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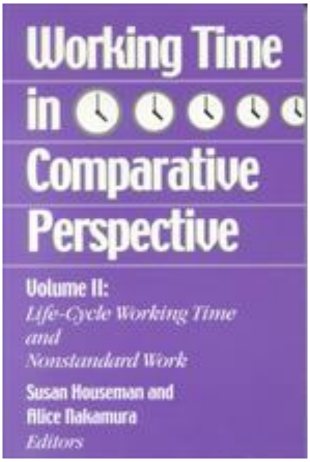
Perspectives on Working Time over the Life Cycle



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Perspectives on Working Time over the Life Cycle

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INTRODUCTION

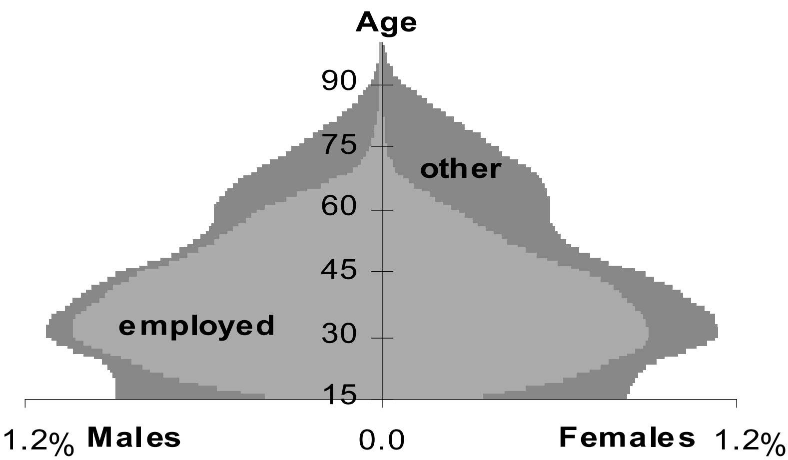
A central topic in social statistics is patterns of work in a population. In addition to the longstanding interest in basic information like unemployment rates and employment/population ratios, there is increasing interest in the way individuals' working careers unfold over their lifetimes.

However, the requisite long-term longitudinal data on working careers are still largely unavailable in Canada and many other countries. As a result, statistical impressions have typically been generated either by examining trends in cross-sectional age-specific patterns, or by piecing together data using synthetic statistical methods. LifePaths, a microsimulation model recently developed by Statistics Canada (Wolfson 1995, 1997), provides an alternative means of combining information from different cross-sectional and longitudinal data sources to infer individual life paths. This model offers a means to estimate and display coherent pictures of work and other kinds of time use over various time scales ranging up to the full life cycle.

BACKGROUND—THE GENERAL SOCIAL SURVEY TIME-USE DATA AND LIFE TABLE APPROACHES

The most common perspectives on working time over the life cycle draw on cross-sectional labor force survey or population census data.

Figure 1 Population Age 15+, by Age, Sex, and Employment Status, 1991



For example, Figure 1 shows a standard population pyramid from the 1991 Census. The proportion of individuals at single years of age is divided between those who were employed and those who were not, based on having positive labor market income in the previous calendar year.

Another less frequently presented perspective on working time over the life cycle draws on life table methods. The first such estimates for Canada were Denton and Ostry (1969), in turn updated by Gnanesekaran and Montigny (1975). More recently, Bélanger and Larrivée (1992) have made multistate life table estimates.

The original working life table efforts required only limited cross-sectional age-specific labor force participation and mortality rate data. These working life tables included two states: working and not working ("inactive"). Transitions between these states were based on age-specific labor force participation rates (for males only) and a series of simplifying assumptions. The key assumptions were that individuals could enter the labor market only once and could leave the labor market only once over their entire lifetime, and that overall, labor force participation rates first rise monotonically to an age where they are at a maximum, and then fall monotonically.

The more recent increment-decrement methods used by Bélanger and Larrivée relax these restrictive assumptions on transitions into and out of the labor force by using longitudinal microdata from the Labour Market Activity Survey (LMAS). These data allow gross flow transition probabilities to be estimated directly, so it is no longer necessary to infer these rates based on an assumed equality with net flows and by first-differencing age-specific participation rates. With increment/decrement methods, multiple exits and reentries to the labor force over a lifetime are not ruled out *a priori,* as in the earlier working life tables. However, strong simplifying assumptions are still embodied in the analysis. In particular, transition probabilities into and out of the labor force are assumed to be first order Markov, depending only on age, sex, and labor force status in the previous year, and nothing of subannual flows and seasonal patterns of employment is included.

Table 1 shows the two sets of estimates of working life expectancy in a comparable fashion. Notwithstanding the various simplifying assumptions, this series of male working life table summary results vividly displays the long-run trends of more time spent in schooling, ever earlier ages of retirement, a general reduction in working years, and hence a long-run decline in the ratio of working to inactive or retired years.

The last two rows give Bélanger and Larrivée results for 1986, first using the older gross equals net flow assumption (the 1986[a] row), and then using an increment/decrement life table based on gross transition probabilities (the 1986[b] row). The rather large 5.2-year difference in expected working life in these last two rows is indicative of the sensitivity of these kinds of results to the assumptions on transition rates.

However, both kinds of working life table assumptions, as well as the population pyramid in Figure 1, take the calendar year as the smallest time period and treat working within the year as a dichotomous variable. There is no allowance for part-time or part-year rather than full-time, full-year work, and nothing on unpaid work. Data from the 1992 General Social Survey (GSS) (Statistics Canada 1997), in contrast, suggest a high degree of heterogeneity in actual hours worked. For example, Figure 2 contrasts 1992 GSS data on hours of work in the reference day with 1991 Census data on hours of work (employed and

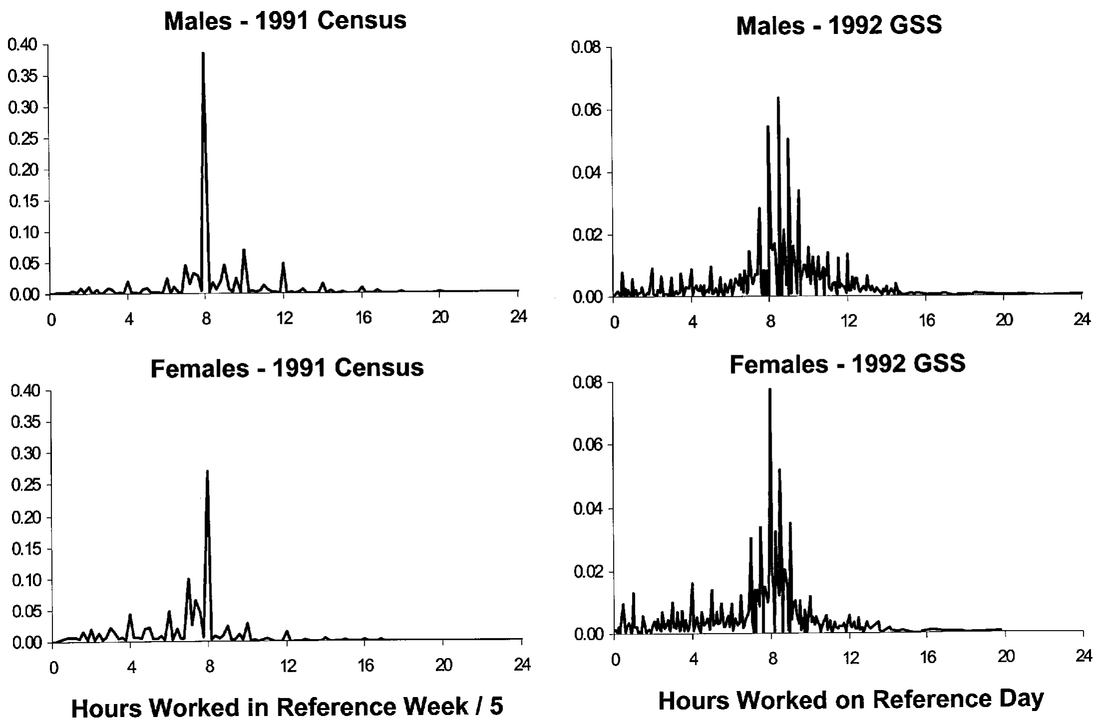
Table 1 Historical Stationary Male Life and Working Life Expectancies at Age 15

Year	Average age at: Labor force entry	Average age at: Retirement	Average age at death	Number of years: Working	Number of years: Retired
1921	17.5	62.7	67.6	45.2	4.9
1931	18.0	63.0	68.4	45.0	5.4
1941	18.2	63.1	69.1	44.9	6.0
1951	18.5	82.9	70.4	44.4	7.5
1961	19.2	63.0	71.2	43.8	8.2
1971	19.8	62.3	71.3	42.5	9.0
1986[a]	20.0	65.5	73.8	44.8	8.3
1986[b]	20.0	60.3	73.8	39.4	13.5

SOURCE: Adapted from Gnanasekaran and Montigny (1975) for decades 1921 to 1971 (Tables 2.1 and 12, 1975), and from Bélanger and Larrivée (1992) for the two 1986 rows (Tables 1 and 2, 1992).

NOTE: The Bélanger and Larrivée results were given only at age 16; age 15 results have been extrapolated. Working life expectancy is taken from Table 2 for both the active and inactive populations for the 1986[b] row. Also, they have only estimated the average age at death, and the expected number of working years, so the average age at retirement and number of years retired were derived based on the simple assumption that the average age at labor force entry was exactly 20. There also appears to be an inconsistency in the Gnanasekaran and Montigny results for 1971 average number of years working in comparison to all their other estimates, so this figure has been adjusted. The Bélanger and Larrivée definition of "working" is having worked at least one hour in a reference week in September of each year. The Gnanasekaran and Montigny definition for 1971 was essentially working or looking for work in the week prior to census enumeration, but then excluding summer students.

Figure 2 Relative Frequencies of Hours of Work, 1991 Census and 1992 GSS



self-employed) in the reference week (the latter hours divided by 5 for comparability).

In common with similar survey data on hours worked in a week, the census data exhibit a marked spike corresponding to exactly 40 hours (nearly 40 percent of responses for males and about 25 percent for females). In contrast, the GSS reveals no more than about 8 percent of exactly 8-hour-day responses. The GSS data suggest significant rounding bias in the reported census data. In turn, the impressions of working time over the life cycle given in Figure 1 and Table 1 may be significantly biased due to this considerable heterogeneity in weekly patterns, as well as the omission of part-year (seasonal) work.

LIFEPATHS: A MICROANALYTIC APPROACH

As an alternative to the population pyramid and multistate life table approach, detailed impressions of working time over the life cycle can be generated using microsimulation methods. This approach is grounded in the simulation of a representative sample of realistic heterogeneous individual life paths, in contrast to the cell-based methods of multistate life tables. As noted in Wolfson and Manton (1992), a microanalytic approach can always be devised that nests any given multistate life table analysis as a special case.

LifePaths is a monte carlo longitudinal microsimulation model designed, among other things, to support generalizations of working life tables. Like any empirical socioeconomic model, LifePaths draws on multiple data sets, since no one data set contains all the required information. Analytical results like transition probability functions are estimated from various data sources. The simulation model then serves as an "inferential apparatus." The LifePaths apparatus serves as a repository for diverse empirical results, and as an inference engine where these results are synthetically integrated and their joint implications drawn out.

LifePaths achieves this objective by synthesizing realistic sets of full individual life cycle histories, with each set representing a period birth cohort. Generalized working life expectancies and associated life tables are then by-products. It is simply a matter of cross-tabulating the individual life histories comprising the cohort to construct working life table results analogous to those just presented. LifePaths' explicit microdata foundations further enable a wide range of "views" of cohort work patterns over the life cycle.

Unlike a life table, which follows groups of individuals, LifePaths generates one individual at a time, and follows him or her until death. LifePaths allows individuals to be highly heterogeneous, since each individual's life path is uniquely simulated. Also, LifePaths models individual dynamics in continuous time. LifePaths uses semi-Markov processes, usually represented by multivariate hazard functions or waiting time distributions. At any moment in time, an individual faces chances of making a number of transitions. For example, depending on his or her current state or set of attributes, this could be a transition into the labor force, or into a marital union.

In the current version of LifePaths, individuals are jointly characterized by the following basic attributes at each point in their lives:

- age—as a continuous variable;
- fertility—exact ages at the birth of children, and information on the presence of children in the familial home;
- nuptiality—unattached, in a common-law or marital union, separated, or divorced;
- work status—including labor force participation and employment status (hours per week, weeks in the year);
- school status—grade and type of institution if attending, educational attainment otherwise;
- work income—hourly rate, weekly and annual earnings;
- time use—17 categories, including various kinds of work, learning, leisure, and personal care; and
- spouse attributes—including age, educational attainment, and labor market experience.

In addition, a wide range of derived attributes can be constructed from these basic attributes.

The core of the LifePaths model is the set of processes by which the trajectories for each attribute are generated. A brief sketch is given in the following paragraphs.

Demography. Fertility is modeled as a sequel to conception, which in turn is modeled as a series of piecewise constant hazard rates, conditional on age, marital status, and number of previous live births. The main data source is birth registrations, supplemented by data from the 1983 Family History Survey to account for biases arising from conceptions while single or in a common-law union that are then followed by a marriage before the birth of the child. Mortality rates are conditional on age, sex, and marital status, and are based on death registrations. In both cases, the population census provides the denominators.

Union formation and dissolution are represented by a series of hazard functions (Rowe 1989). From the single state, there are competing risks of entering a common-law union or a legal marriage. Marriage breakdown involves risks of separation and subsequent divorce. These hazards have been separately estimated for men and women, and depend in a complex way on previous history. For example, a woman's "risk" of entry to a union is positively related to being pregnant, and is highest shortly following labor force entry. Risk of separation for a woman is higher if there are no young children at home, if the woman was a teenage bride, and if she has recent work experience.

Educational Progression. Transition rates for progression through elementary and secondary school were constructed to be as close to jointly consistent as possible with the 1986 and 1991 population census data on the school attendance rates of children of the relevant ages. Progression through postsecondary institutions (colleges, trade schools, universities) is based on hazard rates jointly estimated from the National Graduates Survey (NGS), administrative data on school enrollments, and the LMAS for cases where young people quit work to return to and continue their studies.

Labor Market. Labor market experience is simulated in two main parts: whether or not employed, and earnings from employment. The first of these, transitions into and out of employment, is estimated from the LMAS separately for males and females, and also separately for first entry, second and subsequent entry, and exit from employment. First entry is represented by waiting time distributions, while the other transitions are represented by multivariate hazard functions. Sex and educational attainment are important determinants of the waiting time to first employment. Reentry hazards depend on sex, educational attainment, and duration of the current spell of nonemployment, and for women the presence of infant children has an additional depressing effect.

Earnings are in turn based on employment status as just described, and separate models for weekly hours of work, and hourly wages. Upon first entry to employment, a weekly hours value is randomly assigned, drawn from an age-, sex- and educational attainment-specific distribution, in turn based on data from a combination of NGS, LMAS, and the Survey of Consumer Finances (SCF, the annual household income distribution survey). Subsequently, the weekly hours variable is updated as a function of age, sex, last year's weekly hours, and educational attainment. At the same time that weekly hours is assigned, each individual is assigned a percentile rank for hourly earnings. The hourly earnings rate is then "looked up" from age-, sex- and educational attainment–specific distributions. Percentile ranks are adjusted from year to year based on estimates of rank order "churning" from the LMAS.

Daily Time Use. The 1992 General Social Survey (GSS) collected 24-hour time-use diary data for about 9,000 individuals, evenly distributed by age, sex, day of the week, and month of the year. The GSS also collected basic data on educational attainment, employment status, and family status. After extensive analysis of these data, a LifePaths module was created that imputes to every simulated person-day one vector of time spent over a 24-hour period in each of a series of 17 activities. (Special assumptions have been made for children under age 15 and the elderly living in institutions, since they were not covered by the GSS.)

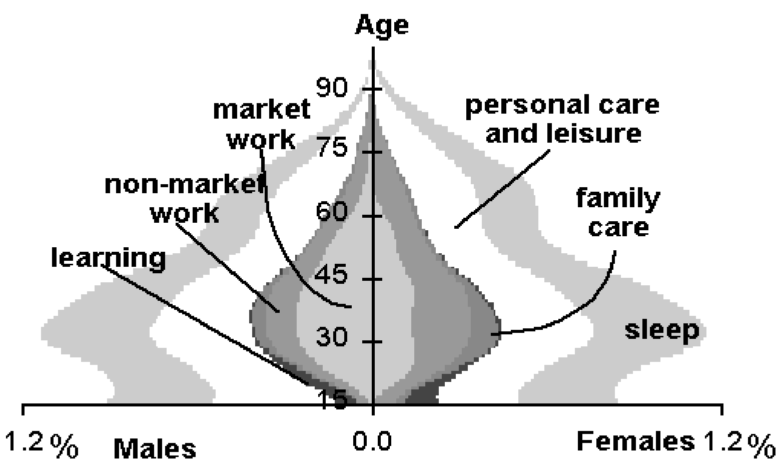
The statistical analysis indicated that age, sex, day of the week, marital status, presence of young children, educational attainment, and main activity (i.e., student, employed or self-employed, other) were all significantly associated with these vector patterns. Thus, all of these attributes, as generated by other LifePaths processes, were used in the imputation. The imputation process was also designed to reproduce the observed variability in time-use patterns among individuals with the same attributes, based on using the distribution of vector residuals from a multivariate regression analysis. Further details are given in the appendix.

The multivariate life cycle histories generated by a LifePaths simulation enable basic working life table results to be extended in several directions. Annual patterns of paid work can be examined in more detail, going beyond a two-way breakdown between working and nonworking years. For example, part-time work, hours worked per week, subannual spells of unemployment or withdrawal from the labor force, periods where work and school are simultaneously pursued, and self-employment are all taken into account. In addition, the time aspects of work are combined with earnings, formal schooling, and familial context (e.g., living alone or with other family members).

PRELIMINARY RESULTS

Before presenting results based on LifePaths simulations, Figure 3 shows the 1992 GSS time-use patterns in a manner analogous to "employment" in the population pyramid in Figure 1. This time, however, instead of distributing total person-years in the population by age, sex, and a dichotomous characterization of employment, Figure 3 shows the distribution of total person-hours in the population by age, sex, and main type of activity. The 1992 detailed time-use patterns have been combined with the same census population data for 1991 as

Figure 3 Total Population Age 15+ by Age, Sex, and Main Activity, 1991



in Figure 1 by reweighing the GSS sample to correspond not only to census counts of individuals by age and sex, but also by labor force status, census family size, and the age of the head of the census family.

Perhaps the most dramatic change from Figure 1 to Figure 3 is in the apparent importance of paid or “market” work. Using a binary classification on person-years as in Figure 1 gives the impression that employment is a major use of time. On the other hand, using daily hours as in Figure 3 suggests that paid work is of much lesser relative importance in the daily (or even waking) lives of Canadians. This pair of figures also indicates the limitations of conventional demographic dependency ratios, which use raw counts of individuals of working age (e.g., age 20 to 64) as the denominator. In the context of Figure 3, such ratios clearly understate the degree of economic dependence of many individuals in society.

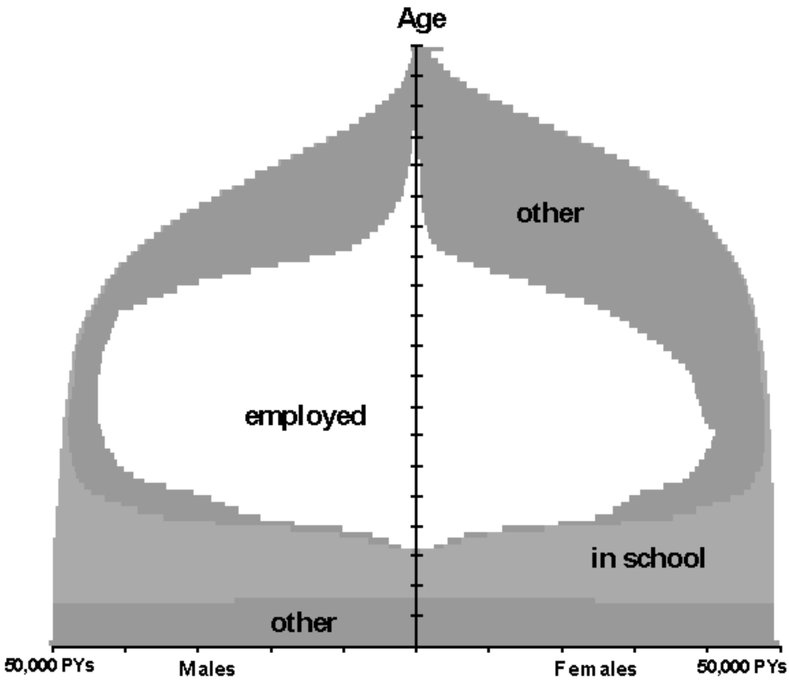
BASIC LIFEPATHS RESULTS

The baseline LifePaths simulation consists, fundamentally, of a sample of complete (synthetic) individual life cycle histories. This longitudinal micro database of sampled life histories is too complex to be examined directly, so we offer here only selected summary “views” of the underlying microcosm.

To start, Figure 4 shows the population pyramid for the base case simulation scenario. This is similar to Figures 1 and 3 except that the population envelope is the steady-state or period life table population, rather than an actual population distribution by age and sex. It is based on late 1980s and early 1990s transition probability functions, as sketched above. As expected, at higher ages, the survival curve for females falls more slowly than that for males, a counterpart to (or, more accurately, the underlying reason for) females’ higher life expectancy. (The blip in the age 99 interval reflects the fact that this is actually the age ≥ 99 interval.)

Figure 4 also shows the population broken down into three socioeconomic categories—“employed,” “in school,” and “other.” “School” starts at grade 1, so day care and kindergarten are part of “other.” Since the LifePaths framework tracks individuals through time contin-

Figure 4 LifePaths Population (person-years) by Major Activity, Age, and Sex

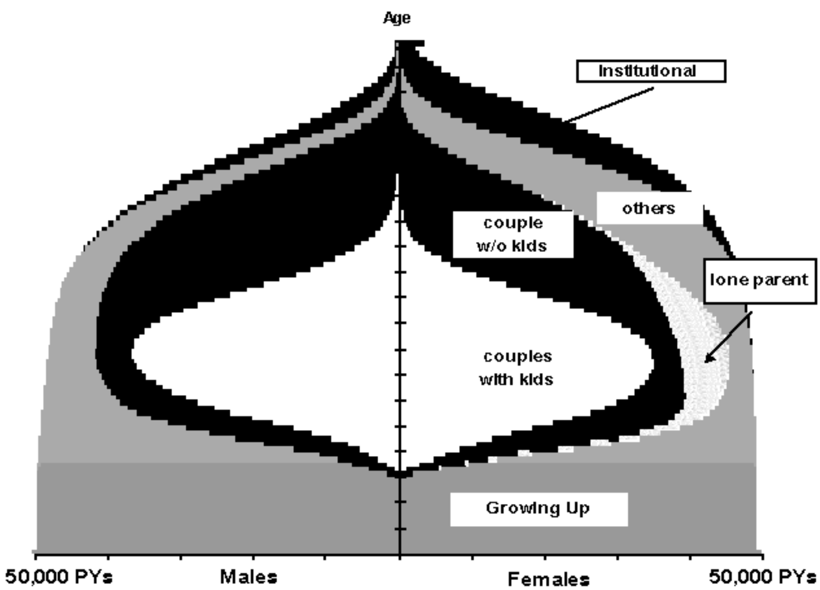


uously, some arbitrary classifications have been applied in years where individuals engage in more than one activity. Specifically, for a person-year to be considered "employed" in this diagram, the individual had to be working at least 15 hours per week, and the plurality of time during the year had to be spent working at this hours-per-week rate. Thus, someone who spent 5 months as a student, 4 months working at least 15 hours per week, and the remaining 3 months of the year working less than 15 hours per week (including not working at all) would be considered in "school" that year; while if the 5 and 4 were reversed, they would be considered "employed." (Definitions such as these are under the control of the LifePaths user.) The diagram shows that virtually everyone is in school by age 8, a few start leaving at age 16, most have left by age 20, but there is a tail of both males and females who are in school through their twenties.

No one appears to make a transition directly from school to employment, though we return to this point in a later figure. Instead, a perhaps surprising proportion of individuals are in the "other" category, which includes the unemployment as well as those not in the labor force (e.g., homemakers, the retired). As expected, males are more likely to be employed at various ages than are females. There is a bit of a dip in the employed profile for women in the prime child-bearing years. Men show a relatively sharper decline in participation in the age 60–65 age range than women, whose participation begins dropping at earlier ages.

Parenthetically, Figure 4 corresponds to Sir Richard Stone's "active sequence" (i.e., transitions among working and learning states) in his proposed System of Social and Demographic Statistics (United

Figure 5 LifePaths Population (person-years) by Family Status, Age, and Sex



Nations 1975). Figure 5 gives the corresponding LifePaths view for Canada of his "passive sequence," the other main demographic focus in the SSDS. It uses the same population pyramid graphic form, and refers to exactly the same underlying LifePaths synthetic population, but classifies individuals along a different dimension: family status. By definition, all individuals under age 18 are classified as "growing up" unless they are married or have a child. Also, whenever a marriage breaks down, any children are assumed to remain with the mother. This assumption explains why there are female but no male lone parents. (Future versions will incorporate more realistic data on custody arrangements.)

Comparing the male and female curves for the married states (couples with and without children) shows the male curves displaced a few years toward higher ages. This is a reflection of the general pattern where husbands tend to be a few years older than their wives. Figure 5 also shows there are many more widows than widowers ("others" at higher ages). This is a consequence of both the positive average age difference between husbands and wives, and the greater life expectancy of women. Finally, the diagram indicates the much higher rates of institutionalization of women (principally in nursing or chronic care facilities), due in turn to their greater longevity and higher prevalence of health problems at older ages, and the fact that similarly incapacitated males more often have a wife who can care for them at home.

Figures 4 and 5 show only two rather straightforward "views" (in this case, cross-tabulations) of the full underlying LifePaths microcosm—a multivariate longitudinal micro data set for a synthetic "early 1990s" period birth cohort. Exactly this same underlying longitudinal micro data set can be tabulated to generate a view of the flows between states rather than stocks within each state. For example, Table 2 displays the flows corresponding to the stocks in Figure 4. Each cell of the table presents the average number of individuals making each kind of transition each year (within each age range) for a cohort of 100,000 births.

The first transition is from "other" (early childhood or preschool) to "school." Figure 4 indicates that all male and female children make this transition by ages 6 and 7. The next major transition is at the end of "school," where the peak flow rate to "work" occurs around age 20 for both males and females. A smaller number, also peaking at about

Table 2 LifePaths Gross Flows between Major Activities Average Persons per Year, by Age and Sex

Age	Other→school	School→work	School→other	Other→work	Work→other
Females					
15–19	91	3727	1215	912	1202
20–24	493	5397	1236	4695	5388
25–29	179	1339	229	6352	5185
30–34	59	394	86	5231	4849
35–39	67	190	56	3319	3749
40–44	74	191	45	2807	2957
45–49	73	159	47	2411	3291
50–54	27	91	19	2165	3352
55–59	3	56	18	1499	3436
60–64	0	15	6	586	2882
65+	0	0	0	721	1260
Males					
15–19	137	3505	1431	803	1302
20–24	719	5151	1574	3913	4175
25–29	222	1423	224	4157	2562
30–34	82	478	69	2899	2571
35–39	41	215	42	2455	2291
40–44	33	164	33	2153	2076
45–49	19	105	19	2000	2107
50–54	4	42	3	1997	2021
55–59	5	88	15	1955	3456
60–64	0	30	7	1373	4756
65+	0	0	0	971	2405

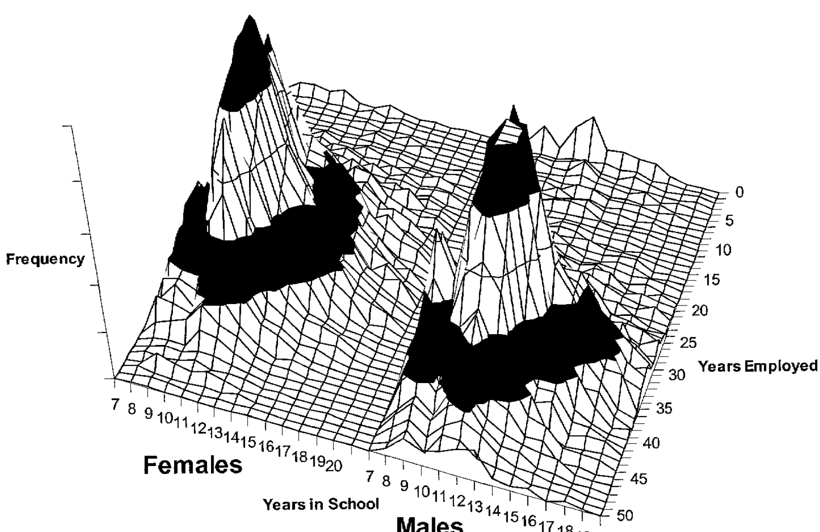
NOTE: From early adult ages to the 60s, the main flows are between the "work" and "other" categories. Note that all these flows are gross rather than net. It is notable that the net flow between work and other (based on comparing the gross flows) shifts direction toward "other" in the 40–45 age range for females, but remains quite small for males through age 50. This is followed by retirement peaks in the 55–65 age range, the one for males being more pronounced.

age 20, move from school to "other" activity. Recall that the "other" category is any person-year where the plurality of the year (i.e., at least a tiny bit more than one-third) was spent neither as a student nor working more than 15 hours per week.

In addition to stocks and flows of individuals in various categories of activity, LifePaths also supports data views showing sojourn times, which are the lengths of time individuals spend in various states. Such sojourn times have already been illustrated in Table 1 above, giving earlier life table estimates of working life expectancy. A major additional capability in LifePaths, given its explicit micro data foundations, is the option of viewing uni- or bivariate distributions of durations or sojourn times across the population. For example, Figure 6 shows the joint distribution for males and females of years spent mainly in school and mainly in employment, as a 3-d plot of simulated frequencies.

This graph indicates modes at around 12 years of school, for both men and women, and about 30 years of employment for women compared to 35 to 40 for men. The expected distribution of years of school

Figure 6 LifePaths Joint Distribution of School and Work Sojourn Times



is a bit wider for men, while the distribution of years of employment is considerably wider for women.

Note that a year of employment in Figure 6 is based on the amount of time (essentially week by week) that LifePaths is simulating the individual as "employed" (yes or no, based on labor force dynamics estimated from the LMAS). This is similar to an annual average of monthly labor force surveys, which is essentially the proportion of weeks employed. Years of schooling are analogously defined.

However, impressions of working life expectancy are sensitive to the precise way work time is measured. For example, Figure 7 compares three definitions for a subsample of individual life histories generated by a LifePaths simulation. The straight line represents lifetime work in hours, based on the most detailed time use data imputed from the GSS. This ranges up to 10 years for women, and 12 years for men, where these are years of working 24 hours per day and 365 days per year.

The two clouds of points in Figure 7 represent annualized definitions like those used in Figures 1 and 6. The solid squares correspond in concept to Figure 6, the amount of time LifePaths is simulating the individual as "employed" (yes or no). The hollow squares then apply a calendar year window, and count a year as "employed" if at any time during the year, the individual was "employed" in the sense of the solid squares. This latter definition corresponds to Figure 1, where the census data counted an individual as employed if he or she had strictly positive labor market income in the calendar year.

The slopes of the point clouds suggest (reassuringly) that every "solid" year of work (24 hours per day, 365 days per year) is associated with about three years of work as more conventionally defined. However, each solid year of work is also associated with a considerable scatter in the point cloud, representing the fact that annual dichotomous representations of working time are a considerable homogenization of reality.

Finally, Figure 8 gives another set of views of the LifePaths cohort. This is also a small subsample of the cohort simulated. This time, individuals were "checked" every three months during their entire lifetimes. At each "check" time, their cumulative time spent in market work, nonmarket work, and leisure was recorded. The various curves in Figure 8 show individuals' trajectories through the life cycle of time

Figure 7 Lifetime Work Durations, Three Definitions

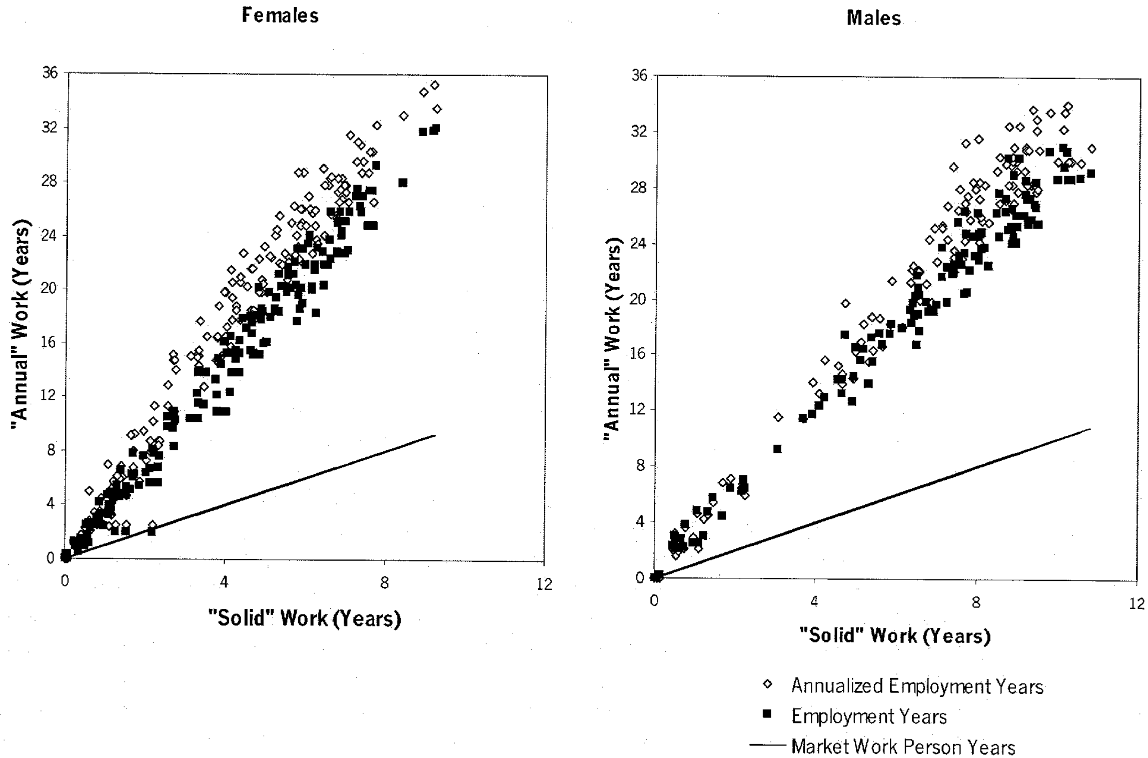
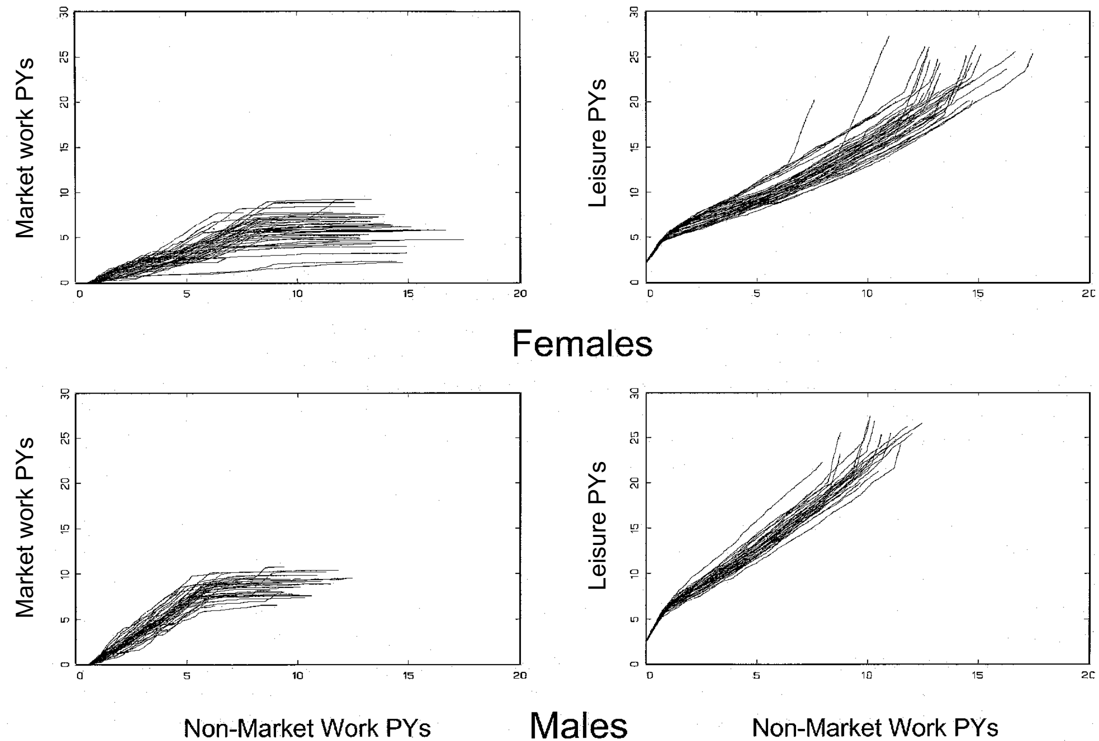


Figure 8 Sample LifePaths



spent in pairs of these activities. For example, the graph in the upper left shows time spent in nonmarket work along the horizontal axis, and time spent in market work along the vertical. In all cases, individuals move from the origin in the southwest toward the northeast.

Comparing the left pair of graphs, men tend to spend less time in nonmarket work (the slope of their set of curves is higher) than women, while women far more often interrupt their periods of market work and have intervals where they spend most of their time in nonmarket work (indicated by trajectories that head almost due east). Judging by the typical slopes of the trajectories in the right-hand pair of graphs, for every hour of nonmarket work, men spend almost twice as much time in leisure as women.

VALIDATION AND DATA QUALITY CONCERNS

The synthetic microcosm of individuals' life paths on which this LifePaths analysis is based should, by construction, reproduce the major marginal joint distributions from which it was built. This was the case with labor force participation rates, fertility rates, mortality rates, union formation and dissolution rates, educational enrollment rates, and age/sex-specific distributions of labor market earnings.

During the course of constructing LifePaths, these comparisons have been continually checked. By and large, agreement is good. The main instances of disagreement arise when the underlying data sources are inconsistent with each other (for example, as with administrative data on school enrollments and census data on school attendance by children).

CONCLUDING COMMENTS

LifePaths is a richly multivariate longitudinal microsimulation model. It constructs estimates of birth cohort life cycles by synthesizing samples of hypothetical but realistic individual life histories. It therefore generalizes a variety of life table analyses, including working life tables, and affords a much wider variety of "views" of working time over the life cycle. More recent work has extended LifePaths from a single "period" cohort to a sequence of overlapping historical birth cohorts; for example, to consider questions of the intergenerational equity of public pensions (Wolfson et al. 1998), and the intersection of adequate income, health, and leisure time (Wolfson and Rowe 1998).

One of the most striking results in this LifePaths analysis is the difference in impressions of the importance of paid work over the life cycle depending on the "granularity" of the time accounting. Conventional approaches, when viewing the entire life cycle, tend to go year by year, so that a typical life cycle can be expected to involve 20 to 40 years of work. However, when the analysis uses much finer units of time (e.g., hours and days), it becomes clear that paid work is a much smaller part of life.

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Appendix: Microsimulation of Patterns of Time Use

This appendix provides further detail on the methodology by which the time use data collected in the 1992 General Social Survey (GSS) (Statistics Canada 1997) were imputed to the individual histories simulated by LifePaths. These GSS data by nature provide a cross section of the time-use patterns of Canadians in 1992, and cannot directly provide a view of time use over the life course. LifePaths simulations therefore require an imputation of time use patterns over the lifetimes of synthetic individuals.

Structuring and Interpreting the Data

For these purposes, GSS time uses were partitioned into 17 mutually exclusive activity types:

1) employment	7) self-employment	13) commuting
2) family care	8) domestic work	14) volunteer work
3) adult education	9) formal education	15) sleep/nap
4) shopping	10) personal care	16) social leisure
5) active leisure	11) serviced leisure (movies, etc.)	17) passive leisure (tv, etc.)
6) reading	12) other	

Given this classification of activities, the GSS data set can be thought of as an array of 8,815 rows, each 17 columns wide (each row corresponding to one of the 8,815 respondents with a complete set of responses). About 60 percent of all the cells of this array indicate zero reported time use. However, for two reasons, these zeros should not necessarily be interpreted as representing a complete absence of time engaged in a given activity:

- reported time use activities are "main" activities that partition the day into mutually exclusive periods (for example, joint time use such as reading for leisure while travelling to work on the bus would be reported as commuting); and
- there is evidence of substantial rounding in the responses (for example, 32 percent of reported durations of sleep are even multiples of an hour, while 16 percent are even multiples of half an hour).

Moreover, it is important to distinguish between two types of zeros in this overall array:

- Response zeros—zeros that represent activities that are engaged in with small probability, for short intervals or that are unlikely to be a main activity. Ideally, the expected values of such zeros in the observed GSS data should be represented as small positive quantities.

- Structural zeros—zero time spent in an activity that is likely to be a main activity, where such a zero is reasonable in relation to the stage in the life cycle. For example, retirement usually implies no paid work. Such zeros should be modeled as zeros—they are essentially impossible events.

Zero time spent in an activity was operationally identified as a structural zero for:

- Employment or self-employment—if the main activity in the previous seven days was either retirement, long-term illness, maternity/paternity leave, or other nonwork if no work was reported in the previous year.
- Commuting—where both employment and self-employment are structural zeros.
- Formal education—if employment and/or self-employment are nonzero.
- Family care— if no spouse or child were present in the household.

About 12,000 structural zeros were identified by these definitions, representing about 13 percent of the zeros in the data array.

Regression Analysis

A sequence of three equations was then estimated as the basis for imputing daily time-use patterns to the individual trajectories simulated by LifePaths. In all cases, *k* indexes the 17 activities, and *i* the individual respondents to the GSS. These equations were estimated from the GSS 8815 by 17 array.

The first set of logistic equations describes the patterns of occurrence of structural zeros:

(A1) $$E(\text{ZERO}_{ik}) \approx (1 + \exp\left[-X^{*}_{ij}\beta_{jk}\right])^{-1}$$

The second set of 17 log-linear equations provide estimates patterns of time use conditional on the structural zeros estimated in the first equation:

(A2) $$E(\text{GSS}_{ik}\text{ZERO}_{ik} = 0) = \exp\left[X_{ij}\beta_{jk} + \beta_i\right]$$

where GSS_{ik} = the proportion of daily time spent by individual *i* in activity *k*. A special feature of this second set of equations is the term *i* representing a constant term for every respondent in the sample. These individual level constants represent a constraint on each individual's predicted time-use pattern (i.e., it must sum to 100 percent of 24 hours). The individual level constants may also be interpreted as reflecting random factors at the individual level that can be further modeled.

The third set of equations then captures patterns in individual variability of time spent in each activity. Residual variances are defined in terms of differences in square-root proportions, rather than the more usual log differences, to avoid problems with response and structural zeros (since the log residual (ln(0) – ln(u)) is undefined). As well as being defined for zeros, the vector distance measure expressed in terms of differences in square roots is a true distance (i.e., satisfying $d(x,y) \geq 0$, $d(x,y) = d(y,x)$ and $d(x,y) + (d(y,z) \geq d(x,z))$ and is unique in that respect among common distance measures on the unit simplex.

(A3) $$SD_i = \sqrt{\left(\Sigma\left(\sqrt{GSS_{ik}} - \sqrt{\exp\left[X_{ij}\beta_{jk} + \beta_i\right]}\right)^2\right)}.$$
$$= \exp\left[X_{ij}\theta_{jk} + \delta\varepsilon_i\right],$$

where $\varepsilon \approx \text{Normal}\left(O,\ \delta^2\right)$. In other words, it is being assumed that the standard deviations (SD_1) of time-use proportions are log normal, though with means depending on X_{ij}.

Estimation for Eqs. A1 and A2 was carried out by iterative proportionate adjustment, while Eq. A3 was estimated by least squares.

The choice of predictor variables in each of the equations was constrained by what was available both on the GSS and in the LifePaths model. The following variables were used:

Predictor variables	Definitions
Reference day	Sunday, . . . , Saturday
Sex	male, female
Age group	15–17, 18–19, 20–24, 25–29, . . . , 65–69, 70+
Marital situation	married or CLU (spouse not working last week), married or CLU (spouse worked last week), never married, widowed, divorced or separated.

Children	no children at home, all children at home aged 5+, one or more children at home aged <5
Education attainment	less than secondary school, secondary school only, at least some postsecondary.
Respondent's work	mainly a full time student last week, working last week, not working and not mainly a full time student last week.
Response rounding	zero responses in multiples of one-half hour, 1 response in a multiple of one-half hour, two responses in multiples of one-half hour, more than three responses in multiples of one-half hour.

An evaluation of the fit of these equations is difficult both because of the zeros in the data, and because the statistical properties of entries in time use diaries are difficult to specify. The following evaluation measures were calculated by analogy to statistical models of count data and should be taken as merely suggestive of the explanatory power of each variable.

Reduction in deviance due to addition of independent variables	Structural zero model		Time-use model	
	(Equation 1)		(Equation 2)	
Variable	Deviance	# Fitted parameters	Deviance	# Fitted parameters
Reference day	17.1 ns	42	4645**	119
Sex	875.0**	12	923.1**	34
Age group	4611.8**	78	1241**	221
Marital situation	29.1 ns	24	198.5**	68
Children	230.5**	18	1325**	51
Education attainment	327.9**	18	389.7**	51
Work	—	—	4355**	51
Rounding	—	—	48.55 ns	68

NOTE: ** denotes significance at 5%; "ns" denotes not significant at 5%.

Imputation algorithm

Finally, given the estimated set of equations, imputation of the 17 element time-use activity vectors was based on an algorithm that started with annual features, and then successively expanded the imputation to weekly and ultimately daily features. For each individual life cycle history simulated by LifePaths, and for each year, the following procedure was implemented.

Starting at the annual level,

- choose ZERO day - based on a uniform random number ranging from 1 to 365. Note that the interval between successive ZERO days will range from 1 to 729 days.
- on ZERO day, it is decided whether or not a structural zero will be imputed to market work, commuting, formal learning and/or care for family members for the next "year" (actually until the next ZERO day), based on probabilities determined from the logistic regression Eq. A1 estimated from GSS data.

Given these annual level imputations, the process next focuses on a week:

Starting at the annual level,

- choose a random REF day, based on a uniform random number ranging from 1 to 7. Note that the interval between successive REF days will range from 1 to 13 days.
- on REF day each week, one of the actual 8,815 empirical residual vectors RESID is chosen at random. The residual vectors are in standardized form:

$$\text{RESID} = [(\sqrt{\ }(\text{GSS}) - \sqrt{\ }\text{fitted from equation 2})]/\text{SD}.$$

- also on REF day, a random heterogeneity term (δε) is generated from the log-normal distribution represented by Eq. A3.

Finally, the imputation algorithm determines a set of daily activity patterns for all 365 days of the year (actually, all the days until the next ZERO day):

- each day, the appropriate average time use vector (AVG) is determined—corresponding to the day of week, sex, age, marital situation, presence of children, employment/schooling and education attainment—by applying Eq. A2 to the LifePaths variables pertaining to that day. A corresponding calculation, based on Eq. A3, provides the heterogeneity term (SD) appropriate to the day of the week, etc. and to δε.

- subsequently, the average, residual, and heterogeneity terms are combined.

  $\sqrt{(AVG)} + RESID \times SD$

  The added variability due to the RESID and SD terms preserves correlations among time use activities and accounts for interindividual variation. By varying RESID and SD only on a weekly basis, some (possibly spurious) correlation is induced between days of a given week.
- impossible time uses are set to zero—for example,

  age < 6: preschool: domestic work, formal learning and reading;

  age < 12: family care;

  age < 15: market work, commuting and adult education;

  institutional: market work, commuting, family care, domestic work, and volunteer work.

Likewise, structural zeros as prescribed above are set if necessary conditions are still met:

- employment time use = 0, if no work simulated for the previous 12 months
- self-employment time use = 0, if no work simulated for the previous 12 months
- commuting time use = 0, if no work simulated for the previous 12 months
- formal learning time use = 0, if currently employed
- family care time use = 0, if no spouse & no children are present at home
- finally, negative [$\sqrt{(AVG)} + RESID \times SD$] combinations are set to zero, with the remaining values transformed and scaled to sum to 1.0.

The algorithm thus provides simulated time use proportions that will approximately reproduce time use averages, variances and covariances as observed in the GSS data.

Note

The work reported here is very much a team effort, principally by members of the Socio-Economic Modeling Group of the Analytical Studies Branch, Statistics Canada.

Very helpful suggestions were provided by Alice Nakamura, though we remain responsible for any errors and infelicities in this chapter.

Part II

Working Time in Comparative Perspective

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Alice Nakamura
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