the bottom of Figure 2 represents the treatment technique (TT) and price (P) matrices (with the bottom half of the block referring to exactly the same physical resources as the top half). The third dimension represents a combination of all the other subscripts for the TT and P matrices given in Table 1 (other than *t* and 1).

The TT matrix thus shows not only a breakdown by type of hospital, but also variations by presenting disease, in actually observed practice, and possible proposed treatment strategies. Initially, a treatment technique can be represented by a fixed coefficients I/O style column vector. Subsequently, given appropriate data, it can be represented by more general non-linear algorithmic processes.

The two major blocks—population status and health care production—are connected by utilization and efficacy. Health care utilization (or the treatment rate, TR) can be dependent on both the nature and severity of disease, and the supply and practice styles of health care professionals [including Evans' (1984) "doctor-induced demand"]. In turn, these treatments or health care services presumably affect disease progression via their efficacy, though this is increasingly a controversial question [for example Ivan Illich's (1975) concept of iatrogenesis or doctor-induced disease].

Given the two major blocks on the left of Figure 2, and their connecting processes, the smaller blocks on the right show three of the major kinds of statistical results that can be derived. Population health expectancy (PHE) is derived by first computing the weighted years of life for each individual in the population with the weights based on the annual health status index. These weighted years of life are then averaged over a birth cohort. Since PHE derived in this way is an average over a representative sample, it is also possible to derive distributions across population subgroups, and measures of inequality in PHE.

The total costs of illness notion, shown in the second box on the right, requires the construction of a counterfactual—an hypothetical scenario where a given disease is absent. It thus requires a simulation describing in a rigorous and detailed way what would have happened if the given disease did not exist, but all other diseases, treatments, and socio-economic processes continued in some sort of *ceteris paribus* manner. Such modeling is something the SHS framework is designed to accommodate. It is already undertaken, though probably implicitly, by national statistical agencies when they produce tables of cause-eliminated life expectancy and potential years of life lost ("PYLL"). (This cost of illness analysis, however, is open to the criticism of unduly reifying diseases.) Finally, the SNA-style accounts for any given year can be derived by multiplying prices times

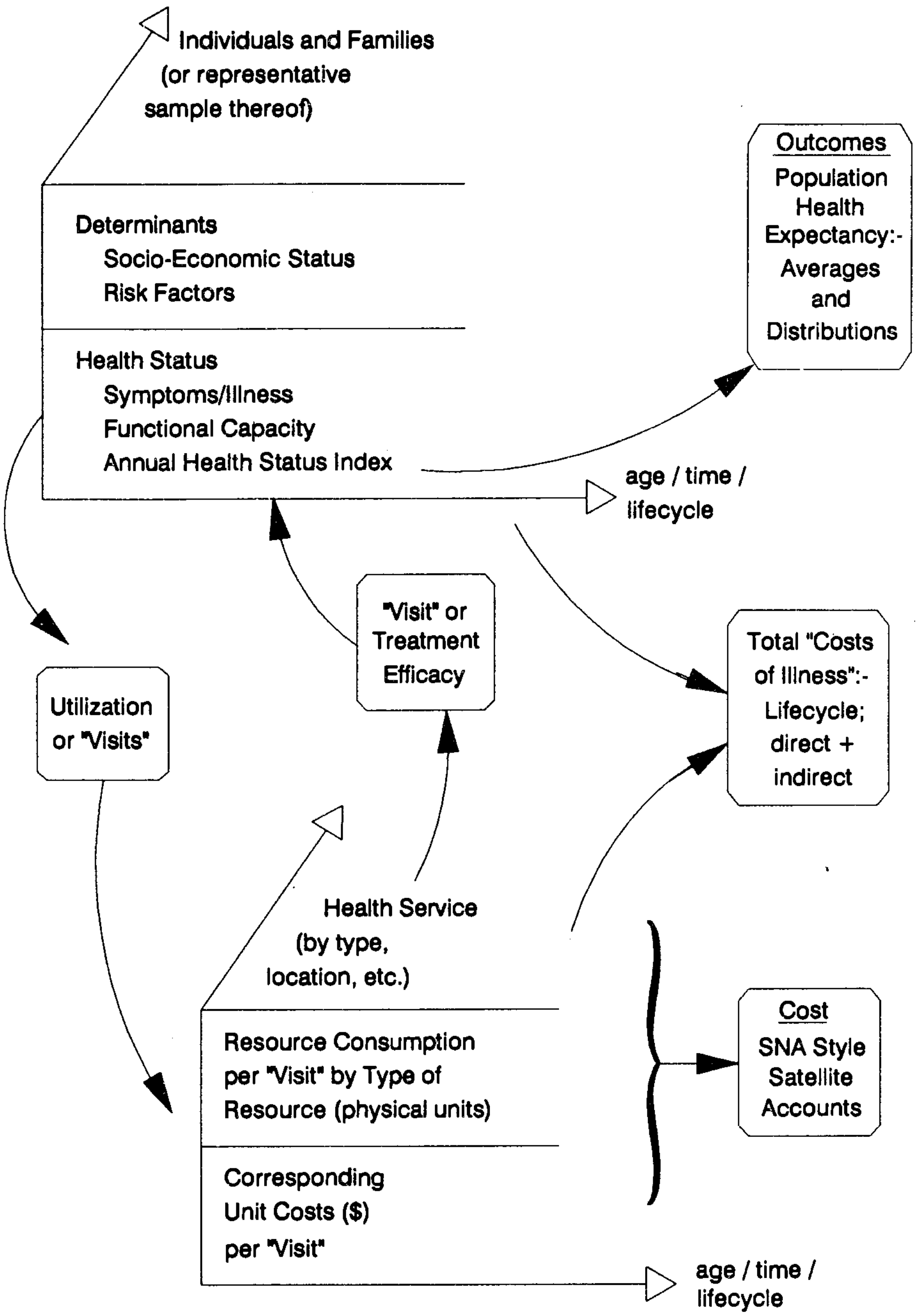

Figure 2. The system of health statistics framework

resources consumed times number of visits for various types of treatment in various aggregations of health care settings.

These three resulting sets of partially summarized data clearly cohere because they are all derived from a common underlying set of linked data; and they include an appropriate balance of population health outcome and institutional health care resource use information. They thus meet both of the principal objectives of the SHS.

As already noted, the population status block is based on microsimulation. Ultimately, the full population can be represented by a sequence of overlapping birth cohorts. The model is generally recursive. As a result, each individual can be described by his or her initial conditions or status at $t=0$ (e.g. genetic endowment, birth weight), and a set of processes for determining status at time $t+1$ as a function of their own status at times $0, 1, \ldots, t-1, t$, as well as the status over the same time periods of "significant others" (e.g. a spouse).

Each process consists of an algorithm and parameters. Processes for updating SES and HS are generally stochastic, relying on a set of conditional transition probabilities. For example, marriage breakdown can be described by a hazard function estimating the risk of divorce in terms of such variables as age, duration of the marriage, presence of children of various ages, and labour force history. Similarly, there are hazard function estimates for heart attacks as a function of age, sex, obesity, cholesterol, smoking, and hypertension. Other processes such as health care treatments will be generally deterministic.

In the first instance, the model is a period model. This means that the processes are not embedded in historical time. Instead, each process attempts to represent what is going on "now" and assumes that current practice has been going on for time immemorial and will continue indefinitely. For example, a set of 1980 fertility rates (conditional on age and marital status of the mother and birth order) is used as if fertility had always been and would always be constant at the 1980 rates. This simplifying assumption of what might be considered a steady state equilibrium makes it easier to understand the model in its first incarnation. It also allows simulation of only a single birth cohort to be used to represent the entire population.

The steady state assumption means that time t is exactly equal to the age of the cohort (assuming everyone is born $t=0$). Thus, the t subscripts in Table 1 would really correspond to age rather than calendar time. This is a major source of the tension between observed and simulated versions of the matrices in Table 1. For example, the current age structure of the population is not in a "1980" steady state. Also, disease prevalence in 1980 reflects disease onset and progression patterns that have evolved over years and decades, not 1980 point-in-time or cross-sectional patterns.

In principle, it would be possible eventually to incorporate time-varying descriptions of disease onset and progression. There is little technical difficulty in doing so given that the model is being realized as a computer simulation program. However, historical data limitations probably make this impossible; it will be difficult enough to assemble current descriptions. In any case, the range of statistical indicators that can be produced with only a period model, particularly health expectancy, should be of considerable interest.

6. Illustrative Standard Tables

In Table 2 we present an outline of a set of standard tables that could be produced given the formal structure outlined in Table 1 and the model process just sketched. These tables generally follow the flow of the basic matrices in Table 1, combined with the simulation capability of the SHS.

It may be noted that this set of tables combines items that are directly observable at a point in time (e.g. resource consumption for a particular treatment technique), extrapolations of data that are directly observable (e.g. life expectancy based on age-specific mortality rates observed at time *t* and assuming these rates held constant throughout time—so-called period life expectancies), and substantially hypothetical data (e.g. disease eliminated life expectancies).

For comparison, it is interesting to examine the list of detailed tables for a recent issue of the annual U.S. publication of health statistics, *Health United States* (NCHS, 1985). While the many tables in this document generally do *not*

TABLE 2

Illustrative Standard Tables

$SES_{t..}$ overview of the current distribution of the population by family type, age, province and income

$HS_{t..}$ overview of the current distribution of health status, e.g. malaise by age group and family type or income

Implied Morbidity Propensities—derived as the ratio of HS for specific diseases to SES within socio-economic groups. (Note that such simple propensities will not always be inputs to the microsimulation model; the intention is to utilize explicit longitudinal representations of disease progression.)

Expected Sojourn Times—derived as in multi-state life table style analyses from SES and HS matrices
- total life expectancy
- various demographic expectancies (e.g. marriage, divorce, fertility, remarriage, labour force participation)
- "health expectancy"—the overall measure of healthful equivalent life expectancy
- various health expectancies (e.g. expected distribution of mortality by cause, proportions of the population who can expect to have at least one episode of disease *k*)

$TR_{t..}$ utilization and take-up rates (e.g. by age and disease type)

$TT_{t..}$ current I/O table for the health sector; range of variations in observed treatment techniques

$TD_{...}$ total demands for treatments from various perspectives (e.g. by age and disease type, by province and disease type)

$RC_{t...}$ resource consumption in physical units (e.g. doctor-hours per capita by province and per doctor—given also data on the total numbers of doctors and people by province)

Capacity Utilization—resource consumption as a proportion of stock capacity

$TC_{t....}$ Resource consumption in dollars (e.g. by disease, type of resource, province, age group, source of funding)

Lifecycle Health Costs—assuming constant treatment techniques and prices, average and distribution of present discounted values of direct health care costs as well as indirect costs over individual lifetimes, also expressed as percentages of lifetime earnings (i.e. on a basis comparable with public pensions)

Disease Eliminated Sojourn times—similar to expected sojourn time tables above except based on hypothetical scenarios where a given disease is assumed to be eliminated

Disease Eliminated Lifecycle Health Costs—similar to lifecycle health costs except where a given disease is assumed to be eliminated—the increment in costs is then the "cost of illness" for the given disease

Best Practice Resource Costs—total resource consumption in dollars under the assumption that each province adopted the least resource intensive treatment technique observed in any province, disease by disease cohere or add up, they follow almost the same structure and flow as is set out in Table 2. The tables suggested in Table 2 also follow fairly closely the extensive set of health indicators developed by federal and provincial officials for the National Health Information Council (1989).

7. Scope of the Accounts

So far, the terms health, health sector, and health care delivery system have been used without any precise definition. The reason, simply, is that the precise scope of an SHS is yet to be determined. In comparison to the Sunga and Swinamer (1986) prototype account, this SHS is clearly broader. It attempts to encompass population health status, resource consumption in heterogeneous physical units, and total costs by politically relevant factors such as province and funding program.

It is not clear how far the concept of sickness or health status, for example, should be extended. It is probably easier to determine whether a person has diabetes than whether he or she is "fully healthy." While doctors and hospitals are clearly part of anyone's notion of the health sector, what about healthy lifestyle promotion programs, regulatory constraints for cigarette advertising, and municipal sanitary sewage systems? Presumably interns working in hospitals are part of the health sector, but what about medical students, or pre-medical students? These questions are intended to highlight the question of the boundary of the health sector. Perhaps Richard Stone's pragmatic answer is most appropriate—start with those portions that can be well-defined and are clearly part of the health sector, and then expand the boundaries as and when concepts are refined and practical data collection processes become feasible.

8. From Proposal to Practice

Implementation of the SHS as described so far is a major undertaking. Recall that one of the premises was to restrict consideration only insofar as the data could in principle be collected. Thus, most of the data assumed are not yet available, and major costs would be involved in establishing the requisite data feeder systems—though these costs are not as large as one might think because of various initiatives underway to develop highly detailed computerized files of administrative data. In any case, when embarking on a very large project such as an SHS as described, where a successful outcome is uncertain, it is often prudent to define a prototype as an initial milestone.

The Population Health Module (POHEM) is precisely such a prototype and has been under development for the past year. POHEM is intended to serve as a "proof of concept." The health status portion of the SHS was chosen as the starting point because it is the least developed area of the health statistical system, and the most difficult. POHEM is essentially an extension of the DEMOGEN microsimulation model described in Wolfson (1989a); its use for estimating PHE is described in Wolfson (1990).

The strategy has been to choose a handful of major diseases. Then for each disease, the literature has been searched for "off the shelf" information that can provide the basis for the process models sketched above. These diseases (or disease complexes) can be chosen to highlight such aspects as the difference between chronic diseases and those whose onset can be seen as largely random, those impacting mainly young versus old individuals, the potential efficacy of preventative strategies and modifying life-style factors, high versus low ratios of direct to indirect costs, and pairs of diseases that raise the complex questions of statistical inference related to competing risks.

In practice, the choice of diseases for prototyping has been somewhat opportunistic, depending on the quality of "off the shelf" research and the availability of quantitatively oriented subject matter experts. So far, work has focused on coronary heart disease (CHD), breast cancer, arthritis/rheumatism, and dementias. The CHD model is the most elaborate because we have been able to build on the model (and hence a suite of detailed transition probabilities) already developed by Weinstein *et al.* (1987).

Institutional data is also being sought to describe the variety of treatment techniques in use and their resource requirements, both in heterogeneous physical units and in financial costs. This will allow some shorter term benefits from the prototyping effort. For example, a study is now underway to assess the relative costs per unit of health expectancy of alternative CHD interventions, ranging from smoking cessation to the latest in diagnostic imaging and heart surgery. Another aspect of scope is geographic domain. It is conceptually possible to have a heirarchy of SHSs—at the municipal and provincial as well as national levels.

POHEM is clearly still a work in progress. It has been successfully used to estimate health expectancy—illustratively based on the four disease groups being considered. Future work will focus on validation, extension to other diseases, and development of the associated treatment technique and cost matrices.

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