Pollak, Robert A. (1971) "Additive utility functions and linear Engel curves", *Review of Economic Studies*, 38(116):401–414.
Rees, Albert (1974) "An overview of the labor supply results", *Journal of Human Resources*, 9(2):158–180.
Rees, Albert (1979) "Douglas on wages and the supply of labor", *Journal of Political Economy*, 87(5): Part 1, 915–922.
Robbins, Lionel (1930) "On the elasticity of demand for income in terms of effort", *Economica*, 10(29):123–129.
Robins, Philip K. and Richard W. West (1980) "Program participation and labor supply response", *Journal of Human Resources*, 15(4):499–544.
Rosen, Harvey S. (1976) "Taxes in a labor supply model with joint wage-hours determination", *Econometrica*, 44(3):485–508.
Rosen, Harvey S. (1978) "The measurement of excess burden with explicit utility functions", *Journal of Political Economy, Supplement*, 86(2): Part 2, S121–S135.
Rosen, Sherwin (1969) "On the interindustry wage and hours structure", *Journal of Political Economy*, 77(2):249–273.
Rosen, Sherwin and Finis Welch (1971) "Labor supply and income redistribution", *Review of Economics and Statistics*, 53(3):278–282.
Samuelson, Paul A. (1956) "Social indifference curves", *Quarterly Journal of Economics*, 70(1):1–22.
Sargent, Thomas J. (1978) "Estimation of dynamic labor demand schedules under rational expectations", *Journal of Political Economy*, 86(6):1009–1044.
Schoenberg, E. and P. Douglas (1937) "Studies in the supply curve of labor: the relation in 1929 between average earnings in American cities and the proportion seeking employment", *Journal of Political Economy*, 45(1):45–79.
Simon, Herbert A. (1951) "A formal theory of the employment relationship", *Econometrica*, 19(3):293–305.
Smith, James P. (1975) "Assets and labor supply", R-1728-HEW, The Rand Corporation.
Smith, James P. (1977) "Family labor supply over the life cycle", *Explorations in Economic Research*, 4(2):205–276.
Smith, Shirley J. (1983) "Estimating annual hours of labor force activity", *Monthly Labor Review*, 106(2):13–22.
Smith-Lovin, Lynn and Ann R. Tickamyer (1978) "Nonrecursive models of labor force participation, fertility behavior, and sex role attitudes", *American Sociological Review*, 43(4):541–557.
Spinnewyn, Frans (1981) "Rational habit formation", *European Economic Review*, 15(1):91–109.
Teper, Lazare (1932) *Hours of labor*. Baltimore: Johns Hopkins Press.
U.S. Department of Labor, *Multiple jobholders in May 1979*, Bureau of Labor Statistics, Special Labor Force Report 239, January 1981.
Wales, Terence J. (1973) "Estimation of a labor supply curve for self-employed business proprietors", *International Economic Review*, 14(1):69–80.
Wales, Terence J. (1978) "Labour supply and commuting time: an empirical study", *Journal of Econometrics*, 8(2):215–226.
Wales, T. J. and A. D. Woodland (1976) "Estimation of household utility functions and labor supply response", *International Economic Review*, 17(2):397–410.
Wales, T. J. and A. D. Woodland (1977) "Estimation of the allocation of time for work leisure, and housework", *Econometrica*, 45(1):115–132.
Wales, T. J. and A. D. Woodland (1979) "Labour supply and progressive taxes", *Review of Economic Studies*, 46(1):83–95.
Wales, T. J. and A. D. Woodland (1980) "Sample selectivity and the estimation of labor supply functions", *International Economic Review*, 21(2):437–468.
Weiss, Yoram (1972) "On the optimal lifetime pattern of labour supply", *Economic Journal*, 82(328):1293–1315.
Welch, Finis (1978) "The labor supply response of farmers", in: John L. Palmer and Joseph A. Pechman, eds., *Welfare in rural areas: the North Carolina-Iowa income maintenance experiment*. Washington, D.C.: Brookings, 77–100.
Winston, Gordon C. (1966) "An international comparison of income and hours of work", *Review of Economics and Statistics*, 48(1):28–39.
Woytinsky, W. S. (1940) *Additional workers and the volume of unemployment in the depression*. New York: Social Science Research Council.

Chapter 2

FEMALE LABOR SUPPLY: A SURVEY

MARK R. KILLINGSWORTH

Rutgers University

JAMES J. HECKMAN*

University of Chicago

1. Introduction

This chapter surveys theoretical and empirical work on the labor supply of women, with special reference to women in Western economies, primarily the United States, in modern times.[1] The behavior of female labor supply has important implications for many other phenomena, including marriage, fertility, divorce, the distribution of family earnings and male–female wage differentials. The labor supply of women is also of interest because of the technical questions it poses. For example, since many women do not work, corner solutions are at least potentially a very important issue in both the theoretical and empirical analysis of female labor supply, even though in other contexts (e.g. studies of consumer demand) corner solutions are often ignored. [For recent discussions of this issue

*We thank Ricardo Barros, Bo Honoré, Tom Mroz and John Pencavel for invaluable comments and suggestions; Wolfgang Franz, Heather Joshi and Alice and Masao Nakamura for help in assembling data on the "stylized facts" about female labor supply presented in Section 2; Eileen Funck and Paul Rubideau for research assistance; and Orley Ashenfelter and Richard Layard for patience.

[1]For a general overview of women in the U.S. labor market, see Smith, ed. (1979); Fuchs (1984), Goldin (1980, 1983a, 1983b, 1984, 1986), Goldin and Sokoloff (1982) and Smith and Ward (1984a, 1984b) discuss historical and recent trends. The collection of papers in Layard and Mincer (1984), includes work on female labor supply in Australia, Britain, the Federal Republic of Germany, France, Israel, Italy, Japan, the Netherlands, the Soviet Union, Spain, Sweden, and the United States. See also Joshi (1985), Joshi and Owen (1984, 1985), and Martin and Roberts (1984) on Britain; Nakamura and Nakamura (1981), Nakamura, Nakamura and Cullen (1979), Smith and Stelcner (1985), Stelcner and Breslaw (1985), Stelcner and Smith (1985) and Robinson and Tomes (1985) on Canada; Franz (1981) and Franz and Kawasaki (1981) on the Federal Republic of Germany; Bourguignon (1985) on France; Hill (1983, 1984, 1985), Yamada and Yamada (1984, 1985) and Yamada, Yamada and Chaloupka (1985) on Japan; and Kapteyn, Kooreman and van Soest (1985), Kooreman and Kapteyn (1984a, 1985), Renaud and Siegers (1984) and van der Veen and Evers (1984) on the Netherlands.

Handbook of Labor Economics, Volume I, Edited by O. Ashenfelter and R. Layard

in the context of consumer demand studies, see Deaton (forthcoming) and Wales and Woodland (1983).]

The plan of this survey is as follows. We first present some "stylized facts" about female labor supply, and then discuss a number of theoretical models of special interest for understanding female labor supply. After considering empirical studies of the labor supply of women, we conclude with some suggestions for future research.

2. Female labor supply: Some stylized facts

This section presents some of the more important stylized facts about female labor supply. We first discuss major trends and cyclical patterns in time-series data, and then examine cross-sectional phenomena.

2.1. *Trends and cyclical patterns in time-series data*

432

Substantial secular increases in the labor force participation of women are a striking feature of the labor market in most developed economies in the twentieth century. Growth in participation began at different times and has proceeded at different rates, but since the 1960s most advanced economies have seen considerable, and at times dramatic, rises in the proportion of women – particularly married women (especially those with small children) – in the labor force.

Tables 2.1–2.4 set out the time series of female participation rates for the United States, Canada, Great Britain and Germany, respectively [see also Sorrentino (1983)]. As shown there, participation rates have risen in all countries

Table 2.1
United States: Female civilian labor force participation rates (in percent) by age over time.

Age (in years)	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980
10–13	5.4	6.1	3.9	2.9	1.5					
14/16–19[a]	24.4	26.8	28.1	28.4	22.8	18.8	22.5	23.9	35.3	45.7
20–24	30.8	32.1	35.5	38.1	42.5	45.1	42.5	44.9	56.3	67.8
25–44	15.6	18.0	21.0	22.5	25.4	30.2	33.0	39.1	47.8	64.9
45–64	12.6	14.1	17.1	17.1	18.7	19.8	28.6	41.6	48.2	50.5
≥ 65	8.3	9.1	8.6	8.0	8.0	5.9	7.6	10.4	10.0	8.7
All[b]	18.6	20.4	22.8	23.3	24.3	25.4	28.6	34.5	41.6	50.5

[a]14–19 years old (1890–1960) or 16–19 years old (1970, 1980).
[b]Age 14 or older (1890–1960) or age 16 or older (1970, 1980).
Sources:
1890–1950: Long (1958, Table A-2, p. 287).
1960: U.S. Department of Commerce, Bureau of the Census, *U.S. Census of the Population 1960: Employment Status and Work Experience*, Subject Reports PC(2)-6A, Table 1.
1970: U.S. Department of Commerce, Bureau of the Census, 1970 *Census of Population: Employment Status and Work Experience*, Subject Reports PC(2)-6A, Table 1.
1980: U.S. Department of Commerce, Bureau of the Census, 1980 *Census of Population*: Vol. 1, *Characteristics of the Population*, Chapter D, Detailed Population Characteristics, Part 1, United States Summary, Section A: United States, Table 272.

Table 2.2
Canada: Female labor force participation rates (in percent) by age over time.

Age (in years)	1911	1921	1931	1941	1951	1961	1971	1981
≤ 19[a]	26.9	24.0	21.7	25.8	37.2	33.0	36.9	61.2
20–24	23.8	35.0	42.3	41.8	46.8	49.3	62.8	44.5
25–44	13.5	14.5	17.9	21.0	23.1	30.2	44.2	65.2
45–64	9.4	10.1	10.7	12.1	17.9	29.7	40.0	46.3
≥ 65	5.2	6.3	6.1	5.5	5.1	6.7	8.2	6.0
All[b]	15.8	18.3	19.1	20.7	24.1	29.5	39.9	51.8

[a]14–19 years old (1911–31) or 15–19 years old (1941–81).
[b]Age 14 or older (1911–31) or age 15 or older (1941–81).
Sources:
1911–31: Long (1958, Table A-11, p. 305).
1941–61: 1961 *Census of Canada*, Vol. 3, Part 1, Table 2, pp. 2-1–2-2.
1971: 1971 *Census of Canada*, Vol. III, Part 7, Table 1, p. 1
1981: 1981 *Census of Canada*, Vol. I, National Series, Table 1 (for those 65 or older) and Table 3 (for other age groups).

Table 2.3
Great Britain: Female labor force participation rates (in percent) by age over time.

Age (in years)	1891	1901	1911	1921	1931[d]	1951	1961	1971	1981
< 20[a]				48.4	70.5	78.9	71.1	55.9	56.4
20–24[b]	58.4	56.7	61.9	62.4	65.1	65.4	62.0	60.1	69.3
25–44	29.5	27.2	24.3	28.4	30.9	36.1	40.8	50.7	59.5
45–64	24.6	21.1	21.6	20.1	19.6	28.7	37.1	50.2	51.9
≥ 65	15.9	13.4	11.5	10.0	8.2	5.3	5.4	6.4	3.7
All[c]				32.3	34.2	34.7	37.4	42.7	45.6

[a]12–19 years old (1921), 14–20 years old (1931), or 15–19 years old (1951–81).
[b]21–24 years old (1931) or 20–24 years old (1891–1921, 1951–81).
[c]Age 12 or older for 1921; age 14 or older for 1931; age 15 or older for 1951–81.
[d]No census conducted in 1941.
Sources:
1891–1961: Department of Employment and Productivity, *British Labour Statistics Historical Abstract 1886–1968*, London: HMSO, 1971, Table 109, pp. 206–207.
1971: *Census 1971*: *Great Britain*, *Economic Activity*, Part 1, Table 1.
1981: *Census 1981*: *Great Britain General Tables*, Table 12.

433

Table 2.4
Germany: Female labor force participation rates: (in percent) by age over time.

Age (in years)	1895[c]	1907[c]	1925[c]	1939[c]	1939[d]	1946[d]	1950[d]	1960[d]	1970[d]	1981[d]
14/15–19[a]	60.6	67.8	67.2	79.2	81.3	75.7	67.3	75.7	64.4	40.4
20–24	58.3	62.0	67.8	67.8	68.6	53.7	70.4	75.6	67.1	71.0
25–44	26.9	37.6	41.9	45.8	44.2	37.0	40.5	46.4	47.6	58.4
45–64	25.6	35.5	36.3	36.4	36.9	29.1	31.0	33.5	35.5	39.8
≥ 65	19.7	21.6	17.6	14.1	17.3	13.3	9.7	8.2	5.8	2.8
All[b]	36.2	44.1	45.7	45.5	46.1	38.0	39.3	41.5	38.2	39.8

[a]15–19 years old (1891–1950) or 15–19 years old (1960–81).
[b]Age 14 or over for 1891–1950; age 15 or over for 1960–81.
[c]Post-World War I boundaries, excluding Saar.
[d]Boundaries of Federal Republic of Germany, excluding Berlin.

Sources:
1895–1950: Long (1958, Table A-16, p. 313).
1960: *Statistiches Jahrbuch 1962*, Table 2, p. 143.
1970, 1981: ILO, *Yearbook of Labour Statistics*, 1975 (Table 4, p. 39) and 1982 (Table 4, p. 29).

Table 2.5
United States: Female labor force participation rates (in percent), by marital status and year.

	Married	Single	Widowed/Divorced
1890	4.6	43.1	29.9
1900	5.6	45.9	32.5
1910	10.7	54.0	34.1
1920	9.0	–	–
1930	11.7	55.2	34.4
1940	13.8	53.1	33.7
1950	21.6	53.6	35.5
1960	31.8	50.7	36.1
1970a	38.2	47.5	35.0
1970b	40.8	53.0	39.1
1980	40.8	61.5	44.0

Sources:
1890–1950: Long (1958, Table A-6, p. 297). Refers to persons age 16 or older.
1960: U.S. Department of Commerce, Bureau of the Census, *U.S. Census of Population 1960, Employment Status and Work Experience*, Table 4, p. 24. (Original data given for age 14 or older; figures in text calculated on assumption that half those age 14–17 were age 14–15 so as to refer to persons age 16 or older.)
1970a: U.S. Department of Commerce, Bureau of the Census, *U.S. Census of Population 1970, Employment Status and Work Experience*, Table 3, p. 37. Refers to persons age 16 or older.
1970b, 1980: U.S. Department of Labor, *Employment and Training Report of the President*, Table B-1, pp. 209–210. Data from March Current Population Survey for persons age 16 or older.

Table 2.6
Canada: Female labor force participation rates (in percent), by marital status and year.

	Married	Single	Widowed/Divorced
1921	21.5	48.1	21.7
1931	3.5	50.6	20.5
1941	3.8	60.1	20.2
1951	11.2	62.2	19.4
1961	22.0	54.2	23.0
1971	36.9	53.4	26.5
1981	51.9	61.8	31.3

Sources:
1921–51: Long (1958, Table A-12, p. 307). Refers to persons age 16 or older.
1961: *Census of Canada 1961*, Vol. III, Part 1, Table 17 (p. 17) and Vol. I, Part 3, Table 78 (p. 1). Refers to persons age 15 or older.
1971: *Census of Canada 1971*, Vol. III, Part 7, Table 6 (p. 1). Refers to persons age 15 or older.
1981: *Census of Canada 1981*, Vol. I–National Series, Table 1 (p. 1). Refers to persons age 15 or older.

and in almost all individual age groups (except for those 65 or over). Germany is to some extent an exception, for its aggregate female participation rate has changed little since 1946. The constancy of Germany's aggregate female participation rate is the net result of sizeable increases in participation among those age 25–64 accompanied by sizeable decreases for the young and the elderly.

Most of the increase in the aggregate female participation rate in recent years is attributable to an increase in the participation rate of married women, as shown in Tables 2.5–2.8, for the United States, Canada, Great Britain and Germany, respectively. Indeed, as shown in Tables 2.5 and 2.7, the participation rate of single women has actually declined somewhat in the United States and Britain, respectively. Table 2.8, for Germany, provides essentially the same evidence albeit for the more heterogeneous group of "nonmarried" (single, widowed or divorced) women. Moreover, as Tables 2.5–2.8 indicate, participation has increased markedly for married women, although the participation rate of married women remains lower than that of other women.

The substantial increase in participation among women, particularly married women, stands in sharp contrast with the secular decline in male participation rates. As Pencavel (Chapter 1 in this Handbook) notes, male participation rates in developed economies have generally been falling – both in the aggregate and for most age groups – since at least the first quarter of the twentieth century. (See Pencavel's Tables 1.1–1.4, analogous to our Tables 2.1–2.4.)

Table 2.7
Great Britain: Female labor force participation rates (in percent), by marital status and year.

	Married	Single	Widowed/Divorced
1911	9.6	70.1	29.4
1921	8.7	72.5	25.5
1931	10.1	74.0	21.2
1951	21.5	73.7	20.9
1961	30.1	69.4	22.8
1971	42.9	61.5	23.6
1981	47.2	60.8	22.9

Sources:
1911–51: Long (1958, Table A-10, p. 304). Refers to persons age 16 or older.
1961: *Census 1961 Great Britain Summary Tables*, Table 32, p. 76. Refers to persons age 15 or older.
1971: *Census 1971 Great Britain Advance Analysis*, Table 1, p. 1. Refers to persons age 15 or older.
1981: *Census 1981: Economic Activity Great Britain* (10 percent sample), Table 48. Refers to persons age 15 or older.

434

On the other hand, weekly hours by women workers appear to have been falling secularly, as shown for the United States in Tables 2.9 (for manufacturing) and 2.10 and 2.11 (for the entire economy) and for Britain in Table 2.12. This decline in weekly hours worked by women workers parallels the decline in weekly hours worked by men that is documented by Pencavel (see his Tables 1.7–1.9 and 1.12, analogous to our Tables 2.9–2.12).

Considered alongside the substantial secular increase in women's participation rates, these secular reductions in hours of work raise several interesting questions. First, has the secular reduction in weekly hours worked by women workers been enough to offset the secular increase in the female participation rate and reduce the total number of hours of market work of women? One may address this question using Owen's (1985) constructed measure of "total" weekly labor supply, "labor input per capita", computed as the product of the employment–population ratio and weekly hours worked by employed workers. The time series behavior of Owen's measure of female labor input per capita is presented in Table 2.13. As shown there, Owen's total female labor supply measure has approximately doubled among women age 25–64, has increased slightly among women age 20–24 and has declined only for the youngest (age 14–19) and oldest (65 or over) women.

Thus, the secular decline in female weekly hours worked has dampened, but has by no means fully offset, the effect of the secular increase in female

Table 2.8
Germany: Female labor force participation rates (in percent), by marital status and year.

	Married	Single	Widowed/ Divorced
1895[a]	12.0	60.7	
1907[a]	26.0	63.7	
1925[a]	28.7	64.7	
1933[a]	29.2	62.1	
1939[a]	32.7	62.5	
1939[b]	30.6	67.6	
1950[b]	25.0	57.7	
1961[b]	32.4	37.5	23.3
1970[b]	35.6	27.0	21.6
1980[b]	40.6	28.2	19.3

[a] Post-World War I boundaries, excluding Saar.
[b] Boundaries of Federal Republic of Germany, excluding Berlin
Sources:
1895–1950: Long (1958, Table A-17, p. 314). Refers to persons age 16 or older.
1961: *Statistiches Jahrbuch 1963*, p. 140. Refers to persons age 14 or older.
1970: *Statistiches Jahrbuch 1971*, p. 122. Refers to persons age 15 or older.
1980: *Statistiches Jahrbuch 1981*, p. 94. Refers to persons age 15 or older.

participation in the labor force and in employment. On balance, the trend in total weekly labor input of women is clearly positive. Moreover, although participation and weekly hours of work are two of the most easily measured aspects of labor supply, they do not measure all aspects of labor supply. In particular, it is important to consider weeks worked per year as well. (We provide indirect evidence on this topic below.)

The fact that weekly hours worked by women workers have fallen even as women's labor force participation has risen also poses a subtle question concerning within-cohort as opposed to across-cohort effects. The most obvious and straightforward interpretation of the secular decline in women's weekly hours of work is that hours worked per week by women workers have indeed fallen across successive cohorts. However, the decline in weekly hours worked has been accompanied by a substantial increase in participation, and this raises the question of whether the decline in weekly hours worked may be at least partly a consequence of the addition of "low-hours" women, *within each cohort*, who would not be working had participation not increased. In other words, if increased participation amounts to an influx of part-time workers (e.g. because

Table 2.9
United States: Percentage distribution of weekly hours in manufacturing industry by employed females for the Decennial Censuses of Population, by year.

Hours worked	1940	1950	1960	1970	1980
≤ 34	21.4	13.1	16.5	19.2	14.9
35–39	8.8	8.1	12.4	10.9	70.0
40	51.2	68.8	60.4	59.2	
41–48	17.7	8.7	9.1	8.3	
49–59	0.7	1.0	1.2	1.7	15.1
≥ 60	0.3	0.3	0.5	0.7	

Notes:
1940–50 data refer to wage and salary workers only;
1960–80 data refer to all employed persons.
1940–60 data refer to persons age 14 or older;
1970–80 data refer to persons age 16 or older.
"Hours worked" refers to hours worked during Census survey week.
Sources:
1940: *Sixteenth Census of the United States 1940*: *Population*, *Vol. III: The Labor Force*, Part I: U.S. Summary, Table 36, p. 259.
1950: 1950 Census of Population, *Industrial Characteristics*, Table 11.
1960: 1960 Census of Population, *Industrial Characteristics*, Table 9.
1970: 1970 Census of Population, *Industrial Characteristics*, Table 39.
1980: 1980 *Census of Population*, Vol. 1, *Characteristics of the Population*, Chapter D, Detailed Population Characteristics, Part 1, United States Summary, Section A: United States, Table 288.

435

greater availability of jobs with flexible hours has made work more attractive than before), then *average* hours worked may well fall even if hours worked by those *already* in the labor force stay the same or even rise.

Unfortunately, developing evidence on this issue is quite difficult: there are no data on the number of hours that a woman not now participating in the labor force *would* work *if* she were to work, must less data showing how this number has changed over time.

It does, however, seem clear that successive cohorts of women have generally supplied steadily increasing amounts of labor, where "labor supply" is defined as participation in the labor force, employment, weekly hours worked by the total population or annual hours worked (by either the working population or the total population). First, as shown in Table 2.14 and Figure 2.1, respectively, participation in the labor force and in paid employment have increased in successive cohorts of U.S. women: in general, more recent cohorts are more oriented

Table 2.10
United States: Percentage distribution of hours worked of employed females during the census week from the Decennial Census of Population, by Year.

Hours worked	1940[a]	1950	1960	1970	1980[b]
1–14	2.9	4.6	9.8	9.3	
15–29	8.3	10.0	11.4	13.5	30.8
30–34	7.0	6.0	6.5	8.7	
35–39	8.2	7.5	11.6	11.6	56.4
40	31.1	45.4	42.7	44.8	
41–48	27.7	17.2	11.8	7.7	
49–59	6.9	4.6	3.0	2.3	12.8
≥ 60	7.9	4.8	3.3	2.1	

[a] For 1940, figures refer to wage and salary workers only (for all other years, figures refer to all employed persons). The categories "1–14" and "15–29" for 1940 mean "under 14" and "14–29."
[b] For 1940–70, figures refer to persons age 14 or older; for 1980, figures refer to persons age 16 or older. In all cases, figures refer to persons employed during Census week.
Sources:
1940: *Sixteenth Census of the United States*: *1940*, *Vol. III*, *The Labor Force*, Part 1: U.S. Summary, Table 86, p. 259.
1950: *U.S. Census of Population 1950*, *Vol. IV*, *Special Reports*, Part I, Chapter A, Employment and Personal Characteristics, Table 13.
1960: *U.S. Census of Population 1960 Subject Reports*, Employment Status and Work Experience, Table 12.
1970: *U.S. Census of Population 1970 Subject Reports*, Employment Status and Work Experience, Table 17.
1980: 1980 *Census of Population*, Vol. 1, *Characteristics of the Population*, Chapter D, Detailed Population Characteristics, Part 1, United States Summary, Section A: United States, Table 288.

towards market work than were earlier cohorts. Moreover, among the most recent cohorts there appears to have been a dampening or even a disappearance of the decline in market activity at childbearing and childrearing ages that was characteristic of earlier cohorts. Table 2.15 and Figure 2.2 show data on employment rates by cohort for Britain that tell a story similar to the one in Table 2.14 and Figure 2.1, which refer to the United States.

A final piece of evidence on the behavior of successive cohorts appears in Tables 2.16 and 2.17, which present alternative measures of "total" labor supply (defined to include both employment and hours worked) for successive cohorts of U.S. women. [See also Smith (1983), who presents more detailed calculations for the shorter period 1977–81.] Table 2.16 presents Owen's (1985) series on total weekly labor input per capita by cohort, in which total labor supply is defined as the product of the employment rate and weekly hours worked by working women. Although it is obviously too early in the "lifetime" of the 1960 cohort to

Table 2.11
United States, 1955–82, and United Kingdom, 1939–82:
Average weekly hours worked.

	United Kingdom: All adults	United States: Females					
		All	14/16–17 years	18–24 years	25–44 years	45–64 years	≤ 65 years
1938	47.7						
1940–44	46.9						
1950–54	47.9						
1955–59	48.4	36.4	20.0	37.1	37.0	37.7	33.8
1960–64	47.5	35.3	16.2	35.9	35.8	37.1	31.9
1965–69	46.4	36.2	17.2	35.8	36.6	38.3	33.5
1970–74	45.2	34.2	18.8	33.1	34.8	35.9	29.0
1975–79	44.0	34.2	19.2	32.7	35.3	35.5	27.0
1980–82	43.0	34.1	18.4	32.5	35.4	35.2	27.5

Notes: The U.K. data relate to full-time manual workers and are taken from each October's earnings and hours enquiry of the major industries. The data are published in various issues of the *Ministry of Labour Gazette* and of the *Department of Employment Gazette*. The United States data derive from household interviews in the Current Population Survey and measure the average hours actually worked (not those paid for) of female employees in nonagricultural industries at work. (Consequently, those absent from work because of illness, vacation, or strike are not represented in these figures.) For the years 1955–58, the data are published in the *Current Population Reports*, Labor Force Series P-50, issues number 63 (Table 3), 72 (Table 18), 85 (Table 18), and 89 (Table 24). For the years 1959–64, the data are from *Special Labor Force Reports*, Table 0-7 of each issue, Report numbers 4, 14, 23, 31, 43, and 52. For the years 1965–82, the data are taken from each January's issue of *Employment and Earnings* which give the figures for the preceding year. Before 1967, the youngest age group relates to those aged 14–17 years and from 1967 it relates to 16–17 years.

be sure, Table 2.16 suggests that total weekly labor supply may well be higher (at least between the ages of 25 and 64) for more recent cohorts than it was for earlier cohorts.

Table 2.17 presents two series on cohort *annual* labor supply derived by Smith and Ward (1984, 1985). The first panel refers to annual hours worked by working women (calculated as the product of weekly hours worked times weeks worked per year among women who work). It suggests that, at a minimum, *annual* hours worked by working women have not fallen at the same rate as *weekly* hours worked: evidently, the secular downtrend in the latter has been offset to a considerable extent by a secular increase in weeks worked per year. The second panel of Table 2.17 provides analogous information by cohort on "total" annual labor supply, i.e. the product of the employment–population ratio and annual hours worked by working women. Although the changes in total annual labor supply across cohorts are somewhat uneven, there is some indication that total annual labor supply is higher among more recent cohorts (though the increase in

Table 2.12
Great Britain: Percentage distribution of weekly hours worked
by female employees in 1968, 1977 and 1981.

	September 1968	April 1977	April 1981
$0 < h \leq 24$	20.4	22.7	24.3
$24 < h \leq 30$	10.7	12.4	11.7
$30 < h \leq 35$	10.9	13.1	13.3
$35 < h \leq 37$	9.9	16.5	16.7
$37 < h \leq 39$	15.8	10.7	17.1
$39 < h \leq 40$	15.4	18.9	12.0
$40 < h \leq 42$	9.2	1.9	1.6
$42 < h \leq 44$	3.1	1.4	1.1
$44 < h \leq 46$	1.8	0.8	0.7
$46 < h \leq 48$	1.4	0.6	0.6
$48 < h \leq 50$	0.5	0.3	0.3
$50 < h \leq 54$	0.5	0.3	0.3
$54 < h \leq 60$	0.3	0.2	0.2
$60 < h \leq 70$	0.1	0.1	0.1
$70 < h$	0.0	0.0	0.1

Notes: These data cover all women (both manual and nonmanual workers) whose pay for the survey period was not affected by absence.

Sources:
1968: Department of Employment and Productivity. *New Earnings Survey 1968*, H.M.S.O., 1970, Table 83, p. 120.
1977: Department of Employment, *New Earnings Survey 1977, Part A: Report and Key Results*, H.M.S.O., 1977, Table 27, p. A35.
1981: Department of Employment, *New Earnings Survey 1981, Part A: Report and Key Results*, H.M.S.O., 1981, Table 27, p. A90.

Table 2.13
United States: Female labor input per capita
in selected years, 1920–77, by age.

Age	1920	1930	1940	1950	1955	1960	1965	1970	1977
14–19	12.4	9.0	6.2	9.3	8.4	6.8	6.2	6.8	8.0
20–24	17.6	18.3	17.3	16.6	16.5	16.0	17.1	18.7	20.8
25–44	10.1	10.7	11.0	13.2	13.7	13.6	14.5	15.3	19.5
45–64	8.1	8.3	8.4	12.1	14.3	15.9	16.8	17.1	16.5
≥ 65	3.9	3.7	2.8	3.4	3.7	3.4	3.0	2.8	2.1

Source: Owen (1985, Table 1.3). "Labor input per capita" calculated by multiplying proportion of population employed times weekly hours of work by employed workers.

Table 2.14
United States: Female labor force participation rates by age for successive female birth cohorts.

Birth Cohort	Ages: 15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64
1886–90				19.8		21.1		21.2	*	20.6
1891–95			27.0		22.3		23.7	*	25.9	
1896–1900		37.5		23.6		26.0	*	30.8		29.4
1901–05	28.4		30.2		28.3	*	34.8		39.7	
1906–10		41.8		30.9	*	36.4		45.9		36.4
1911–15	22.8		35.5	*	33.8		47.4		47.6	
1916–20		45.6	*	31.0		45.3		52.4		41.4
1921–25	18.9	*	32.6		40.2		53.3		41.4	
1926–30		42.9		35.5		52.4		61.1		
1931–35	22.6		35.0		48.7		61.1			
1936–40		44.9		44.6		66.8				
1941–45	23.9		45.7		66.8					
1946–50		56.3		66.7						
1951–55	22.5		66.7							
1956–60		69.6								

Note: Birth cohorts 1916–20 to 1936–40 are mothers of the baby boom generations.
* Denotes ages of each birth cohort during World War II.
Source: Smith and Ward (1984, p. 8).

total annual labor supply, relative to earlier cohorts, is not nearly as dramatic as the increase in participation rates shown in Table 2.14).

Although the quantitative changes in female labor supply documented in Tables 2.1–2.17 are quite remarkable, the twentieth century has also seen striking qualitative changes in female labor supply, both in absolute terms and relative to men. In particular, in the United States the growth in the amount of female labor supply has been accompanied by a pronounced shift in its character: to a much greater extent than was true at the turn of the century, the representative woman worker today holds a white-collar – particularly a clerical – job. To some extent this simply reflects the economy-wide growth in the importance of white-collar work, but that is not the only factor, for the influx of women into white-collar (especially clerical) work occurred at a faster rate than did that of men.

Table 2.18 documents the changing occupational distribution of the male and female work force in the United States and shows that 20.2 percent of all women workers held white-collar jobs in 1900, versus 65.6 percent in 1980. Thus, the proportion of women in such jobs more than trebled over the period 1900–80, whereas the proportion of men in such jobs increased by a factor of only about 2.4. The proportion of men in clerical jobs increased by a factor of about 2.3, whereas the proportion of women in such jobs increased by almost ten-fold!

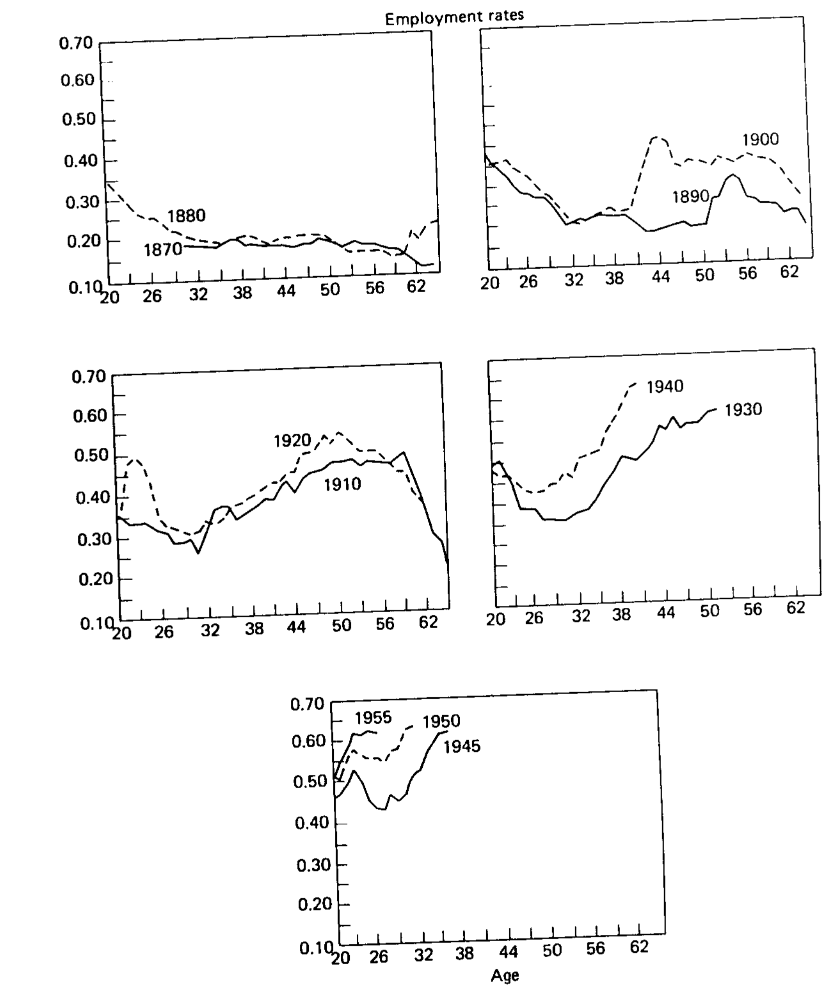

Figure 2.1. Employment–population ratios by age for successive female birth cohorts, 1870–1955, United States. *Source*: Smith and Ward (1984, p. 7).

Table 2.15
Great Britain: Employment–population ratios by age for successive female birth cohorts, 1920–60.

Birth cohort	Age 15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59
1920–24	90	71	40	37	46	55	63	66	55
1925–29	89	63	39	40	51	62	70	65	
1930–34	90	65	39	39	51	70	73		
1935–39	93	66	41	46	65	73			
1940–44	91	60	41	50	69				
1945–49	90	66	50	56					
1950–54	88	69	49						
1955–59	85[a]	63[a]							
1960–64	78								

[a]Age 16–19 only.
Source: Martin and Roberts (1984, Table 9.1, p. 117), derived from 1980 Department of Employment/Office of Population Censuses and Survey Women and Employment Survey. Full-time students excluded from all calculations.

Finally, note that the proportion of women in blue-collar and service jobs fell during 1900–80 while the proportion of men in both kinds of jobs rose. Thus, both in absolute terms and relative to men, the concentration of women in white-collar (especially clerical) jobs has increased, whereas the concentration of women in blue-collar and service jobs has decreased over the period 1900–80.

We conclude this discussion of secular trends in female labor supply by briefly considering educational attainment, marital status and fertility. First consider schooling. As shown in Tables 2.19 and 2.20, there has been a substantial increase in educational attainment of successive female cohorts in the United States and in Britain, respectively. Moreover, as Table 2.19 indicates, although median educational attainment for U.S. women has increased only slightly over time among cohorts born since 1926–30, the proportion of women with four or more years of college in successive cohorts born since that date has gone up by more than 50 percent.

If the phrase "dramatic trends" provides a nutshell characterization of women's educational attainment and labor supply, "dramatic fluctuations" provides a suitable description of the behavior of fertility and the distribution of women by marital status during the period 1890–1980. Table 2.21 documents the behavior of the distribution of women by marital status in the United States. There has clearly been a secular increase in the proportion of women in the "other" category (which consists for the most part of divorced women), but otherwise the most noteworthy feature of women's marital status distributions in the United States has been the degree to which they have fluctuated. In 1980, the proportion never married and the proportion currently married were both approximately

438

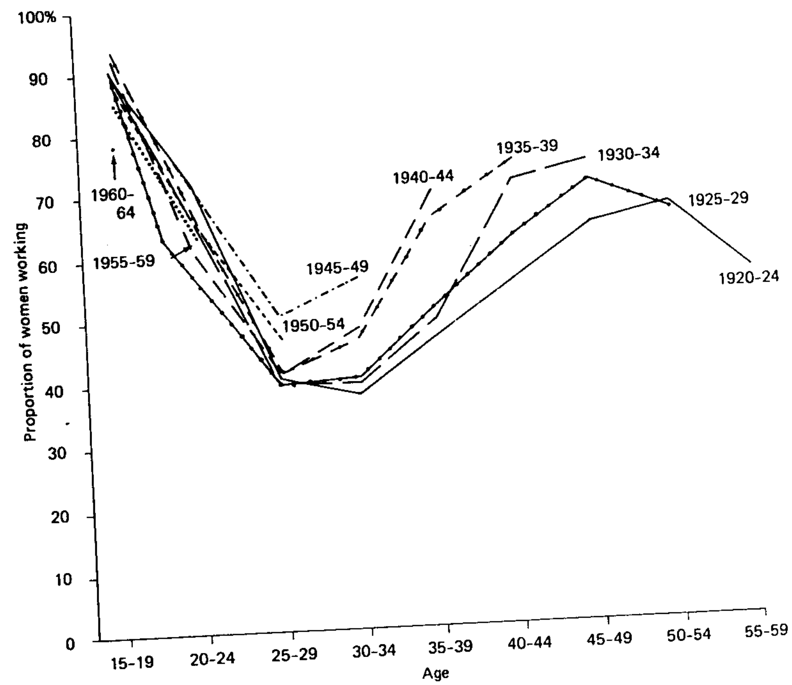

Figure 2.2. Employment–population ratios by age for successive female birth cohorts, 1920–60, Great Britain. *Source*: Martin and Roberts (1984, p. 119).

Table 2.16
United States: Labor input per capita by age for selected female cohorts.

Year entered labor force	14–19	20–24	25–44	45–64	> 65
1880	–	–	10.2	8.1	3.7
1900	14.1	18.6	10.1	8.4	3.4
1920	12.4	18.0	11.6	14.9	2.8
1940	6.2	17.9	13.7	16.5	–
1960	6.8	17.1	20.8	–	–
1977	8.0	–	–	–	–

Source: Owen (1985, Table 1.4). See notes to Table 2.13 for calculation of labor input per capita. Year of entry into labor force obtained by transforming age ranges as follows: 14–19 = 17; 20–24 = 22; 25–44 = 34; 45–64 = 54; 65 and over = 67. Estimates for intermediate years obtained by linear interpolation.

Table 2.17
United States: Annual hours worked, by age, selected female birth cohorts.

Birth Cohort	16	20	25	30	35	40	45	50	55	60	64
						Annual hours worked by working women					
1902								1627	1580	1620	1633
1910						1496	1591	1565	1605	1511	1294
1918					1479	1456	1506	1636	1726	1620	
1926			1416	1402	1379	1471	1531	1524	1600		
1934	485	1339	1285	1296	1352	1483	1554				
1942	368	927	1382	1328	1391						
1950	298	1136	1426	1480							
						Annual hours worked by all women					
1902								774	789	742	639
1910						723	859	914	877	765	375
1918					686	765	895	900	929	693	
1926			716	627	679	832	942	895	924		
1934	169	861	656	626	800	930	1084				
1942	139	639	784	709	924						
1950	118	837	974	1081							

Source: Smith and Ward (1984, p. 85).

439

equal to what they were in 1890, but each of these ratios has varied substantially during the period 1890–1980. For example, in both 1890 and 1980 slightly less than half of the women age 20–24 were married, but in 1960 almost 70 percent of the women in this age group were married.

Figure 2.3 plots age-specific fertility rates for the ages between 20 and 30 for cohorts of U.S. women between 1890 and 1950. As shown there, fertility rates rose substantially starting with the 1920 cohort (the 1910 cohort was in the relevant age range during the years of the Great Depression, which is probably a major reason why its fertility was below that of the 1900 cohort). However, starting with the 1940 cohort, fertility began to fall again; indeed, the pattern of fertility by age for the 1950 cohort was almost identical to that of the 1910 cohort.

Although we have frequently referred to the patterns shown in Figures 2.1–2.3 and Tables 2.1–2.21 as "trends", they are actually just sets of time-series patterns and, as such, combine not only secular but also cyclical factors. For a rough and ready decomposition of observed time series into trend and cycle, we follow Pencavel (Chapter 1 in this Handbook) in regressing first differences in the labor force participation rate of a given female group (whites age 16–17, all nonwhites, etc.) on contemporaneous first differences in the unemployment rate of white males age 35–44, using annual data for 1955–82. As Pencavel notes, the intercept

Table 2.18
United States: Occupational distribution of workers by sex and year.

	1900	1910	1920	1930	1940	1950	1960	1970	1980
					Women				
White collar	20.2	26.0	38.5	44.3	44.9	52.3	55.3	60.5	65.6
Professional, technical	8.2	9.5	11.7	13.6	12.8	12.2	12.4	14.5	16.8
Managerial, administrative	1.6	2.0	2.4	2.7	3.3	4.3	5.0	4.5	6.9
Sales	4.4	5.0	6.3	6.8	7.4	8.6	7.7	7.0	6.8
Clerical	3.8	9.0	18.5	20.8	21.4	27.2	30.3	34.5	35.1
Blue collar	27.9	25.5	23.9	19.9	21.8	22.2	16.6	16.1	13.8
Craft	1.6	1.5	1.0	1.0	1.2	1.4	1.0	1.1	1.8
Operatives	24.0	23.0	20.0	17.2	19.3	20.1	15.2	14.5	10.7
Nonfarm laborers	3.3	1.5	2.4	1.4	1.2	0.7	0.4	0.5	1.2
Service	35.5	32.5	23.9	27.6	29.2	21.5	23.7	21.7	19.5
Farm	19.1	16.0	13.6	8.6	4.1	3.6	4.4	1.8	1.2
					Men				
White collar	17.6	20.1	21.4	25.2	26.7	30.5	37.4	41.0	42.4
Professional, technical	3.4	3.5	3.8	4.9	5.8	7.2	10.9	14.0	15.5
Managerial, administrative	6.9	7.8	7.8	8.7	8.6	10.5	13.6	14.2	14.4
Sales	4.5	4.6	4.5	6.2	6.5	6.4	5.8	5.6	6.0
Clerical	2.8	4.4	5.3	5.5	5.8	6.4	7.2	7.1	6.4
Blue collar	37.6	41.2	44.5	45.2	45.7	48.4	46.5	47.0	44.8
Craft	12.6	14.1	16.0	16.2	15.5	19.0	19.0	20.1	21.0
Operatives	10.4	12.5	14.5	15.4	18.1	20.5	19.6	19.6	16.8
Nonfarm laborers	14.7	14.6	14.1	13.6	12.2	8.7	7.9	7.3	7.0
Service	3.1	3.9	3.8	4.7	6.1	6.2	6.5	6.7	8.8
Farm	41.6	34.8	30.4	24.8	21.7	15.0	9.6	5.3	4.0
					Women / men				
White collar	1.15	1.29	1.80	1.76	1.68	1.71	1.48	1.48	1.55
Professional, technical	2.41	2.71	3.08	2.78	2.21	1.69	1.14	1.04	1.08
Managerial, administrative	0.23	0.25	0.31	0.31	0.38	0.41	0.37	0.33	0.48
Sales	0.98	1.09	1.40	1.10	1.14	1.34	1.33	1.25	1.13
Clerical	1.36	2.05	3.49	3.78	3.69	4.25	4.21	4.86	5.48
Blue collar	0.74	0.61	0.53	0.44	0.47	0.46	0.36	0.34	0.30
Craft	0.13	0.11	0.06	0.06	0.08	0.07	0.05	0.05	0.09
Operatives	2.31	1.84	1.38	1.12	1.06	0.98	0.77	0.73	0.64
Nonfarm laborer	0.22	0.10	0.17	0.10	0.10	0.08	0.05	0.07	0.17
Service	11.45	8.33	6.29	5.87	4.79	3.47	3.65	3.23	2.21
Farm	0.46	0.46	0.45	0.34	0.19	0.24	0.45	0.34	0.30

Note: Figures in the panel labelled "Women" ("Men") show the proportion of all women (men) in the indicated occupational category in the indicated year. Figures in the panel labelled "Women/Men" show the ratio of the female to the male proportion for the indicated occupational category for the indicated year.

Sources:
1900–50: *Employment and Training Report of the President 1976*, p. 387 (summary of Census data). Due to rounding, figures for individual categories may not sum to totals shown.
1960–80: *Statistical Abstract of the United States, 1981*, Table 673, p. 401 (summary of Census data).

Table 2.19
United States: Schooling completed by the female population, by age, 1980.

Years of age in 1980	Year of birth	Median years of school completed	Proportion of cohort whose highest schooling level completed was: ≥ 4 years of college	≥ 2 years of college	≥ 4 years of high school	≥ 8 yrs of elementary school	≥ 5 years of elementary school
≥ 75	≤ 1905	8.9	6.4	12.3	34.3	72.8	89.6
70–74	1906–10	10.6	8.1	14.8	41.5	79.4	93.5
65–69	1911–15	11.4	7.6	13.9	46.0	82.8	94.8
60–64	1916–20	12.1	7.8	14.3	53.8	86.9	96.0
55–59	1921–25	12.3	8.2	15.7	60.8	89.5	96.6
50–54	1926–30	12.3	9.9	18.0	64.2	91.2	97.1
45–59	1931–35	12.4	11.2	19.7	69.1	92.6	97.5
40–44	1936–40	12.5	13.1	22.4	73.6	94.4	98.1
35–39	1941–45	12.6	16.4	26.9	78.5	95.8	98.6
30–34	1946–50	12.8	20.2	32.4	83.3	96.6	98.8
25–29	1951–55	12.8	20.5	34.0	84.7	97.3	99.0

Source: 1980 *Census of Population*, Vol. 1, *Characteristics of the Population*, Chapter D, Detailed Population Characteristics, Part 1, United States Summary, Section A: United States, Table 262.

in these regressions is an estimate of the secular trend in a given group's labor force participation rate, and the coefficient on the male unemployment variable is a measure of the group participation rate's cyclical sensitivity.

The results of this exercise appear in Table 2.22. In general, there is a strong secular uptrend in the participation rates of most female groups (as measured by the size and significance levels of the intercept parameter, a), especially among

Table 2.20
Great Britain: Highest educational qualification attained by female population in 1981 by age.

Age in 1981	Year of birth	Percentage of cohort whose highest educational qualifications were at the level of: Higher education	Middle education	Lower Education
≥ 65	≤ 1916	1.1	2.3	96.6
60–64	1917–21	1.2	3.3	95.5
50–59	1922–31	2.1	4.4	93.5
40–49	1932–41	3.6	6.3	90.1
30–39	1942–51	5.5	7.1	87.4
25–29	1952–66	8.1	8.1	83.8

Notes: "Higher education" includes university degrees and equivalent professional qualifications. "Middle education" includes qualifications beyond the GCE "A" level but below first degree level. "Lower education" means no qualifications attained beyond GCE "A" level.
Source: Office of Population Censuses and Surveys, *Census of 1981: Qualified Manpower Tables* (10 percent sample), Table 1.

Table 2.21
United States: Marital status of women by age and year, in percent.

Year	Ages 20–24: Never married	Currently married	Other	Ages 25–29: Never married	Currently married	Other
1890	51.8	46.7	1.4	25.4	71.4	3.2
1910	48.3	49.7	1.7	24.9	71.8	2.8
1930	46.0	51.6	2.1	21.7	74.3	3.8
1940	47.2	51.3	1.5	22.8	74.1	3.1
1950	32.3	65.6	2.1	13.3	83.3	3.4
1960	29.4	69.5	2.1	10.5	86.2	3.3
1970	36.3	60.5	3.2	12.2	82.5	5.4
1980	50.2	45.9	3.8	20.8	70.3	9.9

Source: Smith and Ward (1984, p. 15).

whites. Note that most of the intercept or secular coefficients a in Table 2.22 are larger in absolute value than are the analogous coefficients for men in Pencavel's Table 1.6.

Table 2.22 also suggests that female labor force participation is procyclical, in that the coefficient on the (change in the) male unemployment rate, b, is almost always negative and are larger in absolute value than the analogous coefficients for men reported by Pencavel. However, in most cases this relation is imprecisely estimated and would not be called significant at conventional test levels.

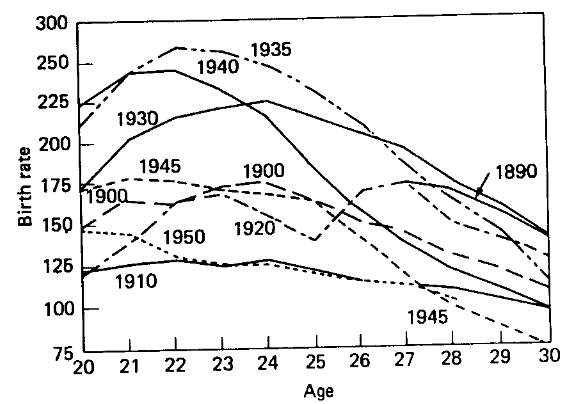

Figure 2.3. Age-specific birth rates for birth cohorts of 1890–1950, United States. *Source*: Smith and Ward (1984, p. 14).

Table 2.22
United States: Estimates of trend (a) and cycle (b) in female civilian labor force participation rates, by race and age, 1955–82.

Ages in years	*a*	*b*	R^2	D-W
		White		
Total ≥ 16	0.695*(0.080)	−0.102 (0.089)	0.05	1.09
16–17	0.652*(0.226)	−1.098*(0.297)	0.34	1.58
18–19	0.472*(0.204)	−0.198 (0.228)	0.03	1.74
20–24	0.988*(0.175)	−0.021 (0.196)	0.00	1.50
25–34	1.257*(0.183)	0.078 (0.204)	0.01	0.46
35–44	1.006*(0.136)	−0.024 (0.152)	0.00	0.74
45–54	0.781*(0.135)	−0.105 (0.150)	0.02	0.74
55–64	0.460*(0.151)	−0.189 (0.169)	0.05	0.95
≥ 65	−0.039 (0.075)	−0.085 (0.084)	0.04	1.36
		Black and other		
Total ≥ 16	0.292*(0.114)	−0.067 (0.127)	0.01	1.99
16–17	0.007 (0.444)	−0.226 (0.497)	0.01	2.58
18–19	0.312 (0.601)	−0.509 (0.672)	0.02	2.43
20–24	0.434 (0.326)	−0.439 (0.364)	0.05	1.51
25–34	0.709*(0.222)	−0.292 (0.248)	0.05	2.26
35–44	0.437*(0.202)	0.405 (0.226)	0.11	1.52
45–54	0.305 (0.217)	0.219 (0.242)	0.03	1.65
55–64	0.164 (0.270)	−0.500 (0.301)	0.10	2.24
≥ 65	−0.131 (0.170)	−0.085 (0.190)	0.01	2.53

Notes: Estimated standard errors are in parentheses next to their associated regression coefficients. "D-W" is the Durbin–Watson statistic. For ease of reading, an asterisk has been placed next to those point estimates more than twice their estimated standard errors. The data are taken from the *Employment and Training Report of the President 1981* and from recent issues of *Employment and Earnings*; 28 observations are used in each regression summarized above.

Thus, Table 2.22 and recent work by Clark and Summers (1981, 1982) and Coleman (1984) suggest that female labor force participation in the United States is not very sensitive to cyclical factors. [Joshi and Owen (1985) report similar findings for Britain.] In contrast, older work, most notably Mincer's (1966), found that participation – at least among married women – is strongly procyclical in the United States. A major difference between Mincer's work and the more recent work is that the latter controls either implicitly or explicitly for possible serial correlation (e.g. by first-differencing, as in our Table 2.22, or by maximum likelihood methods, as in Clark and Summers), whereas Mincer's work did not. Moreover, the recent results replicate Mincer's finding that the participation of teenage and prime-age women is relatively sensitive to cyclical variation; the finding of cyclical insensitivity in recent work has to do primarily with women age 45 or older.

2.2. Cross-section patterns of female labor supply

Most of the tables discussed in Section 2.1 present gross or unadjusted relationships between a measure of labor supply (e.g. labor force participation) and a single variable such as age or marital status. In this section we present a set of relatively simple adjusted relationships between labor supply and such variables in cross-section, where "adjusted" means that other factors have been held constant via simple statistical procedures. Although these adjusted relationships do not necessarily constitute a behavioral labor supply function, they do shed additional light on labor supply in the limited sense of documenting multivariate associations between labor supply and a number of variables of interest.

Table 2.23 presents labor force participation equations fitted to 1960 Census microdata by Bowen and Finegan (1969) for six different groups of single and married women in the age groups 25–54, 55–64 and 65–74 (the youngest group of married women includes women age 14–24 as well). Since Bowen and Finegan used least squares regression, the results shown in Table 2.23 may be interpreted as estimates of linear probability models.

In general, the results in Table 2.23 imply that labor force participation is strongly related to educational attainment, with greater schooling being associated with increases (at a decreasing rate) in the probability of labor force participation. White single women below the age of 65 have a somewhat higher probability of participation than do black single women under 65, other things being equal; however, older white single women and all white married women have lower participation probabilities than do their black counterparts, other things being equal. Being (or having previously been) married is associated with a lower participation probability; so is having a large amount of "other income" (i.e. income other than own earnings, including transfer income).

Table 2.23 also suggests that, other things (including marital status and number of children) being equal, there is a fairly pronounced inverted-U-shaped relation between the probability of participation and age, especially among married women: among younger women – single or married – being older is associated first with increased and then with reduced participation; among older women, participation tends to decline with age. Finally, for married women age 14–54 with spouse present, the presence of children (particularly children under the age of six) reduces the probability of participation.

2.3. Some cautionary remarks

Although this section has been concerned with stylized facts about labor supply, we want to emphasize, in concluding it, that the stylized facts presented here may not necessarily say much about structural, behavioral or "causal" labor supply functions. Wage–hours combinations observed either in cross-section or over time do not necessarily trace out a behavioral ("causal") supply schedule. Rather, in general such data are the result of the interaction of both supply and demand (see, for example Chapter 1 by Pencavel in this Handbook).

Thus, examination of stylized facts is only the beginning of a behavioral analysis, not the end. Accordingly, we now turn to theoretical models of labor supply and to empirical work aimed at deriving estimates of structural, behaviorally interpretable labor supply parameters.

3. Theoretical models and female labor supply

We now consider theoretical labor supply models that are or might be used in studying female labor supply. Thus, we do not attempt to discuss comprehensively all important labor supply models: Pencavel (Chapter 1 in this Handbook)

442

Table 2.23

Ordinary least squares estimates of labor force participation equations fitted to data on individual women from the 1/1000 sample of the 1960 U.S. Census of Population.

	(1) "Single", age 25–54	(2) Married, spouse present, age 14–54	(3) "Single", age 55–64	(4) Married, spouse present, age 55–64	(5) "Single", age 65–74	(6) Married, spouse present, age 65–74
Estimate of Intercept	82.2	57.3	71.7	56.8	60.8	27.4
Years of school						
0–4	Reference	Reference	Reference	Reference	Reference	Reference
5–7	−3.0(4.4)	8.5(2.3)	13.3(5.0)	1.7(3.1)	8.8(3.9)	1.3(2.1)
8	6.5(4.3)	10.2(2.2)	15.4(4.9)	7.2(3.0)	11.3(3.8)	−0.9(2.0)
9–11	7.4(4.1)	14.0(2.1)	18.1(5.0)	9.8(3.1)	12.4(4.3)	0.9(2.3)
12	12.3(4.0)	18.8(2.1)	24.2(5.1)	14.8(3.2)	15.2(4.2)	7.2(2.4)
13–15	11.1(4.4)	21.9(2.2)	28.3(5.7)	19.9(3.6)	18.7(5.1)	3.9(3.0)
16	14.8(4.7)	27.7(2.4)	28.3(6.1)	19.2(5.1)	22.9(5.8)	13.2(3.8)
≥17	15.8(4.7)	41.6(3.2)		33.5(7.8)		
Ethnicity						
Black	Reference	Reference	Reference	Reference	Reference	Reference
Other non-white		1.6(3.6)				
White	0.6(2.2)	−6.9(1.1)	1.8(4.1)	−4.4(3.0)	−1.9(4.4)	−6.6(2.8)
Marital status						
Never married	Reference	NA	Reference	NA	Reference	NA
Separated/divorced	−2.8(2.0)	NA	−4.3(4.1)	NA	−2.4(5.0)	NA
Widowed	10.8(2.4)	NA	−7.2(3.1)	NA	−16.0(3.4)	NA
Married-spouse absent	−25.0(3.5)	NA	−13.4(6.1)	NA	−7.3(8.6)	NA
Employment status of husband						
Unemployed	NA	Reference	NA	Reference	NA	Reference
Working	NA	−6.1(1.7)	NA	6.9(4.2)	NA	−8.5(5.3)
Not in labor force	NA	−4.6(2.3)	NA	−7.4(1.9)	NA	−9.3(1.4)

Table 2.23 continued

	(1) "Single", age 25–54	(2) Married, spouse present, age 14–54	(3) "Single", age 55–64	(4) Married, spouse present, age 55–64	(5) "Single", age 65–74	(6) Married, spouse present, age 65–74
Other income						
< $0	Reference		Reference		Reference	Reference
1–499	4.2(2.2)	Reference	−1.0(3.4)	Reference	−10.0(4.1)	
500–999	−20.4(3.3)		−34.2(3.5)		−22.7(3.5)	
1000–1999		−5.6(2.4)	−48.0(4.0)	−10.5(4.1)	−34.5(3.7)	−4.6(2.8)
2000–2999		−2.3(2.2)	−54.1(6.2)	−14.2(4.1)	−41.2(5.6)	−3.9(2.8)
3000–3999		−4.2(2.1)		−15.5(4.1)	−43.8(5.8)	−9.5(3.0)
4000–4999		−5.0(2.1)		−20.0(4.1)		−11.9(3.2)
5000–5999		−9.0(2.0)		−18.2(4.1)		−8.3(3.3)
6000–6999	−21.1(3.2)	−12.5(2.1)		−25.5(4.2)		−5.7(3.6)
7000–8999		−18.9(2.1)	−63.3(6.1)	−26.7(4.1)	−44.7(6.9)	−9.6(3.2)
9000–10999		−23.4(2.2)		−34.3(4.5)		−11.1(4.0)
11000–14999		−27.4(2.3)		−32.5(4.5)		−6.5(3.7)
15000–24999		−36.7(2.5)		−34.0(5.0)		−7.9(4.0)
≥ 25000		−52.2(3.3)		−54.3(6.0)		
Age						
14–19/55/65	NA	Reference		Reference	Reference	
20–24/56/66	NA	9.9(2.2)	Reference	−4.0(3.1)		Reference
25–29/57/67	Reference	10.8(2.2)		−6.9(3.0)	−6.4(3.5)	
30–34/58/68	0.1(3.3)	10.0(2.2)		−8.5(3.2)		
35–39/59/69	3.4(3.2)	10.5(2.2)	−6.6(3.2)	−7.3(3.0)		−2.9(1.5)
40–44/60/70	2.0(3.0)	8.5(2.3)		−15.2(3.2)	−13.6(3.1)	
45–49/61/71	1.3(3.0)	3.6(2.3)	−11.6(3.0)	−15.9(3.2)		
50–54/62/72	2.4(2.9)	−5.4(2.3)		−15.9(3.4)		−4.9(1.6)
–/63/73	NA	NA	NA	−20.6(3.4)	−16.5(3.3)	
–/64/74	NA	NA	NA	−22.7(3.3)		
Presence (P) or absence (A) of children age < 6/6–13/14–17						
A/A/A	–	Reference	–	–	–	–
P/A/A	–	−42.8(1.1)	–	–	–	–
P/P/A	–	−41.1(1.2)	–	–	–	–
P/A/P	–	−32.5(2.2)	–	–	–	–
P/P/P	–	−35.4(1.5)	–	–	–	–
A/P/A	–	−19.9(1.3)	–	–	–	–
A/P/P	–	−19.6(1.2)	–	–	–	–
A/A/P	–	−2.7(1.0)	–	–	–	–
F-ratio	13.5	113.0	27.4	10.5	14.1	5.4
nobs	1,662	22,021	1,215	3,464	1,243	1,725
modv	86.8	35.8	62.9	28.2	24.6	7.4
Ref:						
page	664	670	694	698	696	701
table	A-5	A-8	A-16	A-18	A-17	A-19

Notes: Estimates are from Bowen and Finegan (1969); see row labelled "Ref." for page number and table number for each set of estimates. Standard errors appear in parentheses next to estimated coefficients. Number of observations = "nobs"; mean of dependent variable (labor force participation rate) = "modv." All variables above are in the form of dummy variables, with "reference" indicating the category omitted from the list of variables. Under the heading "Age", the categories in the first column (14–19, 20–24, 25–29, etc.) were used in the regressions reported in columns 1 and 2 (for single persons age 25–54 and married persons age 14–54, respectively); the categories in the second column (55, 56, 57, etc.) were used in the regressions reported in columns 3 and 4 (for single and married persons 55–64); and the categories in the third column (65, 66, 67, etc.) were used in the regressions reported in columns 5 and 6 (for single and married persons age 65–74). "Single" denotes all persons other than those who are married with spouse present (e.g. never married, widowed, divorced, separated). "Nonwage income" is the sum of rental income, interest, dividends, alimony, pensions, and welfare payments. Variables for presence or absence of children indicate the presence or absence of children in three age groups: under 6 years old, between 6 and 13 years old, and between 14 and 17 years old. Thus, for example, "A/A/A" denotes no children in any of the three categories; "P/A/A" denotes the presence of children under six but no children age 6–13 or 14–17; etc. NA = not applicable.

provides a most useful treatment of many such models; and in any case our focus is on female labor supply rather than labor supply generally.

Of course, there is no such thing as a distinct "model of female labor supply" per se: any theory worthy of the name ought to be just as applicable to men's as to women's labor supply. On the other hand, Section 3.1.1 points to a number of phenomena – marriage, the family, the occupational characteristics of labor supply – that seem to be important correlates of women's labor supply, and so are likely to be of particular interest for analyses of the labor supply of women. In analyzing the labor supply of women, it is therefore surely not unreasonable to focus on models that permit more than routine consideration of such factors.

3.1. *Static models*

We begin by considering static labor supply models in which decisionmakers are assumed to act as if actions taken today were irrelevant to tomorrow's economic environment, and in which accumulation of nonhuman and human wealth is ignored. From the standpoint of analyses of female labor supply, three kinds of topics seem particularly interesting: the role of the family; the allocation of time; and the heterogeneity of jobs.

3.1.1. *Models of family labor supply*

Family membership and its obligations seem to be very important correlates of levels of and trends in labor supply among women. (For example, the *level* of labor supply is generally lower but the positive *trend* in labor supply has usually been much stronger for married women than for single or other women.) Models that allow explicitly for the impact of family membership on decisions about hours of work, participation, etc. are therefore potentially quite useful for the analysis of female labor supply.

The conventional family labor supply model extends the analysis of the single individual by postulating a single decisionmaking unit, the family, which maximizes a twice-differentiable quasiconcave preference function

$$U = U(L_1, \ldots, L_m, C), \tag{1}$$

where L_i is the "leisure" (nonmarket) time of family member i and C is the family's consumption of a composite consumer good. This maximization is subject to the constraint that total family income – the sum of its exogenous income R and the earnings of its m members – may not exceed the family's total expenditure on the consumer good:

$$PC \le R + \sum_i W_i H_i, \tag{2}$$

where P is the price of one unit of the composite good, R is the amount of "exogenous" income (e.g. dividends) received by the family per period and W_i and H_i are the wage and hours of work of family member i per period, respectively. Available time is divided between market work and leisure, so that $H_i + L_i = T$, where T = total available time per period.

The first-order conditions for a maximum of (1) subject to (2) are

$$PC = R + \sum_i W_i H_i, \tag{3}$$

$$U_i - \mu W_i \ge 0, \quad \text{with} > \to H_i = 0, \tag{4a}$$

$$U_C - \mu P = 0, \tag{5}$$

where μ is a Lagrange multiplier that may be interpreted as the marginal utility or income to the family, U_C is the partial derivative of U with respect to C, and U_i is the partial derivative of U with respect to L_i. Note that (4a) allows for corner solutions, i.e. cases in which $L_i = T$ for at least some of the family members i. [Since the participation rate of married women is generally well below unity, this aspect of (4a) is particularly important.]

The comparative statics of the family labor supply model turn out to be very similar (often, identical) to those of the standard model of consumer behavior, in which an individual allocates a fixed income (and therefore does not treat labor supply or leisure as choice variables) among n different consumer goods. In particular, total differentiation of (3)–(5) yields the following results concerning (any pair of) family members i and j *when all members work*:

$$\mathrm{d}L_i/\mathrm{d}W_j = \mu(F_{ij}/|F|) - H_j(F_i/|F|), \tag{6}$$

$$\mathrm{d}L_i/\mathrm{d}R = -F_i/|F|, \tag{7}$$

$$\mathrm{d}L_i/\mathrm{d}P = \mu(F_{iC}/|F|) + C(F_i/|F|), \tag{8}$$

where F_i and F_{ij} are the cofactors of the elements $-W_i$ and U_{ij}, respectively, in the matrix F, the bordered Hessian matrix of the utility function (i.e. the matrix of second derivatives of U bordered by the $-W_i$ and $-P$), and where

$$F=\begin{bmatrix} 0 & -W_1 & \cdots & -W_m & -P \\ -W_1 & U_{11} & \cdots & U_{1m} & U_{1C} \\ \vdots & \vdots & & \vdots & \vdots \\ -W_m & U_{m1} & \cdots & U_{mm} & U_{mC} \\ -P & U_{C1} & \cdots & U_{Cm} & U_{CC} \end{bmatrix}. \tag{9}$$

The similarity between (6)–(8) and the analogous expressions obtained in the standard model of consumer behavior [see for example, Hicks (1946, esp. pp. 303–314)][2] is evident. The main difference between the two models has to do with the fact that, in the labor supply model, the commodity "time" is sold (in which case it is called work) as well as consumed (in which case it is called leisure), so that whereas in the consumer behavior model increases in commodity prices reduce utility, in the labor supply model an increase in the price of time raises utility.

The first term on the right-hand side (RHS) of (6) is called the compensated cross-substitution effect (or, when $j=i$, the compensated own-substitution effect) on i's leisure of an increase in j's wage. It refers to the effect on i's leisure time of an increase in j's wage with exogenous income R adjusted so as to keep family utility U constant. The total effects of wage changes – the sum of the two terms on the RHS of (6) – are uncompensated effects of wage changes. The leisure times of family members i and j are said to be substitutes or complements in the Hicks–Allen sense depending on whether the cross-substitution term in (6) is positive or negative, respectively. By the same token, the first-term on the RHS of (8) represents the cross-substitution or income-compensated effect of a rise in the price of market goods, P, on family member i's leisure time, L_i, and is positive or negative depending on whether C and L_i are substitutes or complements, respectively.

The second terms on the RHS of (6) and (8), and the sole term on the RHS of (7), is an income effect. By definition, an increase in exogenous income will increase i's leisure time if i's leisure is a "normal" good to the family, and will decrease i's leisure time if i's leisure time is an "inferior" good. By (6) and (8), increases in wages and prices, respectively, are to some extent akin to increases in exogenous income: at a given level of hours of work H_j, an increase in the wage W_j of family member j *increases* family income by H_j times as much as a \$1 increase in exogenous income R and so will have H_j times as big an income

[2]Although (6)–(8) refer to leisure, recall that it is assumed that $L_i + H_i = T$, so that – at least in this model – any change in leisure time is always accompanied by an opposite-signed change in hours of work of equal absolute magnitude. So one may readily convert (6)–(8) to expressions for changes in H_i by simply multiplying their RHS by -1.

effect; at a given level of consumption C, an increase in the price level P *reduces* family income (in real or constant purchasing-power terms) by C times as much as a \$1 *reduction* in exogenous income R and so will have C times as big an income effect.

The empirical content of the model consists of a number of properties that are implicit in constrained (family) utility maximization. The most important of these are homogeneity, symmetry, negativity and negative definiteness. First, the family's leisure and consumption demand functions are homogeneous of degree zero in all wages, exogenous income and the price level taken together: leisure and consumption decisions depend only on real (and not on nominal) variables; there is no money illusion.

Second, since F is symmetric because the utility function (1) is assumed to be twice differentiable, it follows that $F_{ij}=F_{ji}$, and thus that pairs of cross-substitution effects between the same two family members are equal – the property of *symmetry*. As Ashenfelter and Heckman (1974, p. 75) put it, symmetry means (among other things) that "an income compensated change in the husband's wage rate has the same effect on the wife's work effort as an income compensated change in the wife's rate has on the husband's work effort".

Third, F is negative definite, implying that $F_{ii}/|F|<0$, and thus that all own-substitution effects of wage changes on leisure are negative – the property of *negativity*. The negative definiteness of F also implies that the *matrix* of own- and cross-substitution effects is *itself* negative definite; for example, in a family with just two members, 1 and 2, both of whom work, negative definiteness implies that, at the family's optimum,

$$\begin{vmatrix} s_{11} & s_{12} & s_{1C} \\ s_{21} & s_{22} & s_{2C} \\ s_{C1} & s_{C2} & s_{CC} \end{vmatrix} < 0, \tag{10}$$

$$\begin{vmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{vmatrix} > 0, \qquad \begin{vmatrix} s_{ii} & s_{iC} \\ s_{Ci} & s_{CC} \end{vmatrix} > 0 \quad (i=1,2), \tag{11}$$

where $s_{ij}=F_{ij}/|F|$ is the own- or cross-substitution effect on i of the price of j.

Recall that (6)–(8), (10) and (11) hold only if all family members work. In the general case in which some family members do *not* work, the leisure times of nonworking members do not change in response to sufficiently small changes in wages, exogenous income and the price level, so that expressions analogous to (6)–(8), (10) and (11) apply in the general case only to the subset of working family members. (Hence, in that case, F must be redefined to refer only to working members.) Families in which some members j have $H_j=0$, $L_j=T$, may be said to be "rationed" – that is, such families are unable to "purchase" the amount of L_j they would desire to have if it were possible to ignore the constraint $L_j \le T$.

It is interesting to note that such rationing has implications for the behavior of the family's "unrationed" members.[3] Much discussion of this notion relies on the Le Chatelier principle [see, for example, Samuelson (1947, pp. 36–46, 168–169)], which, in general terms, says that an individual with more options will have a more elastic supply (or demand) function in absolute value. Kniesner (1976) invoked this principle to argue that the substitution effect of a rise in the husband's wage on the husband's hours of work will always be more positive in families in which both spouses work than in families in which the wife does not work; and that if the spouses' leisure times are complements (substitutes) and are both normal, the negative income effect of a rise in the husband's wage on the husband's hours of work will be larger (smaller) in absolute value when both husband and wife work than when only the husband works. However, as Samuelson (1960) notes, such comparisons hold only at the identical consumption bundle, so that their usefulness in analyses of actual rationed and unrationed couples (whose consumption bundles are almost surely different) is somewhat limited.

By imposing additional structure on the problem (e.g. by assuming that the household utility function is quadratic in the vicinity of equilibrium), however, Heckman (1971, Essay III) was able to derive similar results for rationed and unrationed households with potentially *different* consumption bundles. For example, consider two households each facing the same wages and prices. One is unrationed, i.e. both husband and wife work; in the other, "rationed," household, the husband works but the wife does not. Then, under Heckman's assumptions, one can show (i) that the male compensated substitution effect will be smaller in the rationed than in the unrationed household; (ii) the income effect on consumption will be larger (smaller) for the unrationed household provided the wife's home time and consumption are net substitutes (complements); and (iii) the compensated or cross-substitution effect of a rise in the male wage on household demand for goods will be smaller (larger) in rationed households if one spouse's leisure is a net substitute for market goods whereas the other's is a net complement (if the spouses' leisure times are *both* either net complements *or* substitutes with market goods).

Like those discussed earlier, these propositions are consequences of the assumption that family members' decisions are the outcome of optimization of a well-defined family utility function. However, families are made up of individuals, and can either grow or dissolve: where, then, do family utility functions come from? There are several possible answers to this question. The first is that all family members simply conform to the preferences of one of the family's

[3] See Deaton and Muellbauer (1981), Hausman and Ruud (1984), Kooreman and Kapteyn (1984a), and Ransom (1985a, 1985b) for discussion of the implications of this kind of "rationing" for specification and estimation of family labor supply functions.

members, who may be called the family head. This answer begs the question of how a head is chosen and why other family members choose to obey the head. The second way to justify the family utility function is to assert that the social choice conditions for the existence of a well-behaved social (i.e. family) utility function are satisfied. The difficulty here is that such existence conditions are rather stringent [on this, see Samuelson (1956)], especially for families settling issues concerning multiple attributes [Mueller (1981)].

A third rationale for the family utility function relies on intrafamily resource transfers and an assumption that family members "care" for one another (in the sense that family member i's utility is affected by member j's consumption of goods and leisure). As Becker (1974, p. 331) puts it, "...if one member of a household – the 'head' – cares enough about all other members to transfer resources to them, this household would act *as if* it maximized the 'head's' preference function, even if the preferences of other members are quite different". (He later adds, p. 343: "In effect, transfers between members eliminate the conflict between different members' utility functions.")

The difficulty with this claim is that it is not generally true [Bergstrom (1984)]: In general, my acting so as to maximize my spouse's utility will not ensure that my own utility will be maximized even if my spouse cares for me (and is willing to transfer resources to me) to some extent; and my acting so as to maximize my own utility will not ensure that my spouse's utility will be maximized even if I care for my spouse (and so am willing to transfer resources to my spouse) to some extent.[4] At least in this sense, then, caring and intrafamily transfers are not generally sufficient to "eliminate the conflict between different [family] members' utility functions." That does not mean that being a family member can never be better than not being part of a family; but it does mean that an individual family member may have reason for questioning whether obeying the dictates of the family utility function will yield his or her potential optimum optimorum within the family – and that intrafamily conflict may well ensue.

Perhaps with these difficulties in mind, some researchers have developed alternatives to the family utility model [Pollak (1985)]. Leuthold (1968) casts family labor supply decisions in a framework that is formally rather similar to the analysis of duopoly [Allen (1938, esp. pp. 200–204)]: each individual family member maximizes his or her own individual utility, assumed to depend on the

[4] For example, consider a very simple model of a family of two persons, m and f, with *fixed* endowments of wealth Z_m and Z_f and utility functions $U_m = (Z_m - A)^a + (Z_f + A)^b$ and $U_f = (Z_m - A)^y + (Z_f + A)^z$, respectively, where A is the amount (negative *or* positive) that m transfers to f. (Note that since wealth is assumed fixed, labor supply is implicitly also assumed fixed, in the interest of simplification.) Then it is straightforward to show that, in general, maximizing m's utility will not simultaneously result in maximization of f's utility, and vice versa. [Equivalently, it can be shown that when the first order condition for a maximum of m's (f's) utility with respect to A is satisfied, the first order condition for a maximum of f's (m's) utility with respect to A is not generally satisfied.]

individual's own leisure time and on *family* consumption C, i.e.

$$U = U(L_i, C), \tag{12}$$

subject to the family budget constraint (2). Thus, the existence of the family is taken as given, and all consumption is implicitly assumed to be a public good. In the duopoly model, each firm seeks to maximize its own profit, but its actions affect the other firm's profit (and hence the other firm's behavior, and hence, indirectly, its *own* profit) because they share the same market. In the Leuthold model, each spouse seeks to maximize his or her own utility, but each family member's own actions affect the utility and behavior of all other members (and thus ultimately their own actions) because (i) each family member is assumed to derive utility from family consumption C, and (ii) all family members pool their incomes and are subject to the common budget constraint (2).

Specifically, in this formulation the leisure times and labor supplies of other family members j do not directly affect the utility of family member i, but they do have indirect effects through their impact on C. Thus, instead of the family utility model's cross-substitution effects, the individual utility model has what may be called indirect income effects. In other words, in the family utility model, the existence of a single family utility function means that a change in the wage of family member j has a cross-substitution effect on i's labor supply that is of indeterminate sign but equal in magnitude to the cross-substitution effect on j's labor supply of a change in i's wage. In contrast, in the individual utility model, each individual maximizes his or her own utility function, but changes in the wages of other family members still affect each member's behavior because all members pool their income. Hence, a change in j's wage generates what may be called an indirect income effect on i's labor supply that is necessarily negative (so long as leisure times are normal goods) but not necessarily equal to the indirect income effect of a change in i's wage on j's labor supply. Thus, whereas the family utility model provides predictions about the magnitudes but not the signs of its cross-substitution effects, the individual utility model provides predictions about the signs but not the magnitudes of its indirect income effects.[5]

Bargaining models of family behavior [e.g. Horney and McElroy (1978), Manser and Brown (1979, 1980), McElroy and Horney (1981)] provide an alternative formulation of family labor supply decisions.[6] The essential idea is to

[5] See Killingsworth (1983, esp. pp. 35–36) for further discussion. Bourguignon (1984) presents a modified version of the Leuthold model and discusses empirical tests of this model against conventional family-utility models of labor supply. For empirical analyses, see Ashworth and Ulph (1981), Kooreman and Kapteyn (1985) and Leuthold (1968).

[6] Mention should also be made of two somewhat less formal analyses of family labor supply decisions. Brown (1985) presents an institutional model of wives' labor supply decisions that

treat the decision of individual family members (and, indeed, the very existence of the family) in game-theoretic terms. For example, McElroy and Horney (1981) derive a Nash-bargained system of labor supply and commodity demand equations for each individual in a two-person household as the outcome of a constrained static, non-zero-sum game. This generalizes Leuthold's approach because it does not take the family as given and because it allows for private goods; unlike Leuthold, however, it ignores public goods.

Three features of such bargaining models are particularly noteworthy. First, because they explicitly treat alternatives to marriage as well as behavior within the family, bargaining models can be used in analyses of marriage and divorce. Second, within the family, differences in the distribution by recipient (husband, wife, etc.) of exogenous income may lead to differences in their bargaining strengths and, hence, their behavior, so that each *individual* family member's exogenous income appears as a *separate* argument in each demand equation (for leisure times, consumption, etc.). Third, some bargaining models [e.g. the Nash demand system developed by McElroy and Horney (1981)] retain some of the properties of the family utility model (e.g. homogeneity) and nest others (e.g. symmetry) as special cases. Thus, in principle, empirical analyses of hours of work can be used to test whether the bargaining model reduces to the conventional familiity utility case [for examples, see Horney and McElroy (1978) and Manser and Brown (1979, 1980); work based on bargaining models by Bjorn and Vuong (1984, 1985) considers labor force participation as opposed to hours of work].

Unfortunately, such tests are not necessarily straightforward [Ashenfelter (1979)]. One problem is that, precisely to the extent that bargaining models generalize the conventional model, one in effect abandons the sharp testable implications of the latter without necessarily putting alternative clearcut predictions in their place. The essential reason for this is that bargaining models are formally equivalent to Basemann's (1956) model with prices in the utility function, a situation in which testable restrictions of conventional theory frequently do not survive. A second problem is that, as a practical matter, it is likely to be

emphasizes interdependency of families and the role of an individual family's relative income position, à la Duesenberry (1952) and Veblen (1973). Grossbard-Shechtman (1984) adopts an individual utility function whose arguments include household time supplied by other persons and a budget constraint specifying that expenditures on market goods produced and on time supplied by other persons may not exceed the sum of nonwage income, earnings from market work and earnings from supplying household time to other individuals. Pay for market work w and implicit prices of household time p^* that the individual receives from or supplies to others are determined in labor and marriage markets, respectively; changes in exogenous factors (e.g. the relative size of the male or female population) affect marriage markets, the relative magnitudes and absolute levels of w and the p^* and, thus, labor supply decisions and marriage rates.

quite different to measure certain variables that play a key role in bargaining models, namely the exogenous income flows that are under the control of particular family members. A final difficulty is common to conventional and bargaining models of family behavior: as Samuelson (1947, pp. 111, 150; 1960, p. 13) observes, the fact that data do not come in infinitesimals means symmetry is not truly testable, and that the only propositions of utility maximization that are truly testable are propositions relating to revealed preference (which are formulated in terms of discrete, not infinitesimal, changes).

3.1.2. *Models of the allocation of time*

As noted in Section 3.1.1, the labor supply of women, especially married women seems to have increased secularly by appreciable amounts, whereas, in contrast, male labor supply seems to have fallen over time (see Pencavel, Chapter 1 in this Handbook). Also, as shown in Section 3.1.3 below, much – although by no means all – of the available empirical evidence suggests that (1) the own-wage uncompensated elasticity of labor supply of women is positive and fairly large, (2) the exogenous-income elasticities of both men and women are small and (3) the own-wage uncompensated labor supply elasticity of men is small and perhaps even negative. This being the case, it is certainly possible (especially if cross-wage effects are ignored) to devise a relatively simple explanation for the difference in secular trends of men's and women's market work: secular increases in exogenous income have had a minor negative effect on both groups; secular wage increases have reduced men's labor supply to a minor degree and have increased women's labor supply to a substantial degree.

However, this explanation begs an important question: Why is the female uncompensated wage elasticity of labor supply relatively high, as suggested in many empirical studies?

In principle, answering this question is also fairly straightforward. The first step is to apply to commodity demands the discussions of input demands of Hicks (1965, pp. 242–246), Marshall (1920, pp. 386, 852–853), and Pigou (1946, p. 682): the elasticity of demand for a good (in this case, leisure) with respect to its price (in this case, the wage rate) will be greater, the greater is the availability of alternatives to that good. The next step [Mincer (1962, 1963)] is to observe that women in effect have more alternative uses for their time – market work, home work and leisure – than do men, who for the most part divide their time between only two uses, market work and leisure. In other words, the substitution towards market work that men undertake when their wage rises is primarily a substitution away from leisure, whereas a wage increase leads women to substitute away for both leisure and home work. This argument does not explain why home work is

primarily women's work. However, it does at least suggest, albeit informally,[7] why – when that is so – women's labor supply might be more wage-elastic than men's.

There remains the task of dressing these rather imprecise ideas in formal clothing. In doing so, researchers have moved away from a preoccupation with market work and the rather diffuse concept of "leisure", and towards a more general treatment of the allocation of time along a great variety of activities.

Becker (1965) remains the basic inspiration for much work along these lines. In his approach, the basic objects of choice are not consumer goods and leisure times, but rather *commodities* (sometimes called *activities*), Z_i, which are "produced" using consumer goods C_i and time as "inputs": time, cooking utensils and raw ingredients produce a cooked meal; time and a television set produce a form of entertainment; and so on. Hence, the family's utility U is now given by

$$U = U(Z_1, \dots, Z_N), \tag{13}$$

where, in turn, Z_i is given by the *household production function*

$$Z_i = f^i(C_{1i}, \dots, C_{zi}, L_{1i}, \dots, L_{mi}), \tag{14}$$

where C_{ci} is the amount of the cth consumer good devoted to production of the ith commodity and L_{ki} is the amount of time of the kth family member devoted to production of Z_i. As before, maximization of utility, as given by (13), is subject to the usual family budget constraint, (2). The model yields a set of

[7]There is, however, a technical caveat to this argument. Leisure demand is simply the sum of demands for all different uses of nonmarket time (which, by Hicks' composite commodity theorem, can legitimately be aggregated to form a single composite, leisure, because the price of each use of nonmarket time is the wage rate); but an increase in the elasticity of demand for one component in this composite (e.g. nonmarket work) need not increase the elasticity of demand for the composite (total nonmarket time) itself. For example, assume that there are only two kinds of nonmarket time: nonmarket work, $L(1)$, and "pure" leisure, $L(2)$, with composite leisure L equal to $L(1)+L(2)$. It can be shown [Heckman (1971)] that the income-compensated elasticity of demand for L is equal to $s(LL) = s(11)+2s(12)+s(22)$, where $s(ij)$ is the compensated elasticity of $L(i)$ with respect to the price of $L(j)$ $(i, j, = 1$ or $2)$ and where $s(LL)$ and $s(ii)$ are negative by concavity of preferences. It can also be shown that in the restricted case, when $L(1)=0$ (as for the stereotypical male), the restricted compensated demand elasticity for L, $s(LL)^*$, is given by $s(LL)^* = s(11)-[s(12)^2/s(22)]$ $(<0$, again by concavity of preferences). Since both $s(LL)^*$ and $s(LL)$ are negative, we have $0 > s(LL)^* > s(LL)$ (i.e. the stereotypical male's compensated elasticity of total leisure demand is smaller in absolute value than that of the stereotypical female) if and only if $s(12) \leq -s(22)$. This condition always holds if $L(1)$ and $L(2)$ are net complements $(s(12)<0)$, and will also hold if $L(1)$ and $L(2)$ are not "too substitutable". [If $L(1)$ and $L(2)$ were in fact strong substitutes in the sense that $s(12) > -s(22)$ (>0), then any restriction on performing home work $L(1)$ would – while reducing the compensated elasticity of demand for home work $s(11)$ – end up increasing the elasticity of demand for pure leisure $L(2)$ by so much that the elasticity of demand for total leisure, $L = L(1)+L(2)$, would actually increase.]

functions for the time devoted by each family member k to production of each activity i; k's hours of work are simply the residual, i.e. $H_k = T - \sum_i L_{ki}$.

The main advantage of the time allocation model lies in the fact that it treats explicitly the diverse uses to which nonmarket time may be put, thereby permitting quite detailed analyses of the nonmarket behavior of family members [see, for example, Gronau (1977) and Chapter 4 in this Handbook; Kooreman and Kapteyn (1984b)]. One study [Leibowitz (1974, pp. 246–247)] even finds that husbands' and wives' times are substitutable in the production of meals at the marginal rate of ten minutes of husband time for each five minutes of wife time! More generally, the model emphasizes a point that is implicit in conventional analyses but all too often ignored: goods prices as well as wage rates affect decisions about work and leisure; wage rates as well as goods prices affect decisions about consumption. [See, in particular, Mincer (1963) and Owen (1969, 1971).] In addition, the time allocation approach suggests ideas for specifying the functional form of empirical labor supply models [Wales and Woodland (1977)] and for elaboration of conventional models [see, for example, Atkinson and Stern (1981)].

Finally, the time allocation model provides a useful framework, largely absent from the quite abstract conventional labor supply model, for analyzing a variety of factors that may affect labor supply. For example, researchers since Long (1958, ch. 7) have discussed informally the labor supply effects of improvements in "household technology" – better stoves, refrigerators, etc.; and it is natural in the context of the time allocation model to treat such improvements as technical progress in the household production functions. [However, it should be noted that work such as that of Fisher and Shell (1971) provides a means of treating "quality change" or improvements in existing consumption goods within conventional consumer-behavior models.]

On the other hand, although the time allocation approach clearly represents a great advance in the analysis of *nonmarket* time, its potential for contributing to the understanding of *market* time – hours of work – should not be exaggerated. In this respect, the abstraction of the conventional model is perhaps misleading: even though the conventional model says nothing explicit about the different uses to which nonwork time may be put – meaning that the time allocation approach is clearly superior for analyses of *nonwork* time – virtually all of the time allocation model's predictions about *labor supply* can also be derived using the conventional approach. In this respect, there is little in the time allocation approach that is not also in the conventional approach, even if the former provides a much more detailed description of the setting in which labor supply decisions are made.

The main reason for this is that, in the time allocation model as in the conventional formulation, labor supply and consumption decisions ultimately depend on wages, prices and exogenous income, and utility can always be written

as a function of leisure (nonmarket) times and consumption goods. To see why, note first that one can substitute the household production functions, (14), into the utility function, (13), to obtain:

$$U = U\left[Z_1(C_{11},\dots,C_{z1}, L_{11},\dots,L_{m1}),\dots,Z_n(C_{1n},\dots,C_{zn}, L_{1n},\dots,L_{mn})\right]. \tag{15}$$

Moreover, the opportunity cost of devoting an hour of family member i's time to *any* nonmarket activity is his or her wage, W_i; and the opportunity cost of devoting a unit of consumer good j to any nonmarket activity is likewise the price of that good, P_j. Thus, one may invoke the composite commodity theorem[8] and aggregate the nonmarket times of each family member i devoted to the various activities into a single composite leisure time, L_i; similarly, the amounts of each consumer good j devoted to the various activities may be aggregated into a single composite consumption good, C_j. Just to pursue this aggregation to the limit, one can then aggregate the individual composite consumption goods C_j into a single composite commodity C using the prices P_j of the individual goods C_j as weights. The end result, then, is that the utility function (15) reduces to relation giving utility as a function of the total leisure (or nonwork) times of the m different family members and of a composite good C – exactly as in the conventional model; and all of the major properties of labor supply and commodity demand functions found in the latter will also appear in this rewritten version of the time allocation model.[9]

[8] See Hicks (1946, pp. 312–313). As applied to labor supply models, the theorem asserts that if the prices of a set of consumption goods (or leisure times) always stay in the same relation to each other, then the set of consumption goods (or leisure times) can be treated as a single composite good for purposes of analysis (where the amount of the composite good may be measured as the relative price-weighted sum of the individual goods themselves). Thus, for example, if consumer goods prices stay in the same relation to each other, then instead of writing utility as a function of n different consumer goods and leisure, one may group the n goods into a single composite, C, and analyze the choice of C and L. In the present case, *any* hour of family member i's time always entails the *same* opportunity cost, namely i's wage rate W_i, so the price of i's time in any use relative to any other use is always unity. Hence, the nonwork or leisure hours that i devotes to different activities Z may all be aggregated into a single leisure composite L, which – since all relative prices are unity – is simply i's total leisure time.

[9] Becker (1965, p. 505) appears to think that this is not necessarily the case and, in particular, that the own-substitution effect of a wage increase on labor supply need not be positive in the time allocation model (as must be the case in the conventional model). However, this conjecture is incorrect [for example, see Atkinson and Stern (1981)]. It should be noted that the discussion in the text assumes an interior solution for leisure time for the household's members (since, if a household member does not work, the opportunity cost of his or her time exceeds the relevant real wage rate, and aggregation of the member's nonmarket time allocations using his or her real wage is inappropriate). Thus, it is possible that the time allocation model may offer insights into nonparticipation that do not appear, or are not as readily apparent, in the conventional approach. (We thank Ricardo Barros for pointing this out to us.)

To appreciate the nature of these issues in concrete terms, it is instructive to consider how one might use a very simple version of the time allocation model in analyzing the level and elasticity of women's labor supply [see Graham and Green (1984) for an empirical application similar to the one described here]. Consider a family consisting of two persons, m and f, whose well-behaved utility function depends on the family's consumption of just one activity Z, such that $U = Z^c$. Activity Z is produced via inputs of the family members times L_i and of a single consumer good C according to the constant-returns-to-scale Cobb–Douglas production function $Z = L_f^a L_m^b C^{1-a-b}$. The family maximizes utility subject to the constraints imposed by this production function and by the usual budget constraint, (2). A little manipulation of the first-order conditions for a maximum with respect to the L_i and C yields the following expression for the utility-maximizing level of L_i at an interior optimum:

$$L_i = A_i F / W_i, \quad \text{where } A_f = a,\ A_m = b, \tag{16}$$

and where $F = R + T(W_f + W_m)$, the family's "full income" (i.e. the maximum income attainable, reached if both m and f work all available hours T). Note that (16) implies that, even if m and f can earn equal market wages, f will devote *more* time to nonmarket work than m provided f is "better" at producing the nonmarket activity Z (i.e. provided $a > b$), and that this difference will be even greater if $W_f < W_m$. Here, then, is a simple explanation for married women's relatively low level of labor supply: in terms of the time allocation model, the reason is (at least, could be) a greater elasticity of output of activity Z with respect to married women's nonmarket time.

Exactly the same reasoning also provides a simple explanation for the relatively large elasticity of married women's labor supply. Use (16) and the fact that $H_i = T - L_i$ to obtain the equation for the labor supply H_i of each family member, and then use this labor supply equation to obtain the own-wage uncompensated elasticity of i's labor supply, e_{ii}:

$$e_{ii} = (A_i / H_i)[(F/W_i) - T]. \tag{17}$$

So long as f is "better" at nonmarket production than m (in the sense that $a > b$), $A_f/H_f > A_m/H_m$ and so $e_{ff} > e_{mm}$ even if $W_f = W_m$. These conclusions are reinforced if $W_f < W_m$. In other words, this simple version of the time allocation model implies that so long as wives are "better" at (have a higher output elasticity in) nonmarket production than husbands and earn wages no greater than those of (their) husbands, the *level* of labor supply will be lower but the *elasticity* of labor supply will be greater for wives than for husbands.

That such a simple model can account for two very important stylized facts about female labor supply noted in Section 3.1.1 seems, at first glance, quite

impressive. Unfortunately, there is less to these results than meets the eye; in particular, they do not establish the superiority of the time allocation model over the conventional model for purposes of understanding the labor supply of (for example) wives. To see why, note that one would get *identical* conclusions by simply assuming a conventional Cobb–Douglas utility function,

$$U = L_f^{a^*} L_m^{b^*} C^{c^*}, \tag{18}$$

where, in terms of the time allocation model, $a^* = ac$, $b^* = bc$ and $c^* = c(1-a-b)$. Maximization of (18) subject to (2) *also* yields the expressions (16) and (17) for the level of nonmarket time and the elasticity of labor supply of the two spouses; the only difference is that whereas the time allocation model would interpret differences between m and f in leisure and elasticity of labor supply as a result of household production function elasticity differences, the conventional model would interpret such differences as a consequence of different utility function parameters.[10] Moreover, much of the power of the household production function approach rests on some special assumptions – e.g. separability, the absence of joint production, etc. [Pollak and Wachter, (1974)] – which are not required for (and whose imposition could effectively restrict the scope of) analysis of labor supply per se. Finally, the key variable in the time allocation approach, "output" of the activity Z, is unobservable, which means that from an empirical standpoint the two models are indistinguishable for all practical purposes.

In sum, although the time allocation approach may be useful in analyses of different uses of *nonmarket* time, the novelty of the model and its potential usefulness for analyses of *market* time – labor supply – may be more apparent than real.

3.1.3. Models of labor supply with heterogeneous jobs

Not only the quantity, but also the qualitative nature of women's labor supply has changed substantially in the twentieth century. As shown in Section 3.1.1, women workers in the United States in the 1980s typically hold white-collar jobs – usually, clerical jobs – to a much greater extent than was the case in the 1890s. This shift in the occupational distribution of women workers has been substantial not only in absolute terms, but also – and of equal if not greater significance – relative to men.

[10] Note also that although $a > b$ could be interpreted as a technological relationship – e.g. that the elasticity of actual output of Z with respect to f's time is greater than the elasticity with respect to m's time – one could instead treat $a > b$ as meaning merely that, for reasons (psychological, cultural, etc.) that need have nothing to do with technology as such, the family is biased towards using f's rather than m's time in the production of Z. In other words, the parameters a and b *can* be interpreted in technological terms, but nothing about the model that *requires* that they be interpreted in this way.

This suggests that explicitly addressing the heterogeneity of work may be helpful for understanding secular trends in women's labor supply. It may also be important for analyzing cross-sectional labor supply patterns. The reason is that, when work is heterogeneous, observed combinations of wage rates and hours of work do not necessarily describe a labor supply schedule as such. Rather, such combinations may represent only a labor supply locus with little or no significance for questions about labor supply as such. In other words, a labor supply schedule is supposed to show the amount of labor that a given individual would supply at different wage rates, other things being equal. In contrast, a labor supply locus shows only the hours of work-wage rate combinations that a given individual would choose in conjunction with other attributes of jobs – fringe benefits, working conditions and the like. [As a special but possibly widespread case, Moffitt (1984a), consider a setting in which the hourly wage offered to workers by firms depends on the number of hours worked.]

Since these other attributes may be substitutable for wages and do not necessarily remain constant along the labor supply locus, there is no reason to expect that the labor supply locus necessarily provides much information about the structural parameters of the labor supply schedule (e.g. income and substitution effects). Indeed, considered as estimates of the labor supply function, estimates of the labor supply locus may be badly biased.

On the other hand, simply including job variables in labor supply functions may *also* result in problems, precisely because, like labor supply, they are choice variables.

As a simple example of both kinds of difficulties, consider the regression of hours of work H on the wage W, exogenous income R, a vector of background characteristics X and a "job variable" J (which may denote either some continuous job characteristic, or a discrete indicator of job actually held):

$$H = a + bW + cR + kX + jJ + e, \tag{19}$$

where e is an error term. Fitting (19) by least squares will not provide a consistent estimate of j because J is endogenous, in that it is chosen along with H. Also, to the extent that differences in J are accompanied by compensating wage differentials, W is also now a choice variable, so least squares estimates of (19) may also yield biased estimates of b. Finally, if the individual's choice of J depends on elements in X (e.g. age, schooling), then in general e and those elements in X will be correlated, *given* J; thus least squares estimates of (19) may also yield biased estimates of the coefficients k on those elements in X. In sum, explicit allowance for the heterogeneity of jobs [i.e. inclusion of J in labor supply functions such as (19)] requires revision or extension of existing estimation strategies.

On the other hand, if one simply ignores J, (19) becomes

$$H = a + bW + cR + kX + u, \tag{20}$$

where u, the composite error term, is given by $u = e + jJ$. Fitting (20) by least squares may result in biased estimates of *all* of its parameters. To see why, note that, in the conventional compensating differentials story, J and W are jointly determined; allowing for labor supply (which is usually ignored in compensating differentials models) simply adds H to the list of endogenous variables. If so, then the composite error term $u = e + jJ$ will be correlated with W, R and X. To put the point a bit differently, (19) is a labor supply function whereas (20) is a labor supply locus. Estimates of the parameters of (20) therefore cannot be regarded as (the equivalent of) estimates of the parameters of (19); for example, to a first approximation, estimates of the wage parameter b in (20) incorporate not only the ceteris paribus effect on labor supply of a wage change – the b of (19) – but also the effect of a change in J on labor supply, to the extent that J and W are correlated.

The basic issue raised by expressions such as (19) is behavioral rather than statistical, however. In a world of heterogenous jobs, hours, wages and jobs (or job characteristics) are all endogenously chosen. Thus, even if one had consistent estimates of the parameters of expressions such as (19), such estimates would refer only to choice of hours *given* choice of job (characteristics) J; they would reveal nothing about how exogenous changes are associated with changes in the set of endogenously-chosen variables H, W and J. For example, the coefficient c in (19) refers to the "direct" effect of a change in exogenous income on hours of work with W and J held constant; but in general a change in exogenous income will lead to changes in J and W, and thus to "indirect" as well as direct effects on H.

Despite its potential importance for labor supply analysis, surprisingly little has been done to allow explicitly for the heterogeneity of work in formal labor supply models. For the most part, studies in which job heterogeneity *has* been considered have been concerned with compensating wage differentials, i.e. with wages rather than labor supply per se. Such studies have typically been concerned with regressing wage rates on "job variables" – e.g. continuous variables measuring job characteristics, or dummy variables denoting "job held" – and on other variables, such as schooling, work experience and the like. Studies of this kind usually provide little or no information about preferences (which might be useful for understanding labor supply to heterogenous jobs); for the most part, they estimate the compensating wage differential required by the *marginal* individual in order to change the amount of a particular job characteristic or in order to change jobs per se [Smith (1979)]. Moreover, such studies usually ignore the fact that the "job variables" included in such regressions are endogenous.

Ironically (in view of the neglect of labor supply in such studies), analyzing labor supply in a model of job heterogeneity can also provide useful information on the forces that generate compensating wage differentials. By using information on labor supply as well as wages, one can estimate the supply (e.g. utility function) parameters that underly compensating wage differentials while allowing explicitly for the endogeneity of individuals' "job variables". Thus, studying labor supply in the context of a model of job heterogeneity not only improves understanding of labor supply as such, but also permits consistent estimation of compensating wage differentials and the supply parameters that underly such differentials. The reason for this is that data on labor supply within different jobs are generated by the same preference structure that generates job choice and compensating wage differentials. Analysis of all three outcomes – job choice, labor supply and wages – can therefore yield more information than analysis of wages alone.

Despite the potential importance of job heterogeneity, relatively little has been done to incorporate it into formal labor supply models. Tinbergen (1956) considered the choice of (variable) amounts of job characteristics – with "desirable" job characteristics assumed to reduce pecuniary income but raise utility – but assumed that all jobs (i.e. distinct combinations of job characteristics) require the same hours of work. Extending this approach to allow for variable labor supply is relatively straightforward, however. One approach is to consider the joint determination of labor supply (or leisure) and a set of continuous job characteristics. A second is to consider the joint determination of labor supply (or leisure) and the discrete choice among various distinct jobs.

Atrostic (1982) takes the first approach, specifying utility as a function of consumption of a composite consumer good C, leisure time L and the vector of characteristics of one's job, J. Since desirable (and undesirable) J may be expected to generate compensating wage differentials, the wage rate W is also a function of the J (instead of being given exogenously, as in most labor supply models). This leads to a model that is formally quite similar to the kind of demand system familiar to analysts of consumer expenditure; in effect, the J can be treated as consumer goods that in principle are little different from other consumer goods.

For a simple example, consider the following application of this approach to analysis of a single individual (extension to a family setting is straightforward). First, let W be a linear function of the J, implying that the budget constraint may be written as

$$PC \leq R + H\left[w_0 + \sum_i w_i J_i\right], \tag{21}$$

where the term inside square brackets is the wage *function*. Next, let the individual's utility be given by

$$U = U(C, L, HJ_1, \ldots, HJ_k]. \tag{22}$$

Then the resulting model effectively refers to the choice of labor supply H, leisure

time $L = T - H$, the composite good C and a set of K *additional* consumption goods K ($= HJ$), with utility,

$$U = U(C, L, K_1, \ldots, K_k), \tag{23}$$

being maximized subject to the budget constraint

$$PC + \sum_i w_i K_i \leq R + w_0 H, \tag{24}$$

in which the w_i, $i = 1, \ldots, k$, play the role of prices, directly analogous to P. The parameter w_0 may be thought of as the individual's "potential wage", i.e. as the wage received when all the J (or, equivalently, K) are zero; the J, as nonpecuniary consumption *per hour* of work; the K, as total nonpecuniary consumption. Thus, this specification leads quite simply and conveniently to a model that closely resembles those used in the estimation of systems of consumer demand functions [Barten (1977), Brown and Deaton (1972), Deaton and Muellbauer (1980)]. However, it takes explicit account of the fact that the job characteristics J are endogenously chosen and that exogenous changes (e.g. in the general wage level, in w_0, in exogenous income, etc.) will affect the individual's W and J as well as H.

Killingsworth (1985) takes the second of the two approaches to analyzing heterogenous labor supply, considering the supply of work hours to discrete jobs (as opposed to choice of continuous job characteristics). In this framework, utility itself depends on the job one holds, other things (including the wage rate, exogenous income, etc.) being equal, as given by the (job-dependent) indirect utility function[11]

$$V_j = V_j[W_j, R], \tag{25}$$

where j indexes jobs, and where the wage rate W_j received by the individual when in any particular job j need not be the same as the wage that would be received if the individual were in any other job. Labor supply when in job j is given by direct application of Roy's Identity to (25); analysis of the individual's discrete job choice may be conducted using an index function model. (For example, in a simple world with just two jobs, the individual's discrete job choice could be analyzed using the binary probit or logit model.) Again, wages and job choice are treated as endogenous along with hours of work.

[11]See Pencavel (Chapter 1 in this Handbook) or Killingsworth (1983, pp. 15–16) for discussion. Since the optimal (i.e. utility-maximizing) consumption and leisure values C^* and L^* are functions of W, R and the price level P, *maximum* utility V – which depends on the *optimal* C and L – may be written as a function of W, R and P. [In other words, maximum utility $U^* = U(C^*, L^*) = V = V(W/P, R/P)$.] Roy's Identity asserts that labor supply H is given by the ratio of (i) the partial derivative of V with respect to the real wage W/P to (ii) the partial derivative of V with respect to real exogenous income R/P. (In the expression in the text, P is implicitly normalized to unity.)

Hill (1985) proceeds along similar lines, though without reference to an explicit utility function: she analyzes the labor force status of Japanese women using trinomial logit (where the three labor force categories are out of the labor force, working in family-owned enterprises or working in other paid employment); uses the logit results to derive inverse-Mills'-ratio-like variables analogous to those proposed by Heckman (1976b, 1979); and then includes these variables in regressions for labor supply and wage rates in the two employment sectors (i.e. family-owned and other enterprises).

Both the continuous job characteristics and the discrete job choice models of the supply of labor to heterogenous work have the potential of providing useful insights into important dimensions of female labor supply. Unfortunately, except in Hill's study (1985), such models have yet to be used to explore the structure of the occupational dimension of women's work effort [Atrostic (1982) and Killingsworth (1985) are concerned with male labor supply]. This is an important topic for future research.

3.2. *Dynamic models*

We now consider dynamic labor supply models, ones in which agents act as if today's decisions do in fact have future consequences and in which accumulation of nonhuman and/or human wealth is treated explicitly. We first discuss models in which wages at each moment are assumed to be given exogenously. We then examine models in which wages are endogenously determined, e.g. via human capital accumulation.

3.2.1. *Dynamic labor supply models with exogenous wages*

Until fairly recently, almost all work on labor supply either implicitly or explicitly adopted an essentially static analytical framework. In contrast, Mincer's (1962) pioneering work is noteworthy because it not only contributed significantly to development of that framework, but also introduced ideas of a fundamentally dynamic nature.[12]

A major motivation for Mincer's work was an apparent paradox concerning the labor supply of women, especially married women: in cross-sections, one typically observes *inverse* relations between women's labor force participation rates and males' wage rates, and between wives' labor force participation rates and husbands' earnings; but time-series data exhibit sustained increases in participation rates for women, especially married women – "one of the most striking phenomena in the history of the American labor force" [Mincer (1962, p. 64)] – despite substantial growth in real wage rates and real incomes.

[12]Among the most important early studies of labor supply are Douglas (1934), Durand (1948), Lewis (1957), Long (1958), and Schoenberg and Douglas (1937). Modern empirical work may be said to have begun in earnest with the studies by Cain (1966), Kosters (1966, 1969) and Mincer (1962). See Cain (1982) for an appreciation of Mincer's (1962) seminal paper in light of two decades of further research.

In addressing this paradox, and the labor force participation of married women generally, Mincer considered a variety of essentially static topics (e.g. the importance of the family context and of household production in labor supply decisions), several of which are discussed in Section 3.1. However, his analysis also includes several fundamentally dynamic features, including the notion of life-cycle decisionmaking and the distinction [first developed by Friedman (1957)] between permanent and transitory components of income, earnings, wages, etc. These ideas are encapsulated in the following three paragraphs in Mincer's original paper (1962, p. 68; emphasis original):

> In a broad view, the quantity of labor supplied to the market by a wife is the fraction of her married life during which she participates in the labor force. Abstracting from the temporal distribution of labor force activities over a woman's life, this fraction could be translated into the probability of being in the labor force in a given period of time for an individual, hence into a labor force rate for a large group of women.
>
> If leisure and work preferences, long-run family incomes, and earning power were the same for all women, the total amount of market work would, according to the theory, be the same for all women. Even if that were true, however, the *timing* of market activities during the working life may differ from one individual to another. The life cycle induces changes in demands for and marginal costs of home work and leisure... There are life-cycle variations in family incomes and assets which may affect the timing of labor force participation, given a limited income horizon and a less than perfect capital market. Cyclical and random variations in wage rates, employment opportunities, income and employment of other family members, particularly of the head, are also likely to induce temporal variations in the allocation of time between home, market, and leisure. It is not surprising, therefore, that over short periods of observation, variation in labor force participation, or turnover, is the outstanding characteristic of labor force behavior of married women.
>
> To the extent that the temporal distribution of labor force participation can be viewed as a consequence of "transitory" variation in variables favoring particular timing, the distinction between "permanent" and current levels of the independent variables becomes imperative in order to adapt our model to family surveys in which the period of observation is quite short.

Subsequent researchers have drawn two major practical conclusions from these general remarks. First, some investigators have treated estimated wage and income coefficients obtained in empirical analysis of labor force participation as theoretically equivalent to wage and income coefficients estimated in analyses of hours of work, and so have used estimates of parameters affecting participation to retrieve measures of Hicks–Slutsky income and substitution effects. Second, some researchers have argued that, given the intertemporal considerations that underly labor supply decisions, it is essential to distinguish between temporary and permanent changes in wage rates, exogenous income, and other key determinants of labor supply.[13]

Although such ideas possess considerable intuitive appeal, they have not usually been derived – or even described – rigorously. This is unfortunate, for it has tended to limit quite severely the usefulness of work subsequent to Mincer's that has relied on these notions. In what follows, we develop them formally and then apply them to the analysis of female labor supply.

Perhaps the simplest way to embed Mincer's ideas in a formal model is to reinterpret the simple static analysis of labor supply in lifetime terms: since the single period of that model is of indeterminate length, there is no reason why the U, C, T, H, L, W and P of that model cannot be interpreted as lifetime variables. The only change necessary is to interpret R as the individual's initial real asset holdings (instead of her "exogenous income"). For simplicity, assume a zero market rate of interest (although even that is hardly essential, since all pecuniary variables such as W and P could be appropriately discounted); and introduce an unobserved "taste" or "household production" variable e that affects (lifetime) utility U and is independent of other variables, such that

$$U = U(C, L, e). \tag{26}$$

Note that this implicitly assumes that leisure times at different dates are perfect substitutes for each other (and similarly for consumption of goods at different dates).

The (lifetime) budget constraint subject to which utility is maximized is

$$PC \leq WH + R, \tag{27}$$

exactly as in the single-period static model. However, (27) does not require an assumption that the wage be constant over the worker's lifetime: the W in (27) is the "lifetime" wage, i.e. a kind of life-cycle *average* of (appropriately-discounted) single-period wage rates that may differ across periods.

To fix ideas, assume that the life cycle consists of T periods, and sort single-period real wage rates in descending order, so that $w(1)$ denotes the *highest*

[13] For examples of empirical studies that use analyses of participation to obtain measures of income and substitution effects, see Ashenfelter and Heckman (1974), Cain (1966) and Kosters (1966, 1969). For examples of empirical studies that pursue the distinction between permanent and transitory changes in wages and other labor supply determinants, see Kalachek and Raines (1970), Kalachek, Mellow and Raines (1978), Lillard (1978) and Watts, Poirier and Mallar (1977).

453

real wage and $w(T)$ the lowest. Then, as in the static model, a market wage-reservation wage comparison determines whether the individual will work sometime during her life. Specifically, the individual will work at least one period if $w(1)$ exceeds her (lifetime) reservation or "shadow" wage – i.e. the marginal rate of substitution evaluated at zero (lifetime) hours of work, $U_L(R,T,e)/U_C(R,T,e) = S(R,T,e)$:

$$U_L(R,T,e)/U_C(R,T,e) = S(R,T,e) \leq w^* \to H > 0. \tag{28}$$

The *total number* of periods the individual works can be expressed in terms of a similar comparison: the individual will work exactly k periods if, when the discounted real wage rates w are sorted in descending order,

$$w(k) \geq S(R,T,e) \geq w(k+1) \tag{29}$$

where, by virtue of the sort, $w(k) > w(k+1)$, and where at least one of the inequalities in (29) is strict.[14] By (29), the total number of periods worked, k, is a function of e, real initial wealth R and the "marginal wage" $w(k)$, i.e.

$$k = k[w(k), R, T, e]. \tag{30}$$

Once k and $w(k)$ are defined as "labor supply" and "the wage rate", respectively, this looks just like a conventional static labor supply function.

Finally, the proportion of all periods in the individual's *lifetime* that are devoted to work, h, is simply $h = k/T$. Since k is a function of $w(k)$, R and e by (30), h is also; thus, h may be expressed as

$$h = h[w(k), R, e], \tag{31}$$

where the $h(\cdot)$ function of (31) is proportional to the $k(\cdot)$ function of (30), with T being the factor of proportionality.

A practical difficulty with this model is that its estimation – e.g. fitting (30) or (31) – would seem to require data on labor supply over the entire life cycle (e.g. either k or h), which is surely an imposing hurdle for the empirical analyst. However, Mincer's discussion, quoted above, provides an ingenious way around this difficulty: abstracting from "transitory" factors (children, transitory variation in income or wages, etc.), the timing of work over the life cycle may be

[14] Note that (29) closely resembles expressions obtained in purely *static* models of labor supply under progressive taxation [see, for example, Heckman and MaCurdy (1984), Killingsworth (1983), Hausman (1983)]. In the latter setting, the single-period budget constraint consists of numerous segments, each corresponding to a different marginal rate of tax, with $w(k)$ referring to the value of the real wage *after taxes* on the kth budget line segment [where $w(k) > w(k+1)$ provided the marginal tax rate rises with income].

assumed to be random. If so, and if all individuals work at some point in their lives, then, as Heckman (1978) notes, one may estimate the parameters of (31) by simply replacing h, which refers to *lifetime* participation and is unobservable (or quite difficult to observe), with Z, i.e. a measure of participation *as of a given date*. In general, Z is easily measured: in aggregate time-series or cross-section data, Z would be a labor force participation rate; in microdata, Z would be a binary indicator variable denoting labor force participation or nonparticipation. In either case, then, in the absence of transitory factors, estimates of

$$Z = Z[w(k), R] + \text{error term} \tag{32}$$

serve as estimates of (31) and can be used to retrieve conventional income and substitution effects on labor supply. That is, given estimates of the parameters of (32), one can calculate the uncompensated effect of permanent wage change on labor supply as $\mathrm{d}Z[w(k), R]/\mathrm{d}[w(k)]$, and the income (more precisely, initial wealth) effect as $\{\mathrm{d}Z[w(k), R]/\mathrm{d}R\}Z$.

However, several serious difficulties stand in the way of this approach. Some of the difficulties are practical ones. For example, estimation of (32) requires a measure of the "marginal wage" $w(k)$ rather than of the wage prevailing as of the date referenced by the Z variable; and as (29) implies, to determine which period's wage is in fact the marginal wage, one will need information on at least part of the entire stream of wages over the life cycle. In other words, although one does not need data on lifetime labor supply to estimate (32), one does have to be able to determine which particular wage rate – of all the wages the individual will earn during her lifetime – happens to be the marginal wage rate [in the sense of (29)].

In addition to this practical problem, estimation of (32) must confront an analytical issue: using estimates of (32) to obtain measures of substitution and income effects is appropriate only when all individuals' lifetime labor supply H (or h) is positive, i.e. only when all individuals have an *interior solution* to their lifetime labor supply optimization problem. Although there is considerable controversy about the size of the female population that never works, there is at least some reason for thinking that some women do not, in fact, ever work [Ben-Porath (1973), Boothby (1984), Corcoran (1979), Heckman (1978), Heckman and Willis (1977, 1979), Mincer and Ofek (1979), Stewart and Greenhalgh (1984)]. If so, then analyses of labor force participation at a given date using expressions such as (32) will not provide useful evidence on income and substitution effects [Heckman (1978)].

To see why, note first that (32) is concerned with the probability that a given individual will work at some date t, given a vector of her characteristics X (which would include the sequence of wage rates, the value of R, etc.), which we will write as $\Pr\{H(t) > 0 | X\}$. Now, this probability may be expressed as the product

of (i) the probability that this individual will ever work at any date in the life cycle, given her X, which we write as $\Pr\{h > 0 | X\}$; and (ii) the probability that this individual will work at t given her X *and* given that she works at some point in the life cycle, which we write as $\Pr\{H(t) > 0 | X, h > 0\}$. Thus,

$$\Pr\{H(t) > 0 | X\} = \Pr\{h > 0 | X\}\Pr\{H(t) > 0 | X, h > 0\}. \tag{33}$$

If the timing of participation over the life cycle is indeed "random" (or "random, leaving aside transitory factors"), then

$$\Pr\{H(t) > 0 | X, h > 0\} = \mathrm{E}\{h | X, h > 0\}, \tag{34}$$

where $\mathrm{E}\{x|y\}$ is the conditional expectation of x given y. (34) says that, under the randomness assumption, the probability that someone will work in any particular period t given that she works at some time during the life cycle (and given her X) is simply the proportion of the entire life cycle that she works. By (34), (33) becomes

$$\Pr\{H(t) > 0 | X\} = \Pr\{h > 0 | X\}\mathrm{E}\{h | X, h > 0\}. \tag{35}$$

If everyone does work at some point in the life cycle, then $\Pr\{h > 0 | X\} = 1$ and $\mathrm{E}\{h | X, h > 0\} = \mathrm{E}\{h | X\}$, so (35) becomes

$$\Pr\{H(t) > 0 | X\} = \mathrm{E}\{h | X\}. \tag{36}$$

In this case, then, estimates of (32) – which is equivalent to the left-hand side of (36) – will indeed provide measures of theoretical substitution and income effects [which underly the right-hand side of (36)]. However, note also that if some individuals *never* work, labor force behavior at any date t is described by (33), *not* (36); and that in general the partial derivatives of the right-hand side of (33) with respect to W/P and R/P will not provide useful information about substitution and income effects because they will not be equivalent to the partial derivatives of the right-hand side of (36) with respect to the same variables.

It is worth noting at this point that – contrary to what has sometimes been asserted or conjectured – lifetime labor supply in this model, as given by expressions such as (31), *cannot* usually be written as a function of a "permanent wage" (or, alternatively, as a function of both "permanent" and "transitory" wages). Moreover, this model does not readily yield an expression for hours worked in any given period t, $H(t)$. To proceed further, it is helpful to use the formal model of life cycle behavior with exogenous wages summarized by Pencavel in Chapter 1 of this Handbook (note that we discuss endogenous wages in Section 3.2.2 below). That model explicitly considers $D+1$ distinct periods (e.g. "years") during the life cycle, with D assumed known and fixed, and specifies lifetime utility U as an additively-separable utility function

$$U=\sum_{t=0}^{D}(1+s)^{-t}u[C(t),L(t)], \tag{37}$$

where $C(t)$ and $L(t)$ are the individual's consumption of a composite good and leisure, respectively, in period t; s is the individual's subjective rate of time preference; and $u[\cdot]$ is the strictly concave single-period utility function. [Note that this is more general than (26) in that leisure times (or consumer goods) at different dates are not assumed to be perfect substitutes.] Lifetime utility is maximized subject to a lifetime budget constraint.

$$A(0)+\sum_{t=0}^{D}(1+r)^{-t}[W(t)H(t)-P(t)C(t)]\geq 0, \tag{38}$$

where $A(0)$ is the individual's initial asset holdings; r is the market rate of interest; and $P(t)$, $W(t)$ and $H(t)$ are the price level, wage rate and hours of work, respectively, during period t.[15] Now form the Lagrangian

$$L=\sum_{t=0}^{D}(1+s)^{-t}u[C(t),L(t)] + v\left\{A(0)+\sum_{t=0}^{D}(1+r)^{-t}[W(t)H(t)-P(t)C(t)]\right\}. \tag{39}$$

where v is a Lagrange multiplier, and obtain the first-order conditions for a constrained maximum:

$$(1+s)^{-t}u_C(t)-v(1+r)^{-t}P(t)=0,$$
$$(1+s)^{-t}u_L(t)-v(1+r)^{-t}W(t)\geq 0,\quad \text{with} > \rightarrow H(t)=0,$$
$$A(0)+\sum_{t=0}^{D}(1+r)^{-t}[W(t)H(t)-P(t)C(t)]=0,$$

where $u_i(t)$ is the partial derivative of the period-t utility function u with respect to i ($=C(t)$ or $L(t)$). Note that the second of these equations allows for the possibility that the individual may not work in period t, i.e. for a corner solution during at least part of the life cycle. Note also that v (which may be interpreted as the marginal utility of initial assets at the individual's optimum) is endogenous to the individual just like the $C(t)$ and $L(t)$; and that the value of v is determined along with the $D+1$ values of the $C(t)$ and the $D+1$ values of the $L(t)$ by solving the $2(D+1)+1$ equations above in terms of the exogenous givens of the model: the set of wage rates $W(t)$ and prices $P(t)$ and the level of initial assets, $A(0)$. Thus, when $A(0)$ or the $W(t)$ or $P(t)$ change, v as well as the $L(t)$ and $C(t)$ will change.

Next, to simplify notation, define

$$v(t)=[(1+r)/(1+s)]^{-t}v, \tag{40}$$

where $v(t)$ may be defined as the marginal utility of assets at period t, so as to rewrite the above first order conditions more compactly:

$$u_C(t)-v(t)P(t)=0, \tag{41a}$$
$$u_L(t)-v(t)W(t)\geq 0,\quad \text{with} > \rightarrow H(t)=0, \tag{41b}$$
$$A(0)+\sum_{t=0}^{D}(1+r)^{-t}[W(t)H(t)-P(t)C(t)]=0. \tag{41c}$$

Thus far, our discussion has been concerned with equilibrium dynamics, i.e. with the characteristics of a given individual's lifetime equilibrium plan for her *sequence* of labor supply, leisure time and consumption values $H(t)$, $L(t)$ and $C(t)$ for $t=0,1,\ldots,D$, and for her shadow value of (initial) assets v. [Note also that (41) immediately yields $v(t)$ for $t=1,2,\ldots,D$ once v has been determined.] This equilibrium plan is formulated for a given *set* of wage rates and price levels $W(t)$ and $P(t)$, $t=0,1,\ldots,D$, and for a given initial asset level $A(0)$. To see how the equilibrium plans of *different* individuals will differ as a result of their facing a different $A(0)$ or a different set of $W(t)$, it is necessary to consider the

[15] We ignore bequests, and so the utility function (32) assumes that the only activities that affect utility are consumption and leisure. However, it is straightforward to allow for bequests by, for example, adding a *bequest function* $B[A(D)]$ to the right-hand side of (38), where $A(D)$ is the assets the individual has not spent as of the time of death, $t=D$. Note that (38) is separable in time, so that consumption or leisure at any date t does not affect the marginal utility of consumption or leisure at any *other* date t'. This assumption of intertemporal separability is fairly innocuous in many applications, but it does entail several rather specific behavioral assumptions. The main assumption implicit in intertemporal separability as specified in (38) is that, if leisure times at all dates are normal goods, then leisure times at different dates must be net substitutes (in the income-compensated or lifetime-utility-constant sense). See Brown and Deaton (1972, pp. 1165–1167) and Deaton (1974). Note also that the budget constraint (39), like the utility function (38), ignores bequests. In this case, (39) holds as an equality [see, for example, (42c)]. In the presence of bequests, (39) will usually hold as an inequality, with assets at the end of life $A(D)$ constituting the individual's bequest.

comparative dynamics of the model, i.e. to analyze the way in which changes in exogenous variables such as the $W(t)$ lead to differences in choices [e.g. differences in v, $L(t)$ and $H(t)$].

In working out the model's comparative dynamics, we assume for the time being that equilibrium entails a lifetime interior solution, with positive hours of work $H(t)$ for all t. (We relax this assumption later, however.) Then one may write (41b) as an equality and solve the system (41a)–(41b) for $C(t)$ and $L(t)$ in terms of $v(t)P(t)$ and $v(t)W(t)$:

$$C(t) = C[v(t)P(t), v(t)W(t)], \tag{42a}$$

$$L(t) = L[v(t)W(t), v(t)P(t)]. \tag{42b}$$

These are often called "marginal utility of wealth-constant" or "Frisch" demand functions for C and L [Browning, Deaton and Irish (1985)].

Next, write (41b) as an equality and totally differentiate (41a)–(41b) to obtain:

$$\begin{aligned} \mathrm{d}C(t) &= \mathrm{d}[v(t)P(t)][u_{LL}(t)/\mathrm{d}(t)] - \mathrm{d}[v(t)W(t)][u_{CL}(t)/\mathrm{d}(t)] \\ &= \mathrm{d}P(t)\{[u_{LL}(t)v(t)]/\mathrm{d}(t)\} - \mathrm{d}W(t)\{[u_{CL}(t)v(t)]/\mathrm{d}(t)\} \\ &\quad + \mathrm{d}v(t)\{[u_{LL}(t)P(t) - u_{CL}(t)W(t)]/\mathrm{d}(t)\}, \end{aligned} \tag{43a}$$

$$\begin{aligned} \mathrm{d}L(t) &= \mathrm{d}[v(t)W(t)][u_{CC}(t)/\mathrm{d}(t)] - \mathrm{d}[v(t)P(t)][u_{CL}(t)/\mathrm{d}(t)] \\ &= \mathrm{d}W(t)\{[u_{CC}(t)v(t)]/\mathrm{d}(t)\} - \mathrm{d}P(t)\{[u_{CL}(t)v(t)]/\mathrm{d}(t)\} \\ &\quad + \mathrm{d}v(t)\{[u_{CC}(t)W(t) - u_{CL}(t)P(t)]/\mathrm{d}(t)\}, \end{aligned} \tag{43b}$$

where $u_{ij}(t)$, $i, j = C(t), L(t)$, is a second partial derivative of the period-t utility function u with respect to i and j; and $\mathrm{d}(t) = u_{CC}(t)u_{LL}(t) - u_{CL}(t)^2 > 0$ by concavity of u. The terms in braces that are multiplied times $\mathrm{d}v(t)$ in eqs. (43) are negative provided $C(t)$ and $L(t)$, respectively, are normal goods in the static one-period sense;[16] the terms in (43a) and (43b) that are multiplied times $\mathrm{d}P(t)$ and $\mathrm{d}W(t)$, respectively, are both negative by concavity of u.

Equations (43) show how differences in $v(t)$, $W(t)$ and $P(t)$ at any given date t lead to differences in consumption and leisure at that date. They can also be used to show how a difference in $W(t)$ *with* $v(t')$ *and* $P(t')$ *constant* will affect $a(t') = W(t')H(t') - P(t')C(t')$, the net increment to wealth made at any time

[16]By "normal in the static sense", we mean that if the individual were forced to maximize *single-period* utility u (instead of lifetime utility U) subject to the conventional *single-period* budget constraint $P(t)C(t) = W(t)H(t) + R(t)$, where $R(t)$ and $W(t)$ are exogenous income and the wage rate, then the income effects on $C(t)$ and $L(t)$ of a change in $R(t)$ would be proportional to $-[u_C u_{LL} - u_L u_{CL}]$ and $-[u_L u_{CC} - u_C u_{CL}]$, respectively. For example, see Cohen, Rea and Lerman (1970, esp. pp. 184–186).

t': by (43) [with $\mathrm{d}v(t') = \mathrm{d}P(t') = 0$],

$$\begin{aligned} \mathrm{d}a(t)/\mathrm{d}W(t) &= \mathrm{d}[W(t)H(t) - P(t)C(t)]/\mathrm{d}W(t) \\ &= H(t) - W(t)[\mathrm{d}L(t)/\mathrm{d}W(t)] - P(t)[\mathrm{d}C(t)/\mathrm{d}W(t)] \\ &= H(t) + Y_{LV}(t), \end{aligned} \tag{44a}$$

$$\mathrm{d}a(t')/\mathrm{d}W(t) = 0, \quad t' \neq t, \tag{44b}$$

where $Y_{LV}(t) = \{[u_C(t)u_{LC}(t) - u_L(t)u_{CC}(t)]/\mathrm{d}(t)\}$ and is positive provided leisure at t is normal in the static sense. Thus, *with* $v(t)$ *and* $P(t)$ *constant*, an increase in $W(t)$ will increase period t's addition to net worth provided $L(t)$ is normal; but so long as $v(s)$ and $P(s)$ are constant, an increase in $W(t)$ will not affect additions made at any other date $s = t$.

However, as noted above, a change in $W(t)$ will change not only $L(t)$ and $C(t)$ but also v [and thus, by (40), $v(t)$]: v and $v(t)$ are choice variables, just like $L(t)$ and $C(t)$. For example, it is intuitively plausible that, ceteris paribus, someone who enjoys a higher wage at any date t will feel better off and thus will have a lower v [and so, by (40), a lower $v(t)$ for *all* t] – that is, will regard assets as less "precious" or "scarce", and will begin to spend assets more freely. Indeed, as (44a) indicates, *unless* such a high-$W(t)$ individual changes her v [relative to the v chosen by a low-$W(t)$ individual], she will accumulate "excess assets", thereby violating the budget constraint (41c). Since there are no bequests (by assumption: see footnote 15) and since "you can't take it with you", that cannot be optimal. The appropriate response to higher $W(t)$ is to reduce v [and thus, by (40), to reduce $v(t)$ for *all* t]. To see why, consider the effect on $a(t)$ of increasing $v(t)$, ceteris paribus, as given by eqs. (43):

$$\begin{aligned} \mathrm{d}a(t)/\mathrm{d}v(t) &= -W(t)[\mathrm{d}L(t)/\mathrm{d}v(t)] - P(t)[\mathrm{d}C(t)/\mathrm{d}v(t)] \\ &= \{-W(t)^2 u_{CC}(t) - P(t)^2 u_{LL}(t) \\ &\quad + 2W(t)P(t)u_{CL}(t)\}/\mathrm{d}(t), \end{aligned} \tag{45}$$

which is positive by concavity of u. Thus, *reducing* v – which will reduce $v(t)$, by (40) – will reduce $a(t)$, thereby offsetting the increase in $a(t)$ associated with the ceteris paribus effects of the increase in $W(t)$ as given by (44). Hence, other things being equal, a greater $W(t)$ does indeed entail a lower v:

$$\mathrm{d}v/\mathrm{d}W(t) < 0. \tag{46a}$$

Moreover, by (40) and (46a), a higher $W(t)$ also entails a lower $v(t')$ at *all* dates

t', $t' = 0, 1, \ldots, t, \ldots, D$:

$$\begin{aligned} \mathrm{d}v(t')/\mathrm{d}W(t) &= [\mathrm{d}v(t')/\mathrm{d}v][\mathrm{d}v/\mathrm{d}W(t)] \\ &= [(1+r)/(1+s)]^{-t'}[\mathrm{d}v/\mathrm{d}W(t)] < 0. \end{aligned} \tag{46b}$$

Finally, (43b) and (46b) imply that the lower $v(t')$ at all dates t' caused by the greater $W(t)$ will increase leisure $L(t')$ at all t', provided $L(t')$ is normal in the static sense:

$$\begin{aligned} \mathrm{d}L(t')/\mathrm{d}W(t) &= [\mathrm{d}L(t')/\mathrm{d}v(t')][\mathrm{d}v(t')/\mathrm{d}W(t)] \\ &= \{[W(t')u_{CC}(t') - P(t')u_{CL}(t')]/\mathrm{d}(t')\} \\ &\quad \times [\mathrm{d}v(t')/\mathrm{d}W(t)], \end{aligned} \tag{47}$$

which is positive provided $L(t')$ is normal.

In sum, a greater value of $W(t)$ leads "directly," *with v constant*, to lower $L(t)$ and greater $H(t)$; that may be called the *v-constant* or Frisch effect of the greater $W(t)$, and is given by the first term after the second equals sign in (43b). However, if all leisure times and consumer goods are normal, then the greater $W(t)$ also leads to a smaller v, which leads "indirectly", *with v changing*, to greater $L(t)$ and smaller $H(t)$; that may be called the *v-variable* effect of the greater $W(t)$, and is given (for $t' = t$) by (47).

Thus, variation in the wage at any given date may have consequences not only at that date but also at other dates. Since Mincer (1962), many writers have focused on the labor supply effects of specific kinds of wage changes – "permanent" and "transitory". Their discussions raise both practical and conceptual issues that have rarely been tackled rigorously. Two seem particularly important. First, how should permanent and transitory wages (or wage changes) actually be defined? To our knowledge, this question has rarely been addressed formally. However, informal discussions seem ultimately to adopt essentially the same definition: the permanent wage W_P is defined as the present value of the stream of the individual's future wage rates $W(t)$ from period $t = 0$ to period $t = D$, the age of death, so that

$$W_P = \sum_{t=0}^{D} (1+r)^{-t} W(t). \tag{48a}$$

Thus the transitory wage at t is the difference between the actual wage $W(t)$ and the permanent wage W_P:

$$w(t) = W(t) - W_P. \tag{48b}$$

This raises a second, practical, issue: since researchers rarely if ever have access to data on the entire set of future wage rates of any individual, how should (how can) the permanent wage actually be measured? As far as we can tell, each researcher who has considered this question has answered it differently; by and large, empirical measures of the permanent wage are constructed using essentially ad hoc procedures and depend to a considerable extent on the nature of the data that are available.

The final issue about permanent and transitory wages that has been discussed in the literature – again, not very rigorously – concerns whether transitory as well as permanent wage variation affects labor supply (e.g. hours of work, participation). In one view, which we will call "PO" for short, hours of work and labor force participation in any period t depend on the permanent wage *only*, apparently by analogy with Friedman's (1957) permanent income theory of consumption (according to which consumption depends on permanent, but not transitory, income). Thus, according to the PO hypothesis, one need not include the transitory wage $w(t)$ on the right hand side of expressions such as (32); alternatively, if $w(t)$ is included in such an expression, its coefficient will not be statistically different from zero.

The PO hypothesis has a rival, however, according to which one should include not only the permanent wage but also the transitory wage in estimating equations such as (32). In this alternative view, which we will call "PT" for short, changes in the permanent wage entail changes in both lifetime earning power and the opportunity cost of time, and therefore entail both substitution and income effects; whereas a transitory wage change at some date t does affect the opportunity cost of time at that date, and therefore generates a substitution effect, even though it does not entail any change in long-run earning power (and therefore does not generate an income effect). Thus, according to the PT hypothesis, one should include $w(t)$ as well as W_P in estimating expressions such as (32); moreover, the hypothesis implies that the coefficient on $w(t)$ will be positive and algebraically larger than the coefficient on W_P, since the latter represents the sum of a positive substitution effect and a negative income effect whereas the former represents a positive substitution effect only.[17]

Fortunately, it is straightforward to evaluate the rival hypotheses about permanent and transitory wages offered by PO and PT. Imagine two women, A and B, with the same permanent wage [as defined by (48a)] and identical in all other respects save one: their wage rates at two different dates, t^* and t', are different, so that their transitory wages at these two dates [$w(t^*)$ and $w(t')$, respectively]

[17] For studies that adopt PO, see Kalachek and Raines (1970) and Watts, Poirier and Mallar (1977). For studies that adopt PT, see Kalachek, Mellow and Raines (1978, p. 357) and Lillard (1978, p. 369); note that Mincer (1962, p. 68) contends that "'transitory' variation in variables [will favor] particular timing" of labor force participation, and thus implicitly adopts PT. For further discussion, see Killingsworth (1983, esp. pp. 286–296), who refers to PO and PT as "PT-1" and "PT-2," respectively.

are also different. Will these transitory wage differences lead to labor supply differences? If so, how will these two kinds of differences be related?

Let $dW(t^*)$ and $dW(t')$ denote the difference between A's and B's wage rates at t^* and at t', respectively. By (48) and the fact that A and B have the same permanent wage,

$$(1+r)^{-t^*}dW(t^*)+(1+r)^{-t'}dW(t')=0. \tag{49a}$$

For ease of reference, assume that $dW(t^*)>0$, i.e. A's wage is greater than B's at t^*. Then, by the above,

$$dW(t')=-(1+r)^{-(t^*-t')}dW(t^*)<0. \tag{49b}$$

Without loss of generality, let B's wage at both t' and t^* be equal to the permanent wage, W_P. By (48) and the assumption that the two women have the same permanent wage, this simply means that A has a positive transitory wage at t^* and a negative transitory wage at t'. Recall also that, by assumption, A and B are otherwise identical (e.g. both receive the same wage at all dates other than t' and t^*, have the same initial assets $A(0)$, etc.).

By (41c), (44) and (49), the v-constant effect of A's transitory wages at t^* and t' on the present value of her asset accumulation is

$$\begin{aligned} dz &= (1+r)^{-t^*}[da(t^*)/dW(t^*)]dW(t^*) \\ &\quad +(1+r)^{-t'}[da(t')/dW(t')]dW(t') \\ &= (1+r)^{-t^*}dW(t^*)\{H(t^*)+Y_{LV}(t^*)-H(t')-Y_{LV}(t')\}. \end{aligned} \tag{50}$$

That is, if A had the same value of v as B, the fact that her wage stream differs from B's – even though only in transitory respects – would mean that her life cycle asset accumulation would not be the same as B's [except for the special case in which the expression after either equals sign in (50) is zero]. In other words, even though they have the same permanent wage and initial assets, A will not be able to satisfy (41c) at the same value of v used by B. In general, then, A's value of v will differ from B's. By (45), A's value of v will be higher or lower than B's depending on whether the expression after either equals sign in (50) is negative or positive. If leisure is a normal good in the static sense, then, by (43b), the difference in v values will entail a negative or positive v-variable effect on on A's leisure time (relative to B's) at *all* dates t, including not only t^* and t' but all other dates as well. Moreover, by (43b), A's positive (negative) transitory wage at t^* (t') will have a negative (positive) v-constant effect on A's leisure time, relative to B's, at t^* (t').

In general, then, even transitory wage differences *will* lead to differences in leisure and labor supply – contrary to PO. Likewise, although A's positive transitory wage $dW(t^*)$ has a positive v-constant effect on her labor supply (relative to B's) at t^*, it will also have either a positive or a negative v-variable effect on her labor supply (relative to B's) at t^*, depending on the sign of the right-hand side of (50). Thus, on balance, labor supply and transitory wages at any given date such as t^* need not be positively correlated, even if other things (the permanent wage, initial asset level, etc.) remain the same – contrary to PT.

Thus far our discussion has assumed a lifetime interior solution for labor supply. However, the analysis carries over to the case of corner solutions without essential modification. The main caveat relevant to this case is the obvious one that changes in wages cannot have v-constant *or* v-variable effects on labor supply during any period t'' in which hours of work are zero.

For example, consider again our two workers, A and B, and this time suppose that (i) B works during t' but not during t^*; (ii) A and B have the same "permanent wage" as defined by (37), and (iii) A has a negative (positive) transitory wage at t' (t^*), as given by (49b). Thus, B has $L(t')<T$, $L(t^*)=T$ and, by (41a)–(41b), also has

$$u_L[C(t'),L(t')]/u_C[C(t'),L(t')]=W(t')/P(t'), \tag{51a}$$

$$u_L[C(t^*),T]/u_C[C(t^*),T]\geq W(t^*)/P(t^*). \tag{51b}$$

Now consider A's behavior. If her positive transitory deviation $dW(t^*)$ is sufficiently large, the inequality (51b) will not hold for her: that is, her wage at t^* may exceed her reservation wage [given by the left-hand side of (51b)], and she will work. In this case, A will be a labor force participant whereas B is not, even though both women have the same permanent wage – a contradiction of PO.

What if A's wage is not large enough to reverse the inequality (51b), so that A, like B, will not work at t^*? At time t', A has a negative transitory wage. However, contrary to PT, there is no reason why A must necessarily work fewer hours than B, or be more likely not to be a labor force participant.

To see why, note that if A's $L(t^*)$ is equal to T despite her transitory increase $dW(t^*)$, then this $dW(t^*)$ has no effect on $v(t^*)$ or $v(t')$. By (43a) and the assumption that $u_{CL}=0$, A's $C(t')$ depends only on $v(t')$. By (43b), A's negative transitory wage $dW(t')$ raises her leisure at t' via the usual v-constant effect. However, the increase in $L(t')$ also reduces the asset accumulation A makes at t', $a(t')$, and this *reduces* $L(t')$ via the usual v-variable effect. In other words, the version of (50) relevant to A in this case is

$$dz \doteq (1+r)^{-t'}dW(t')\{H(t')+Y_{LV}(t')\}. \tag{52}$$

Since $dW(t') < 0$, dz is negative provided leisure at t^* is normal in the static sense. By (45), A will therefore have a higher v [i.e. will now act as if assets had a greater (shadow) value, so as to avoid having a negative net worth at or before death]. Hence, by (43b), the increase in $v(t')$ also has a negative v-variable effect on A's leisure at t' that may offset the positive v-constant or "direct" effect on $L(t')$ resulting from the $dW(t') < 0$. Thus, here, as in other cases, it is not possible to gauge the net effect on A's leisure of a wage change. In particular, the negative transitory wage could lead either to less *or* more leisure.

Likewise, the negative transitory wage could lead either to a smaller *or* a greater probability of being a labor force participant. By (43a), the increase in $v(t')$ will have a negative v-variable effect on $C(t')$. Other things being equal, this *raises* the marginal utility of consumption and so *reduces* the reservation wage $u_L[C(t'),T]/u_C[C(t'),T]$ by an amount given by

$$\begin{aligned}\{-u_{CC}[C(t'),T](u_L[C(t'),T]/u_C[C(t'),T]) + u_{LC}[C(t'),T]\}\\ \times\{1/u_C[C(t'),T]\}\{dC(t')/dv(t')\},\end{aligned} \tag{53}$$

where the first term in braces is positive provided leisure is a normal good in the static sense, the second term in braces is always positive and the third term is negative by (44a). Hence, the reservation wage falls as the offered wage falls; there is no particular reason to suppose that the decrease in $W(t')$ must be associated with a greater likelihood of nonparticipation.

In sum, the analysis of this section leads to a number of conclusions about dynamic labor supply analysis. Some are negative: for example, the analysis shows why the distinction between permanent and transitory wages embodied in eqs. (48) is not particularly useful from a theoretical standpoint. Other conclusions are more constructive, however. First, as a number of writers [e.g. Browning, Deaton, and Irish (1985), Heckman and MaCurdy (1980) Pencavel, Chapter 1 in this Handbook] have observed, the Frisch demand functions (42) provide a useful alternative to the kind of permanent–transitory approach embodied in eqs. (48). Indeed, in the Frisch framework, the marginal utility of assets (our v) constitutes a kind of "permanent wage"; and variations in the *observed* wage $W(t)$, *with* v *constant*, constitute a kind of "transitory" wage variation [since, with v constant, differences in $W(t)$ are always negatively correlated with differences in $L(t)$, by (41b)].

Although these concepts are relevant to dynamic labor supply in general, two implications of the Frisch framework seem especially useful for understanding female labor supply. The first concerns an important difference between the conventional static model and the dynamic exogenous-wage model. In the former, the reservation wage is independent of the real market wage rate W/P. In contrast, in the latter, the reservation wage in any given period is in general a function of all wage rates. To see why, note from eqs. (41) that, in the dynamic case, the reservation wage is given by

$$u_L[C(t),T]/u_C[C(t),T] = u_L[C(t),T]/v(t)P(t). \tag{54}$$

Moreover, as indicated above, $v(t)$ is in general a function of all wage rates [recall, for example, eqs. (46)]. This has somewhat unsettling implications about the merits of simple intuition derived from static labor supply models. For example, in such models, a higher current wage must always entail a greater probability of participation: a greater current wage does not affect the shadow or reservation wage but does affect the market opportunities against which home uses of time are compared. In contrast, in dynamic models, a higher current wage need not entail a greater participation probability: especially if wages are positively serially correlated, a higher current wage implies a generally higher wage *profile* (i.e. greater wages during *all* periods), and hence a lower v – which, other things being equal, tends to reduce (the probability of) participation. As Heckman (1978, p. 205) notes, this is relevant to findings by Olsen (1977) and Smith (1977a), according to which, among certain demographic groups, *lower* wage women are *more likely* to participate in the labor force: "It is significant that the 'perverse' association between wage rates and participation status is found in demographic groups with the greatest volume of lifetime labor supply – such as married black women. It is in such groups that income effects [from a higher wage profile] are likely to be the largest."

We conclude this discussion of dynamic exogenous-wage labor supply models by returning briefly to Mincer's (1962) pioneering work. Although it stimulated many subsequent attempts to develop a workable distinction between permanent and transitory wages, it is ironic that Mincer's paper itself was concerned with dividing not *wages* but rather the *income of other family members* into permanent and transitory components. In effect, Mincer was interested in a situation in which the individual receives an exogenous amount (possibly zero) of income in each period t, $Z(t)$, from sources other than work *or* assets. Can this $Z(t)$ be divided into permanent and transitory components, as Mincer contended? If so, how?

To introduce such income, it is necessary[18] to modify the budget constraint, (38) or (41c), which now must be written

$$A(0) + \sum_{t=0}^{D}(1+r)^{-t}[Z(t) + W(t)H(t) - P(t)C(t)] = 0. \tag{55}$$

[18] If $Z(t)$ is to be interpreted as the income of other family members, as Mincer (1962) interprets it, it is necessary to assume that there are no intrafamily cross-substitution effects of the kind discussed in Section 3.1. [In that case, earnings of other family members are analytically equivalent to exogenous income, because they entail income effects only, without (cross-) substitution effects.]

Since the $Z(t)$ are assumed exogenous, it is clear that their introduction does not entail any substantive change in the foregoing analysis. On the one hand, because the analysis implicitly assumes perfect foresight, the present value of the $Z(t)$ can be combined with initial assets $A(0)$ to rewrite the budget constraint still further:

$$A(0)' + \sum_{t=0}^{D} (1+r)^{-t}[W(t)H(t) - P(t)C(t)] = 0, \tag{56}$$

where

$$A(0)' = A(0) + \sum_{t=0}^{D} (1+r)^{-t} Z(t). \tag{57}$$

Clearly, none of the analysis of this section is thereby changed; all that is necessary is to note that $A(0)'$, not $A(0)$, is now the relevant "initial assets" variable. However, one can instead proceed as Mincer implicitly did, defining a permanent (exogenous) income variable Z_P as the amount of an annuity Z_P that, when received each period from $t = 0$ to $t = D$, would have a present value equal to the present value of the $Z(t)$. That is, permanent income satisfies the relation

$$\sum_{t=0}^{D} (1+r)^{-t} Z_P = \sum_{t=0}^{D} (1+r)^{-t} Z(t),$$

so that permanent and transitory income are given by

$$Z_P = \sum_{t=0}^{D} (1+r)^{-t} Z(t) \Big/ \sum_{t=0}^{D} (1+r)^{-t} \tag{58a}$$

$$z(t) = Z(t) - Z_P, \tag{58b}$$

respectively. So (41c) [or (55), or its equivalent] may *also* be written as

$$A(0) + \sum_{t=0}^{D} (1+r)^{-t}[Z_P + W(t)H(t) - P(t)C(t)] = 0. \tag{59}$$

Thus, Mincer's approach does not suffer from the difficulties inherent in attempts to divide wages into permanent and transitory components. As (55) and (59) indicate, one can write the budget constraint in terms of either actual exogenous income $Z(t)$ *or* "permanent" exogenous income Z_P. Moreover, (55), (58) and (59) show that behavior depends on permanent exogenous income only and *not* on "transitory" income $z(t)$, as Mincer (1962) in effect argued.

All this notwithstanding, many writers came to think of Mincer's permanent–transitory distinction as referring to wage rates as well as (or even instead of) exogenous income. Ironically, in the flurry of subsequent work aimed at measuring and estimating the effects of permanent and transitory wage rates, a different but closely related notion of Mincer's concerning the role of credit market constraints in labor supply decisions, was completely overlooked. As Mincer (1962, pp. 74–75) put it:

> According to [the permanent income] theory, aggregate family consumption is determined even in short periods by long-run levels of family income. Adjustment between planned consumption and income received in the short period of observation (current, or measured income) takes place via saving behavior, that is, via changes in assets in debts. However, if assets are low or not liquid, and access to the capital market costly or nonexistent, it might be preferable to make the adjustment to a drop on the family income on the money income side rather than on the money expenditure side. This is so because consumption requiring money expenditures may contain elements of short-run inflexibility such as contractual commitments. The greater short-run flexibility of nonmoney items of consumption (leisure, home production) may also be a cultural characteristic of a money economy. Under these conditions, a transitory increase in labor force participation of the wife may well be an alternative to dissaving, asset decumulation or increasing debt.

An obvious implication of this argument is that transitory as well as permanent components of exogenous income may affect labor supply in the presence of credit market constraints, short-run inflexibility of consumption commitments, etc. However, in general [for a few exceptions, see Johnson (1983) and Lundberg (1985)], little has been done to analyze these or other, related, ideas raised by Mincer's discussion. This is unfortunate, for such analysis may enhance understanding not only of purely microeconomic issues, but even of macroeconomic problems as well.

3.2.2. Dynamic labor supply models with endogenous wages

The notion that wages depend on labor supply (as well as the reverse) has long played an important role in research. The most obvious example concerns discussions of women's wages and of sex differentials in wages, in which labor supply – e.g. the consequences of intermittent or continuous participation in the job market – and human capital investment decisions are usually seen as playing a crucial role [for example, see Mincer and Polachek (1974)].

This being the case, someone who is looking at the life cycle literature for the first time, with an eye to what insights it can provide about the two-way relation between women's wages and labor supply, is likely to come away from that literature feeling somewhat disappointed. Formal theoretical life cycle models of the joint determination of labor supply and wages are generally quite abstract and provide little immediate insight into the dynamics of women's work and wages; for example, not infrequently such models assume an interior life cycle solution for labor supply (i.e. positive hours of work at each point in the life cycle), thereby ignoring the discontinuities in labor force participation that figure so prominently in discussions of women's wages. Empirical work on such dynamic issues has in general either implicitly [Mincer and Polachek (1974)] or explicitly [Heckman and MaCurdy (1980, 1982)] ignored the behavioral linkage between women's work and wages in a life cycle setting [for a recent exception, see Zabalza and Arrufat (1983)].

However, it may be that these difficulties are not really as serious as they seem at first glance. Even relatively simple and quite abstract life cycle models can yield at least some insight into the joint determination of women's work effort and wage rates. Moreover, models of the kind usually found in the literature may be made more concrete and directly applicable to female labor supply. To illustrate both points, we set up a conventional life cycle model modified so as to include a time-varying taste shifter $m(t)$. In our framework, a large (or growing) $m(t)$ denotes a large (or growing) taste for leisure time. It therefore serves as a simple means of representing explicitly (if quite crudely) in a formal analytical model a notion that has figured prominently in informal discussions of women's work and wages over the life cycle: that for a variety of reasons – biological, cultural, etc. – any given woman's desire for "leisure" (nonmarket time for childbirth and childrearing, for example) may first increase and then decrease over time. Of at least equal importance, however, is another rationale for introducing such a taste shifter: that, at any given date, different women will for a variety of reasons have different preferences for such leisure.

We begin by considering the formal structure of a model of an individual woman's life cycle.[19] We assume that she acts as if she enjoyed perfect foresight. Her earnings at any date t, $E(t)$, are given by

$$E(t) = E[H(t), K(t)], \tag{60}$$

where $H(t)$ is her hours of work at time t and $K(t)$ is her stock of "earning power" or "human capital" at t. Let the rate of change of $K(t)$, $\dot{K}(t)$, be given by the stock-flow relation

$$\dot{K}(t) = i[I(t), G(t), K(t)] - qK(t), \tag{61}$$

[19] For general discussion of dynamic endogenous-wage models, see Weiss (Chapter 11 in this Handbook) and McCabe (1983).

where $I(t)$ and $G(t)$ are time and goods, respectively, devoted to increasing one's earning power (to "human capital accumulation") at date t; where inclusion of $K(t)$ in the i or "gross investment" function implies that K is an input into its own production; and where q represents the rate of decay, depreciation or obsolescence of K. As just noted, we use a dot over a variable to denote its rate of change over time; thus, $\dot{X}(t) = \mathrm{d}X(t)/\mathrm{d}t$ for any variable X; note that for convenience, we now switch from the discrete-time approach of Section 3.2.1 to continuous time.

The dynamic or lifetime utility function may now be written

$$U = \int_0^D e^{-st} u[C(t), m(t)L(t), K(t)]\,\mathrm{d}t, \tag{62}$$

where $m(t)$ is the taste shifter described earlier. This specifies lifetime utility U as the present value (discounted at the rate, s, at which the individual subjectively evaluates future amounts) of the stream of utilities u received at each instant t between now (time 0) and the end of life (time D).[20] Inclusion of $K(t)$ in the instantaneous utility function $u[\cdot]$ means that human capital contributes to well-being directly (e.g. helps one use leisure time efficiently) as well as indirectly (i.e. raises earning power). As in Section 3.2.1, we ignore bequests (see footnote 15).

It remains to specify the constraints subject to which lifetime utility, as given by (62), is maximized. The first constraint is that total available time at each moment is fixed at T and is allocated between investment $I(t)$, leisure $L(t)$ and hours of work $H(t)$, so that

$$T = I(t) + L(t) + H(t). \tag{63}$$

The relation between these theoretical constructs and empirically observable variables requires a bit of discussion at this point. The $H(t)$ in (60) and (63) refers to time actually devoted to work. However, in this model time spent *at* work (that is, at one's workplace) can also involve investment time, e.g. on-the-job training. Thus, for persons who have left school, the sum of investment time $I(t)$ and hours *of* work $H(t)$ (= "hours spent actually working") constitutes "labor supply" in the sense in which that term is normally used, i.e. hours spent *at* work. Likewise, the term "wage rate" is generally used to refer to average hourly earnings, i.e. earnings divided by the number of hours spent *at* work. Thus, in terms of the present model, average hourly earnings (= the "observed wage rate"), which as before we will denote by $W(t)$, is equal by definition to

$$W(t) = E(t)/[I(t) + H(t)]. \tag{64}$$

[20] The assumption that the utility function is additively separable in time is primarily just a simplification in the present context, but in other contexts it is not necessarily innocuous [see footnote 15, Hotz, Kydland and Sedlacek (1985) and Johnson and Pencavel (1984)].

The second constraint facing the individual is a dynamic budget constraint, requiring that she at least "break even" over her entire lifetime. For simplicity, we assume that capital markets are perfect, permitting borrowing and lending at market interest rate r. Then the dynamic or lifetime budget constraint may be written as

$$A(D) = A(0) + \int_0^D e^{-rt}[E(t) - P(t)C(t)]\,dt \geq 0. \tag{65}$$

This says that net worth at the end of life, $A(D)$ – i.e. initial wealth, $A(0)$, plus the (discounted) sum of increments to that initial stock made at each moment t, $e^{-rt}[E(t) - P(t)C(t)]$ – must be non-negative.

Further analysis is made somewhat easier by ignoring investment goods $G(t)$ in (61), and is facilitated greatly by introducing a simplification known as the "neutrality" assumption [Heckman (1976a)]. Under this assumption, human capital $K(t)$ acts like Harrod-neutral technical progress by "augmenting" *each* of the individual's inputs of time – leisure, work and investment – *equally*; in the sense that x percent more K would take the place of x percent less of each of L, H and I. Specifically, under the neutrality assumption, eqs. (60)–(62) become

$$E(t) = kH(t)K(t), \tag{66}$$

$$\dot{K}(t) = i[I(t)K(t)] - qK(t), \tag{67}$$

$$U = \int_0^D e^{-st}u[C(t), m(t)L(t)K(t)]\,dt, \tag{68}$$

where k may be thought of as the rental rate of human capital, assumed constant over time in the interest of simplification. In (67) we ignore investment goods $G(t)$, so the resulting human capital production function (or gross investment function) becomes $i[I(t)K(t)]$, with $i' > 0$ and $i'' < 0$ (i.e. i's first and second derivatives are positive and negative, respectively) on the assumption of positive but diminishing returns to IK in the production of (gross) increments to the human capital stock; assume further that $i[0] = 0$, i.e. when no investment occurs ($I = 0$), no gross increments to K are made. The instantaneous utility function u is now $u[C, mLK]$, and is assumed to be concave and increasing in its two arguments, C and mLK. Following Heckman (1976a), we refer to $H(t)K(t)$, $I(t)K(t)$ and $L(t)K(t)$ as effective hours of work, effective investment time and effective leisure, respectively; that is, to work, investment or leisure time as augmented by human capital K.

Letting $v(t)$ and $w(t)$ denote the shadow values (as of time t) of financial assets (A) and of human capital (K), respectively, one may write the first order

conditions for a maximum of lifetime utility, (68), as follows:[21]

$$e^{-st}\{u_C(t) - v(t)P(t)\} = 0, \tag{69}$$

$$e^{-st}\{v(t)kK(t) - u_L(t)K(t)m(t)\} \leq 0, \quad \text{with} < \rightarrow H(t) = 0, \tag{70}$$

$$e^{-st}\{w(t)i'(t)K(t) - u_L(t)K(t)m(t)\} \leq 0, \quad \text{with} < \rightarrow I(t) = 0, \tag{71}$$

where $u_j(t)$, $j = C$ or L, is the partial derivative of $u[C(t), m(t)L(t)K(t)]$ with respect to C or mLK; and $u_{jk}(t)$, $k = C$ or L, is the partial derivative of $u_j(t)$ with respect to C or mLK.

Equations (69)–(71) constitute a set of familiar marginal benefit–marginal cost rules. In each, the first term inside the braces is the marginal benefit of a particular activity – consumption, in (69); work, in (70); investment, in (71) – and the second is its marginal cost. In (69), the marginal benefit of consumption is simply its marginal utility; its marginal cost is the pecuniary price $P(t)$ of the consumer good converted into utility units by multiplication times $v(t)$, the shadow or utility value of an added dollar of wealth. In (70), the marginal benefit of work is the marginal utility of the additional earnings it generates [= the dollar amount of hourly earnings, $kK(t)$, converted to utility units by multiplication times $v(t)$], whereas its marginal cost is the marginal utility of leisure (i.e. the utility value of the leisure that must be given up). Finally, the marginal benefit of investment time is the utility value of the increment to the human capital stock caused by investment time [= the marginal product of investment time $I(t)$ in the production of human capital, $i'(t)K(t)$, multiplied times the shadow value of human capital, $w(t)$]; as with work, the marginal cost of investment time is the utility value of the leisure that must be forgone. Note that (70) and (71) allow for corner solutions for work and investment, respectively, in the sense that either activity's marginal cost may be so high relative to its marginal benefit that it may not be undertaken.

In addition to these marginal cost–marginal benefit rules, optimal behavior must satisfy several other requirements. First, by (62), bequests have no utility value, so assets at death must be zero:

$$A(D) = A(0) + \int_0^D e^{-rt}[E(t) - P(t)C(t)]\,dt = 0. \tag{72}$$

[21] Formal discussion of endogenous-wage life-cycle models such as the one in the text is perhaps best undertaken as it has usually been undertaken in the literature, using optimal control theory. However, many readers may find control theory unfamiliar, and for us to attempt to familiarize readers with it would take us well beyond the scope of our topic. [For an admirably lucid introduction to the subject, see Arrow and Kurz (1972, ch. 2); for more detailed treatments, see Dixit, (1976) and Takayama (1985, ch. 8).] Accordingly, the discussion here will be intuitive and heuristic.

Second, the initial shadow value of assets, $v(0)$, and the *discounted* shadow value at any later date t, $v(t)$, must be equal, where the discount rate is the difference between the individual's subjective rate of time preference s and the market rate of interest r, i.e.

$$v(0)=\mathrm{e}^{-(s-r)t}v(t). \tag{73a}$$

Note that (73a) implies that

$$\dot{v}(t)=(s-r)v(t). \tag{73b}$$

It also implies that, so long as s and r remain the same, the value of v at any given date t, $v(t)$, will change *only* if $v(0)$ changes.

Finally, the individual equates the shadow value of human capital at any date t to the discounted stream of future benefits (measured in utility units) that would result from having an additional unit of human capital at that date. Specifically, optimal behavior requires

$$\begin{aligned} w(t) &= \int_t^D \mathrm{e}^{-(s+q)(z-t)}\big[m(z)u_L(z)L(z)+v(z)kH(z) \\ &\qquad + w(z)i'(z)I(z)\big]\,\mathrm{d}z \\ &= \int_t^D \mathrm{e}^{-(s+q)(z-t)}m(z)u_L(z)T\,\mathrm{d}z. \end{aligned} \tag{74a}$$

The terms after the first equals sign in (74a) represent the three distinct sources of benefits derived from an additional unit of human capital: human capital increases (i) effective leisure, (ii) market earnings and (iii) effective investment time, respectively.[22] Note that (74a) implies

$$\dot{w}(t)=(s+q)w(t)-m(t)u_L(t)T. \tag{74b}$$

This completes the construction of the formal model. What does it imply about women's labor supply, investment, wages, etc.? Here it is helpful to distinguish between equilibrium dynamics and comparative dynamics, or equivalently between responses to "evolutionary" changes and responses to "parametric" changes. In any dynamic model, "equilibrium" is of course an *intertemporal* equilibrium, in which the individual – faced with certain exogenous givens, e.g. initial wealth $A(0)$ and present and (expected) future price levels $P(t)$ – chooses a set of *time paths* for the relevant variables, e.g. $L(t)$, $I(t)$ and $H(t)$. Evolutionary changes refer to the shape of these time paths, i.e. to the way the relevant variables change over time as the individual's intertemporal equilibrium unfolds – for short, to the individual's equilibrium dynamics.

[22] The second line of (74a) follows from the first by (63), (70), and (71). To see why, note that (70) and (71) imply that $H[vk-mu_L]=I[wi'-mu_L]=0$ always. For example, if H is nonzero, then (70) holds as an equality, but if (70) is an inequality, then $H=0$.

Of course, if there were an unanticipated change in an exogenous given such as $A(0)$ or $P(t)$, then the individual would change her intertemporal equilibrium, or, equivalently, would change the time paths she had adopted for all choice variables such as $L(t)$, etc. Responses to such unanticipated or "parametric" changes in these exogenous givens entail *changes in* the individual's intemporal equilibrium and time paths, i.e. are aspects of the individual's comparative dynamics.

First consider equilibrium dynamics. Derivation of equilibrium dynamics results is greatly simplified if one assumes an interior solution for both H and I for all $t<D$.[23] Under this assumption (we consider corner solutions below), (70) and (71) hold as equalities, in which case eqs. (74) may be written as

$$w(t)=\int_t^D \mathrm{e}^{-(s+q)(z-t)}v(z)kT\,\mathrm{d}z, \tag{75a}$$

$$\dot{w}(t)=(s+q)w(t)-v(t)kT. \tag{75b}$$

Now define a new variable, $x(t)=w(t)/v(t)$, which may be interpreted as the money shadow value of human capital at time t (since it is the ratio of the marginal utility of human capital to the marginal utility of money at t). Since $w(D)=0$ by (75a), eqs. (73)–(75) for $v(t)$ and $w(t)$ may be manipulated[24] to yield analogous expressions for $x(t)$:

$$x(t)=\int_t^D \mathrm{e}^{-(r+q)(z-t)}kT\,\mathrm{d}z=kT\big[1-\mathrm{e}^{-(r+q)(D-t)}\big]/(r+q), \tag{76a}$$

$$\dot{x}(t)=(r+q)x(t)-kT=-kT\mathrm{e}^{-(r+q)(D-t)}. \tag{76b}$$

Now consider equilibrium dynamics – that is, the individual's life-cycle paths – under the assumption of an interior solution for I and H. [To simplify notation, we now suppress the time index, (t), on variables except when doing so would cause confusion.] By (71) and the definition $x=w/v$, $xi'=k$; totally

[23] For example, Heckman (1976a) argues that periods of zero investment could be thought of as periods during which I is "low", periods of retirement or nonwork could be thought of as periods during which H is "low", periods of full-time schooling could be thought of as periods during which I is high relative to H, etc.

[24] Note that $\dot{x}=\mathrm{d}[w/v]/\mathrm{d}t=(\dot{v}w-\dot{w}v)/v^2=[(\dot{w}/w)-(\dot{v}/v)]x$, which reduces to (76b) by (73) and (75). In turn, (76b) and the terminal condition $x(D)=0$ form a differential equation system that may be solved to obtain the expression after the first equals sign in (76a), whose integral is the expression after the second equals sign in (76a).

differentiate this with respect to time to get

$$(\dot{IK}) = -(\dot{x}/x)(i'/i''). \tag{77}$$

To characterize the dynamic equilibrium path of IK, note first that, by (76)–(77), the fact that i depends only on IK and the assumption of an interior solution, the life-cycle path of IK is independent of m. By (67), it follows that the life-cycle path of K is also independent of m, and thus that $I = IK/K$ is also independent of m. In other words, knowing that period t is one of high or rising m tells us nothing about the behavior of I, K or IK at time t.

Next, note from (76) that $\dot{x}/x < 0$ throughout the life cycle. Since $i'/i'' < 0$ always, effective investment IK also falls throughout the life cycle. By (67), and our assumption that $i[0] = 0$, it follows that potential earning power $K(t)$ must also ultimately decline so long as depreciation occurs (i.e. so long as $q > 0$), even though $K(t)$ may (and, in reality, usually does) rise earlier in the life cycle.

Now consider the equilibrium behavior of C and LK over the life cycle. Write (70) as an equality to reflect the assumption of an interior solution for H and differentiate (69) and (70) with respect to time, solving for C and $\dot{LK}$ to obtain

$$\dot{C} = \{\dot{v}[mu_{LL}P - u_{CL}k]m + \dot{m}[M]mu_{CL}\}/d, \tag{78a}$$

$$\dot{LK} = \{\dot{v}[u_{CC}k - mu_{LC}P] + \dot{m}[mLKu_{LC}u_{LC} - Mu_{CC}]\}/d, \tag{78b}$$

where $d = m^2[u_{CC}u_{LL} - (u_{CL})^2]$, with $d > 0$ by concavity of u; $M = \mathrm{d}[mu_L]/\mathrm{d}m = u_L + mLKu_{LL}$; and where, to simplify, we assume P is constant.

The life-cycle path of consumption may be described using (78a). In (78a), the first term in square brackets inside the braces is negative if consumption is a normal good in the static one period sense.[25] Thus, if consumption is normal then, at least when m is not changing (so that $\dot{m} = 0$), consumption will rise or fall over time depending on whether v is negative or positive. In turn, (73b) indicates that v will be negative or positive depending on whether s is less or greater than r. Since a positive-sloped life-cycle consumption profile seems much more plausible on a priori grounds than a negative-sloped profile, we will henceforth assume that

$$s < r. \tag{79}$$

Of course, even if $s < r$ the time profile of consumption need not always be positive-sloped, for the life-cycle behavior of C also depends on the taste shifter m, as given by the second term inside braces in (78a). It might be plausible to

[25] See footnote 16. In the present case, the definition of "normal in the static sense" includes the requirement that the individual may not devote time to investment, i.e. must have $I(t) = 0$.

assume $u_{CL} > 0$ (which is sufficient, though not necessary, for both consumption and leisure to be normal goods in the static sense), i.e. that additional consumption raises the marginal utility of (effective) leisure. If so, then a rising m ($\dot{m} > 0$) increases the growth rate of C. Speaking somewhat more loosely, we may say that, provided $u_{CL} > 0$, consumption will tend to be high (or rising) during periods when m is high (or rising) – which might be interpreted as childbearing ages.[26]

Now consider the life-cycle path of effective leisure, as given by (78b). The first term inside the curly braces in (78b) is positive provided leisure is a normal good in the static one-period sense. Thus, if leisure is normal then, by (79) and (73b), during periods when m is constant, effective leisure LK will rise. Moreover, $M > 0$ provided increases in $m(t)$ over time do indeed amount to increases in the marginal utility of (effective) leisure,[27] and so the second term inside the curly braces in (78b) will be positive or negative depending on whether m is rising or falling. Hence a rising m ($\dot{m} > 0$) increases the rate of growth of LK. In less precise terms, one may say that effective leisure LK will tend to be high (or rising) during periods when $m(t)$ is high (or rising), such as the age of childbearing.

Finally, consider the equilibrium path of leisure, L. As noted earlier, the life-cycle path of K is independent of the life-cycle behavior of m. Thus, when $m(t)$ is high (or rising), not only effective leisure LK but also the *level* of leisure L will tend to be high (or rising). In other words, since $(\dot{LK}) = L\dot{K} + \dot{L}K$,

$$\dot{L} = [(\dot{LK}) - L\dot{K}]/K, \tag{80}$$

so that, by (78b), growth in m ($\dot{m} > 0$) increases the rate of growth of leisure, L, as well as the rate of growth of effective leisure, LK. In less formal language, one may say that not only effective leisure but also leisure itself will tend to be high (or rising) during periods when $m(t)$ is high (or rising), such as the child-bearing years.

This leads directly to several propositions concerning labor supply and wage rates. In a model of this kind, the equivalent of "labor supply" in the sense used in static models is "market time", $T - L(t) = I(t) + H(t)$, i.e. "hours spent *at* work". As shown above, $I(t)$'s behavior over time is independent of $m(t)$'s

[26] Both here and in what follows we abstract from the effects of concurrent changes in v [note from eqs. (78) that the growth rates of both C and LK depend on v as well as on m]. The phrase "tends to" as used in the text should thus be understood to mean, "tends to, leaving aside the effects of concurrent changes in v". The same caveat applies to our remarks in the text about the behavior of hours of leisure (L), actual work (H), and market time ($I + H$), and to our discussion of the "investment content" of an hour of market time ($I/(I + H)$).

[27] By (70), mu_L is the marginal utility of effective leisure LK, and is increasing with respect to m provided $M = \mathrm{d}[mu_L]/\mathrm{d}m = u_L + mLKu_{LL} > 0$. Note that $M > 0$ if the elasticity of the marginal utility of effective leisure with respect to effective leisure (LK) is less than unity in absolute value.

behavior, and growth in m ($\dot{m} > 0$) raises the rate of growth of L. Thus, growth in m reduces the growth rates of both hours actually worked, $H(t)$, and hours spent at work, $J(t) = H(t) + I(t)$: that is, growth in m will make the growth of H and J less positive, or else more negative.

Next consider the life-cycle path of the *observed* wage rate, i.e. earnings per hour spent *at* work, $E(t)/[H(t)+I(t)] = kK(t)H(t)/[H(t)+I(t)]$. As noted above, the paths of $I(t)$ and $K(t)$ are independent of $m(t)$ over the life cycle, whereas growth in $m(t)$ reduces the rate of growth of $H(t)$. Thus, growth in m reduces the rate of growth of the observed wage rate. Speaking somewhat more loosely, one may say that the observed wage rate will tend to grow relatively slowly (and could even fall) during periods when m is growing, such as the ages of childbearing and childrearing.

To the extent that the abstract taste shifter construct $m(t)$ can legitimately be given the concrete interpretation we give it – as a measure of the greater preference for "leisure" or nonmarket time $L(t)$ that a given woman may have during the age of childbearing and childrearing – the model described here provides a quite comprehensive and seemingly very satisfactory set of predictions about life-cycle patterns of women's work and wages. The model implies that, ceteris paribus, during the childbearing and childrearing ages leisure will be higher (or rising more rapidly), and both the wage rate and "labor supply" as conventionally defined will be lower (or rising less rapidly), than during other periods in the life cycle. At least in a gross sense, these predictions are clearly consistent with the stylized facts about the age pattern of female labor supply set out in Section 2.

In other respects, however, these predictions are at odds with casual theorizing about the female life cycle. The most obvious example concerns time devoted to investment in human capital, I, and human capital accumulation, K. A long tradition in discussions of women's life-cycle behavior [exemplified by, for example, Mincer and Polachek (1974)], which we will call the "Informal Theory", identifies the age of childbearing and childrearing as a period of reduced *investment* as well as of reduced *labor supply*; and links the low level of (or rate of growth in) women's wages during this period to the hypothesized low level of investment.

In contrast, in the present model, high or growing $m(t)$ – in effect, childbearing and childrearing – does not affect investment time or the human capital stock at all. Moreover, although the model does predict that the observed wage $E(t)/[H(t)+I(t)] = kK(t)H(t)/[H(t)+I(t)]$ will be low (rising slowly, falling) during the age of childbearing and childrearing, that is only because hours of actual work $H(t)$ are low: hours of investment time $I(t)$ and the human capital stock $K(t)$ at any age are completely independent of $m(t)$, i.e. of childbearing and childrearing. Indeed, in this model, the "investment content" of time spent *at* work – $I(t)/[H(t)+I(t)]$ – is relatively *high* during the age of childbearing

and childrearing, even though the *amount* of time spent at work, $H(t)+I(t)$, is low (rising more slowly, falling).

It is certainly true that the model generating these results – in particular the neutrality assumption – is a rather special one. However, one cannot resolve the anomalies highlighted by this model by simply saying that its neutrality assumption is rather restrictive. Generalizing the model – e.g. allowing for possible non-neutrality – would certainly *permit* results more in keeping with the Informal Theory. However, any such generalization would almost certainly not *preclude* results of the kind just discussed. In other words, if even a special case of a formal model generates propositions that effectively call the Informal Theory into question, there is not much reason to suppose that propositions derived from a more general formal model would invariably conform to those of the Informal Theory.

In sum, in several important respects the implications of the formal life-cycle model developed here are at odds with the Informal Theory. Two caveats should be noted immediately, however. The first caveat is that the formal model and the Informal Theory agree about the behavior of observable variables (e.g. hours spent at work, average hourly earnings) and disagree only about the behavior of unmeasurable variables (e.g. investment time, the investment content of an hour spent at work, the human capital stock). Thus, it could be argued that the differences between the formal model and the Informal Theory (i) are much less important than are their similarities, and (ii) may not even be testable anyway.

The second caveat is that the Informal Theory is sufficiently informal that it should *not* necessarily be interpreted as we have thus far interpreted it, namely, as a set of statements about a given woman's behavior over the life cycle – i.e. equilibrium dynamics. Rather, it could be argued that the Informal Theory is really concerned more with cross-sectional differences among different women. To analyze such differences, one needs to consider the model's comparative dynamics: comparative dynamics is literally concerned with how a given individual responds to a change in some exogenous given, but it could equally well be taken to refer to *differences* between two individuals who have *different* values for the relevant exogenous givens. In particular, $m(t)$ need not be the same at any given date, and need not change in the same way over time, for different women. Likewise, different women need not have the same values for other exogenous givens [e.g. initial wealth, $A(0)$]. Do differences in $A(0)$, $m(t)$, etc. among different women lead to differences in labor supply, wages, and the like? If so, how and in what direction? Since the Informal Theory has often been invoked in discussions of questions of precisely this kind, there is ample reason for regarding it as referring at least to some extent to comparative dynamics.

It remains to consider the comparative dynamics of the formal model developed above. We will focus on effects of $m(t)$ and $A(0)$, starting with the comparative dynamics of investment and human capital accumulation [see

Heckman (1976) for a comprehensive discussion of many other comparative dynamics effects]. Because we have assumed an interior solution for both I and H, (70) and (71) hold as equalities, so that

$$k/i'[I(t)K(t)] = x(t). \tag{81}$$

By (76a), $x(t)$ is independent of both $A(0)$ and $m(t)$. It follows that, other things being equal, *women with different levels of initial wealth or tastes for leisure* (e.g. childbearing, marriage) *will nevertheless undertake the same amount of effective investment* $I(t)K(t)$. Since potential earnings $K(t)$ depend only on $I(t)K(t)$, and since $I(t) = I(t)K(t)/K(t)$, it follows that, other things being equal, women with different levels of initial wealth or tastes for leisure (e.g. childbearing, marriage) will nevertheless have the *same* human capital stock $K(t)$ and will devote the *same* amount of time to investment $I(t)$ at each age t.

Next consider how changes in $A(0)$ and $m(t)$ affect the time paths of consumption, leisure, etc. over the life cycle – or, equivalently, how differences in $A(0)$ and $m(t)$ among different persons lead to different levels of consumption, leisure, etc. at any point in the life cycle. Here again, as in the exogenous-wage model of Section 3.2.1, it is extremely helpful to use the Frisch demand system and to distinguish between (i) changes in time paths that would occur even if the shadow price of assets v remained unchanged, and (ii) changes that occur because changes in the relevant variables will in fact change the shadow price v. As in the exogenous-wage model, we will refer to these two kinds of changes as "shadow price-constant" and "shadow price-variable" effects, respectively. These are analogous to the substitution and income effects, respectively, of static labor supply models, but with one important difference: substitution and income effects refer to changes with the *level of utility* constant or variable, respectively; whereas shadow price-constant and shadow price-variable effects refer to changes with the *marginal utility of assets* constant or variable, respectively.

First consider the shadow price-constant effects on C and LK of changes in $A(0)$ and, *at a particular* t, in $m(t)$. By (69)–(70), a change in $A(0)$ will *not* change either $C(t)$ or $L(t)K(t)$ so long as the shadow price v remains unchanged. Thus, *the shadow price-constant effects on C and LK of a change in* $A(0)$ *are both zero*. To derive shadow price-constant effects of a change in $m(t)$, begin by differentiating (69) and (70) totally with respect to $v(t)$ and $m(t)$ *with t constant*, to obtain:

$$\begin{aligned} \mathrm{d}C(t) &= \mathrm{d}m(t)\{m(t)u_{CL}(t)[M(t)]/\mathrm{d}(t)\} \\ &\quad + \mathrm{d}v(t)\{m(t)[m(t)P(t)u_{LL}(t) - ku_{CL}(t)]/\mathrm{d}(t)\}, \end{aligned} \tag{82}$$

$$\begin{aligned} \mathrm{d}[L(t)K(t)] &= \mathrm{d}m(t)\{[-M(t)u_{CC}(t) + u_{CL}(t)^2 m(t)L(t)K(t)]/\mathrm{d}(t)\} \\ &\quad + \mathrm{d}v(t)\{[ku_{CC}(t) - m(t)P(t)u_{LC}(t)]/\mathrm{d}(t)\}, \end{aligned} \tag{83}$$

where $\mathrm{d}(t) = m(t)^2[u_{CC}(t)u_{LL}(t) - u_{CL}(t)^2]$; $M(t) = \mathrm{d}[m(t)u_L(t)]/\mathrm{d}m(t)$; and $\mathrm{d}C(t)$ and $\mathrm{d}[L(t)K(t)]$ denote changes in consumption and effective leisure, respectively, at a *given* date t induced by changes in $m(t)$ and $v(t)$ at that date. If $v(t)$ is constant, $\mathrm{d}v(t) = 0$, so, by (82) and (83), the *shadow price-constant effects of a change in* $m(t)$ *on* $C(t)$ *and* $L(t)K(t)$ *are*

$$\mathrm{d}C(t)/\mathrm{d}m(t) = m(t)u_{CL}(t)[M(t)]/\mathrm{d}(t), \tag{84}$$

$$\mathrm{d}[L(t)K(t)]/\mathrm{d}m(t) = [-M(t)u_{CC}(t) + u_{CL}(t)^2 m(t)L(t)K(t)]/\mathrm{d}(t). \tag{85}$$

So long as an increase in $m(t)$ at given t does indeed connote an increase in the marginal utility of effective leisure, $M(t) > 0$ (recall footnote 15), and so an increase in $m(t)$ at given t *with the shadow value of initial assets constant* will increase effective leisure $L(t)K(t)$ at that date. If consumption raises the marginal utility of effective leisure ($u_{CL}(t) > 0$), then a shadow value-constant increase in $m(t)$ at given t will also increase consumption $C(t)$ at that date.

These results refer only to the shadow price-constant effects of changes in $A(0)$ and $m(t)$. However, such changes will also lead to changes in the shadow prices $v(t)$ themselves. For example, it is intuitively plausible that, other things being equal, someone with greater initial assets will have a lower $v(t)$ at all dates $t \geq 0$ provided goods and leisure are normal – that is, will regard assets as less "precious" or "scarce" – than will someone with lower initial assets. It remains to establish that this conjecture is not merely plausible but also correct; to obtain an analogous result for the effect of greater $m(t)$ on $v(t)$; and then to derive the impact of either kind of change in $v(t)$ on $C(t)$ and $L(t)K(t)$ – the shadow price-variable changes described earlier.

To see how $v(t)$ at each t will change in response to an increase in initial assets $A(0)$, recall that with $v(t)$ constant a change in $A(0)$ has no effect on $C(t)$ or $L(t)K(t)$ [see (82)–(83)]; and note from (64) that, other things being equal, an increase in $A(0)$ will leave some assets unspent at the end of life. Since there are no bequests and since "you can't take it with you", that cannot be optimal. The appropriate response to an increase in $A(0)$ is reduce $v(t)$, i.e. to value assets less highly and spend them more freely. Indeed, as (82)–(83) indicate, at given values of $m(t)$, both $C(t)$ and $L(t)K(t)$ will fall when $v(t)$ is increased (provided consumption and leisure, respectively, are normal goods). That is,

$$\mathrm{d}C(t)/\mathrm{d}v(t) = m(t)[m(t)P(t)u_{LL}(t) - ku_{CL}(t)]/\mathrm{d}(t), \tag{86}$$

$$\mathrm{d}[L(t)K(t)]/\mathrm{d}v(t) = [ku_{CC}(t) - m(t)P(t)u_{LC}(t)]/\mathrm{d}(t), \tag{87}$$

where the expressions after the equals signs in (86)–(87) are negative provided C

and L, respectively, are normal goods in the static sense. Moreover, an increase in $v(t)$ will always *increase* net additions to wealth $a(t)=E(t)-P(t)C(t)=kTK(t)-kI(t)K(t)-kL(t)K(t)-P(t)C(t)$: since $\mathrm{d}K(t)/\mathrm{d}v(t)=\mathrm{d}I(t)/\mathrm{d}v(t)=0$ by (81) and (67), $\mathrm{d}a(t)/\mathrm{d}v(t)=-k\{\mathrm{d}[L(t)K(t)]/\mathrm{d}v(t)\}-P(t)\{\mathrm{d}C(t)/\mathrm{d}v(t)\}$, so, by (86)–(87),

$$\mathrm{d}a(t)/\mathrm{d}v(t) = -\left\{k^2u_{CC}(t)+[m(t)P(t)]^2u_{LL}(t)-2km(t)P(t)u_{CL}(t)\right\}/\mathrm{d}(t), \tag{88}$$

which is always positive by concavity of u. Thus, the disequilibrium caused by higher $A(0)$ – "excess" financial wealth at death, $A(D)>0$ – is remedied by a *reduction* in $v(t)$. Provided C and L are normal, the reduction in v raises both consumption and effective leisure, thereby reducing earnings and increasing expenditure at each date, thereby exhausting the excess asset accumulation that would otherwise show up as $A(D)>0$. It follows that

$$\mathrm{d}v(t)/\mathrm{d}A(0)<0 \tag{89}$$

467

which, along with (86)–(87), implies that *the shadow price-variable effects on consumption and effective leisure of an increase in initial assets are both positive*. That is, the shadow price-variable effects of higher $A(0)$ are, respectively,

$$\{\mathrm{d}C(t)/\mathrm{d}v(t)\}\{\mathrm{d}v(t)/\mathrm{d}A(0)\}>0, \tag{90}$$

$$\{\mathrm{d}[L(t)K(t)]/\mathrm{d}v(t)\}\{\mathrm{d}v(t)/\mathrm{d}A(0)\}>0, \tag{91}$$

provided C and L are normal in the static sense.

Essentially the same reasoning leads to the proposition that *the shadow price-variable effects on consumption and effective leisure of a greater taste for leisure are both negative* – the opposite of the v-variable effects of a greater level of initial wealth. By (82)–(83), or equivalently (84)–(85), with $v(t)$ constant ($\mathrm{d}v(t)=0$) a greater taste for leisure at any date t ($\mathrm{d}m(t)>0$) will (i) increase consumption at that date provided $u_{CL}(t)>0$; and (ii) increase effective leisure at that date provided $M(t)>0$. Hence, net increments to wealth $a(t)$ fall due to the rise in $m(t)$: by (81) and (67), $\mathrm{d}K(t)/\mathrm{d}m(t)=0$, so $\mathrm{d}a(t)/\mathrm{d}m(t)=-k\{\mathrm{d}[L(t)K(t)]/\mathrm{d}m(t)\}-P(t)\{\mathrm{d}C(t)/\mathrm{d}m(t)\}$. Thus, by (84)–(85):

$$\begin{aligned}\mathrm{d}a(t)/\mathrm{d}m(t) = -\{&M(t)[-ku_{CC}(t)+m(t)P(t)u_{CL}(t)]\\ &+m(t)L(t)K(t)u_{LC}(t)\\ &\times[-m(t)P(t)u_{LL}(t)+ku_{LC}(t)]\}/\mathrm{d}(t),\end{aligned} \tag{92}$$

which is negative provided $M(t)>0$, $u_{CL}(t)>0$ and consumption and leisure are normal in the static sense. Thus, *with $v(t)$ constant*, a greater taste for leisure at any given date will lead to a shortfall of financial wealth that would violate (64). The remedy is to *increase* $v(t)$: by (88), an increase in $v(t)$ always increases net increments to wealth $a(t)$. Hence, if $M(t)>0$, $u_{CL}(t)\geq 0$ and C and L are both normal,

$$\mathrm{d}v(t)/\mathrm{d}m(t)>0, \tag{93}$$

which, along with (86)–(87), implies that *the shadow price-variable effects on consumption and effective leisure of an increase in the taste for leisure are both negative*. That is, if $M(t)>0$, $u_{CL}(t)\geq 0$ and C and L are both normal, the shadow price-variable effects of higher $m(t)$ are, respectively,

$$\{\mathrm{d}C(t)/\mathrm{d}v(t)\}\{\mathrm{d}v(t)/\mathrm{d}m(t)\}<0, \tag{94}$$

$$\{\mathrm{d}[L(t)K(t)]/\mathrm{d}v(t)\}\{\mathrm{d}v(t)/\mathrm{d}m(t)\}<0. \tag{95}$$

In sum, women with a greater taste for leisure (e.g. a greater preference for activities such as childrearing) will (have to) put a greater shadow or implicit value on financial assets than will other women: the *v-constant* effect of greater m raises consumption and reduces earnings, which in turn requires greater caution with respect to earning and spending – an increase in v – so as to ensure that the lifetime budget constraint can still be satisfied. Thus, via the v-variable effect, consumption and effective leisure LK both fall. Since changes in v do not affect IK, K or I, the v-variable effect of greater m does not change IK, K or I but does reduce leisure time L ($=LK/K$). Hence the v-variable effect of greater m raises (i) actual hours of work $H=T-I-L$, (ii) hours *at* work $J=T-L=I+H$, and (iii) the observed wage $W=kKH/(I+H)$; and *reduces* the investment content of an hour spent at work $I/(I+H)$.

Now combine the shadow price-constant and shadow price-variable effects to derive the total effects of changes in $A(0)$ and $m(t)$ on consumption, leisure, etc. First consider the effects of greater $A(0)$. All shadow price-*constant* effects of greater $A(0)$ are zero, so the *total* effects of greater $A(0)$ are the same as the shadow price-*variable* effects of greater $A(0)$. Thus, ceteris paribus, a woman who has greater initial assets must necessarily have greater consumption and effective leisure than a woman with less initial assets. Also, other things being equal, the woman with higher initial assets will spend less time at work $J=T-L$, will spend less time actually working $H=T-I-L$, and will enjoy more leisure time L. Her observed wage $E/(I+H)=kKH/(I+H)$ will be lower, but the investment content of an hour of the time she spends at work $I/(I+H)$ will be higher, than for the woman with lower initial assets. Finally, ceteris paribus, the woman with higher initial assets will have the *same* potential earning power or human capital stock K as will a woman with lower initial assets; and both women will invest to the same extent (where investment refers either to investment time I or to effective investment IK).

Although these propositions of course refer in a literal sense to the effects of differences in initial assets, $A(0)$, it is important to note that they could also be interpreted as referring to the impact of marriage (especially if one ignores intrafamily cross-substitution effects of the kind described in Section 3.2): marriage seems to permit substantial economies of scale in consumption, and so to at least some extent is analogous to an increase in financial wealth (which, discounted back to time 0, is simply an increase in *initial* assets). If so, then marriage will (i) raise consumption and leisure time (and thus fertility?) at all ages; (ii) reduce hours *at* work, $J = T - L$, at all ages; and (iii) reduce the observed wage, $kKH/(I+H)$, at all ages.[28]

All this is very much in line with the intuition generated by the Informal Theory, and is certainly consistent with empirical findings on cross-section patterns of women's labor supply and wages by marital status. However, note that some of the implications of the formal model seem at odds with the reasoning of the Informal Theory: to the extent that marriage can indeed be regarded as akin to higher $A(0)$, the formal model implies that marriage does *not* affect investment time I, effective investment IK or human capital K. Moreover, in general no conclusions can be drawn from the formal model about the impact of marriage – higher $A(0)$ – on the *slope* of the earnings profile unless one adopts some specific assumptions about preferences [Heckman (1976, pp. S23, S41)]; in contrast, the Informal Theory has almost always associated marriage with flatter earnings profiles.

Now consider the comparative dynamics effects of greater $m(t)$, which are summarized in Table 2.24. To the extent that a greater $m(t)$ at any given date can be interpreted as a greater taste for leisure (for nonmarket as opposed to market work, for children, etc.), then the above indicates the following: (i) *with v constant*, a woman with a greater taste for raising children and other nonmarket activities will enjoy more consumer goods and leisure, will spend fewer hours at work (with, however, each hour having a higher investment content), and will have a lower wage, than will a woman with a lesser taste for such nommarket activities; (ii) these reductions in hours of work and wages prompt the woman with a greater taste for nonmarket activities to place a greater implicit value on assets, and thus be more conservative about spending on consumption and leisure, implying (iii) that the *v-variable* effect of a greater taste for nonmarket activity will be to *increase* work and wages and *reduce* leisure time.

[28] Since these are comparative dynamics rather than equilibrium dynamics results, it is important to be clear about what they do and do not mean. They do *not* mean that, once a *given* woman marries, her leisure time, hours of work and wages will change in particular ways (relative to their levels at an earlier stage in the life cycle): changes of that kind refer to equilibrium dynamics, i.e. to the development of a given woman's *equilibrium lifetime plan* as she goes through the life cycle. Rather, these results refer to *differences in* lifetime plans between married and unmarried women who are similar in all other respects (e.g. initial human capital stocks, tastes for leisure, etc.). In effect, differences in initial nonhuman assets are treated here as proxies representing unobservable traits that lead otherwise observationally similar women to differ in terms of marital status and equilibrium life cycle paths. As such, the propositions discussed in the text are predictions about the ceteris paribus associations between marital status and other variables of interest (e.g. labor supply, leisure time or wage rates) that will be observed in cross-sections.

Table 2.24
Comparative dynamics effects of greater $m(t)$.

Variable	Effects of greater $m(t)$: v-constant effect	v-variable effect	Total effect
$I(T)K(T)$	0	0	0
$I(t), K(t)$	0	0	0
$C(t)$	$+$[a]	$-$[c]	?
$L(t)K(t), L(t)$	$+$[b]	$-$[c]	?
$H(t)$	$-$	$+$	?
$W(t)$	$-$	$+$	?
$I(t)/[H(t)+I(t)]$	$+$	$-$	?

[a] Provided $u_{CL} > 0$.
[b] Provided $M > 0$.
[c] Provided $u_{CL} > 0$, $M > 0$, and C and L both normal.

On balance, then, the *net* effects of a greater taste for nonmarket activity or "leisure" at any particular age t are generally indeterminate a priori (except as regards investment time and human capital accumulation, which are independent of m). For example, the v-constant effect of greater $m(t)$ acts to increase leisure $L(t)$, but the v-variable effect of greater $m(t)$ acts to reduce it.

It is nevertheless possible to derive some insight into the effects of greater $m(t)$ on individuals' life-cycle paths, thanks largely to the analytical distinction between the v-constant and v-variable effects of greater $m(t)$. On the one hand, the v-constant effects of greater $m(t)$ alter behavior *only* at age t, and not at any other age: since the lifetime utility function U is separable in time, consisting of an integral of instantaneous utility functions u, an increase in $m(t)$ with $v(t)$ constant *does* affect behavior *at time t* but does *not* affect behavior at any *other* date t'. [For example, note from (69)–(71) that $C(t)$, $L(t)K(t)$ and $I(t)K(t)$ are independent of $m(t')$ for all $t' \neq t$.] On the other hand, the v-variable effect of greater $m(t)$ affects behavior (e.g. leisure, the observed wage, hours at work) at *all* ages: the v-variable effects of greater $m(t)$ are spread over the individual's entire life cycle because borrowing and lending make it possible (for example) to earn and save during periods when $m(t)$ is low(er) and to borrow or live off past savings during periods when $m(t)$ is high(er). Thus, for all $t' \neq t$, the *only* effects of higher $m(t)$ are v-variable effects, whereas at t a higher level of $m(t)$ will have both v-variable *and* v-constant effects.

To the extent that the υ-variable effect of greater $m(t)$ at any given age is likely to be small, one would expect the υ-constant effect of greater $m(t)$ to dominate the υ-variable effect *at age t*. At *other* ages $t' \neq t$, higher $m(t)$ has a υ-variable effect *only*. Thus, so long as a greater $m(t)$ can indeed be interpreted as a greater taste for nonmarket work, childrearing, etc., the formal model developed here implies that, *during the childbearing and childrearing ages*, women with a greater taste for nonmarket work, childbearing and childrearing will tend to have (i) *lower* hours of actual work, hours at work, and observed wage rates, and (ii) *higher* hours of leisure and a *higher* investment content per hour spent at work, than will other women, ceteris paribus [provided – as seems reasonable a priori – υ-constant effects dominate during the periods t that $m(t)$ is high]. However, the model *also* implies that, at ages *other than* those of childbearing and childrearing, these patterns will be exactly reversed; then, women with a greater taste for nonmarket work, childbearing and childrearing will spend more time working, earn a higher observed wage, devote *less* time to leisure, and will work at jobs whose investment content is lower. Finally, the formal model implies that, at all ages, women with high tastes for nonmarket work, childrearing, etc. will have the same human capital stock K and will devote the same amount of time to investment I as other women, ceteris paribus.

Thus, the formal model's predictions about behavior during the age of childbearing and childrearing seem quite consistent with the intuition generated by the Informal Theory. However, its implications about behavior at ages other than those of childbearing and childrearing raise some questions about the Informal Theory. For the most part, the Informal Theory ignores the implicit substitution between high- and low-$m(t)$ periods that occurs in the formal model developed here.

The most noteworthy difference between the formal model and the Informal Theory is, of course, that in informal discussions marriage, childbearing, childrearing, etc. are usually assumed a priori to be associated with less investment (I) and human capital accumulation (K), whereas in the formal model developed here both investment and human capital are independent of marriage and children. An important reason for this is probably that the formal model presented above explicitly assumes a lifetime interior solution (i.e. positive H and I throughout the life cycle). Generalizing a model of this kind by allowing for corners (e.g. zero H and/or I during part of the life cycle) would permit explicit analysis of something that is suppressed by the assumption of a lifetime interior solution but that figures prominently in the Informal Theory: discontinuities in employment and work experience.

To sum up: although much informal discussion implicitly or explicitly emphasizes the interrelationships between women's work and wages in a life-cycle setting, rigorous analysis of such issues using formal life-cycle labor supply models with endogenous wages is still in its infancy. To some extent, even quite simple and abstract models have something to say about female labor supply over the life cycle; more important, relatively modest development of abstract models can yield additional insights and propositions about women's work and wages over the life cycle. To some extent, formal models confirm the intuition developed by informal theorizing; in other respects, however, the results of formal models raise questions about the merits of such simple intuition. Further research in this area is long overdue, and would seem to be eminently promising.

4. Empirical studies of female labor supply

We now discuss empirical analyses of female labor supply. We first describe some of the important problems that arise in such studies – concerning specification, measurement of variables, econometric technique, and the like – and then summarize the findings of recent empirical work. To motivate this discussion, we note at the outset that the results of some recent empirical studies of female labor supply differ appreciably from those of research conducted through the early 1980s. There has been a consensus of relatively long standing that compensated and uncompensated female labor supply wage elasticities are positive and larger in absolute value than those for men. In contrast, some recent studies appear to show that the compensated and uncompensated wage elasticities of women workers are little different from those of men; indeed, in this work, the female uncompensated elasticity is often estimated to be negative.

4.1. *Empirical work on female labor supply: Methodological issues*

As documented in Section 2, many women work – supply positive hours to the market – but many women do not. This simple fact has a number of very important implications for empirical work. First, in specifying the labor supply function, one must recognize that the labor supply of many women (those whose offered wage is well below the reservation level) will be completely insensitive to small changes in market wage rates, exogenous income or for that matter anything else. Many "first-generation" empirical studies of female labor supply conducted through the mid-1970s ignored this consideration because they specified the labor supply function as little different from other regression functions, e.g.

$$H = wa + Xb + Rc + e, \tag{96}$$

where H is hours of work per period, w is the real wage, R is real exogenous income, X is a vector of other (e.g. demographic) variables and e is a random error term. The difficulty in using such a relation to analyze the labor supply of all women is that, at best, (96) or functions like it refer only to *working* women rather than to the entire female population. Derivatives of H with respect to any variable are equal to the relevant parameter (a, b or c) only when the real offered or market wage rate w exceeds the real reservation wage w^*. In contrast, when $w < w^*$, all such derivatives are zero for (small) changes in all relevant variables. The same point is relevant to family labor supply models, in which any given family member's labor supply is (in general) a function of that family member's wage, the wages of all *other* family members and exogenous income: for example, the husband's (wife's) labor supply will be affected by small changes in the wife's (husband's) offered wage only if the wife (husband) is working.

A second problem arising from the usually-substantial extent of nonparticipation among women is that, in general, the market wages of nonworking women are not observed. Thus, even if (96) correctly specified the labor supply function, it could not be estimated using data on the entire female population, because measures of one of the relevant variables are usually not available for the entire population.

It might seem (and to many first generation researchers did in fact seem) that the easiest way to avoid both these problems – of specification and measurement – is to fit labor supply functions such as (96) to data on working women *only*. This avoids the specification problem because, among working women, changes in the relevant independent variables X will of course generally induce nonzero changes in labor supply; and it avoids the measurement problem because *working* women's wages are generally observed. Unfortunately, this attempted solution arises an econometric problem, variously known as "sample selection" or "selectivity" bias: if working women are not representative of *all* women, then using least squares regression methods to fit (96) to data restricted to working women may lead to bias in the estimated parameters b. Indeed, it may even lead to biased estimates of the structural parameters relevant to the behavior of *working* women!

To see why, consider the following simple argument [for further discussion, see Pencavel, Chapter 1 in this Handbook, or Killingsworth (1983, ch. 4)]. Working women have $w > w^*$. Thus, among all women who are capable of earning the same real market wage w, *working* women have relatively low *reservation* wages w^*. Similarly, among all women with the same reservation wage w^*, *working* women must have relatively high *market* wages w. Thus, on both counts – low reservation wages and high market wages – working women are likely to be unrepresentative of the entire female population. Least squares estimates of (96) derived from data restricted to working women may therefore suffer from bias. Indeed, they may even fail to provide unbiased measures of the behavioral responses of working women themselves.

The essential reason for this is that, unless wage rates and reservation wages depend only on observable variables and not on any unobservable factors, the labor supply error term e of working women may not be independent of their

observed variables w, R and X. For example, consider the role of exogenous income, R. R is a determinant of hours of work H by (96), and is also a determinant of the reservation wage, w^*. To be concrete, let the reservation wage be a function of R, other observed variables Z and unobservables ("tastes for leisure") u, with

$$w^* = Zk + Rg + u. \tag{97}$$

Among working women, $w > w^*$, or, equivalently,

$$u < -[w - (Zk + Rg)]. \tag{98}$$

Thus, "other things" (the *observed* variables w, Z and R) being equal, working women have relatively low values of u. Moreover, if the labor supply error term e and the reservation wage error term u are correlated[29] then, in general, e will be correlated with R *within the group of working women* even if it is uncorrelated with R *in the female population as a whole*. Why? If leisure is a normal good, $c < 0$ and $g > 0$ (that is, greater exogenous income reduces labor supply and raises the reservation wage, ceteris paribus). Thus, by (98), women who have a high value of R *but who nevertheless work* will tend to have a relatively low value of u, "other things" (w and Z) being equal: in other words, women who work even though they receive large amounts of exogenous income must have a relatively low taste for leisure, ceteris paribus. If u and e are negatively correlated, as seems likely to be the case (see footnote 20), then e and R will be positively correlated *among working women* even if no such correlation exists in the female population as a whole. In this case, using conventional least squares regression to fit (96) to data on working women will yield a biased estimate of the exogenous income parameter c due to the correlation between e and R.

Several further remarks are in order at this point. First, similar arguments establish that the coefficient on any variable in X in (96) fitted to data on working women will be biased if it also appears in the vector Z in the reservation wage function (97). Second, if the observed wage rate w depends on unobservables v as well as observed characteristics (e.g. schooling) and if the wage unobservables v are correlated with the labor supply and reservation wage unobservables e and u, then the same reasoning establishes that the coefficient on w in (96) will also be biased when (96) is derived from data on working women. Finally, a straightforward extension of these arguments will demonstrate that a similar potential for bias can arise in analyses of family labor supply, e.g. when one estimates labor supply functions for wives using data restricted to wives whose husbands are employed.

[29] For example, a measure of "motivation" or "will to work" is unlikely to be available in any dataset, and may be determinant of both labor supply and the wage rate.

In general terms, the solution to these interrelated problems of specification, measurement and econometric technique is to estimate not only "the" labor supply function [that is, the structural relation determining hours of work, such as (96)] but also *other* behavioral functions relevant to work effort [e.g. the discrete choice of whether to supply any work at all, as given by a participation criterion such as (97)]. This approach has characterized so-called "second-generation" research on labor supply undertaken since the mid-1970s. Such estimation can take explicit account of the manner in which available data were generated (e.g. the fact that wages are observed only for workers) and of the fact that nonworkers' labor supply is insensitive to small changes in wages, exogenous income or other variables. Thus, measurement problems can be minimized, specification questions are addressed directly and the econometric bias problem can be avoided.

A variety of second-generation strategies for proceeding in this fashion have been developed in recent years. In lieu of a full description of all of them – which is well beyond the scope of this chapter, and which may be found elsewhere [see, for example, Killingsworth (1983, esp. ch. 3), Heckman and MaCurdy (1985), Wales and Woodland (1980)] – consider the following procedure due to Heckman (1976a, 1979) by way of example. Let the real wage w that an individual earns (or is capable of earning) be given by

471

$$w = Yh + v. \tag{99}$$

An individual works if $w > w^*$ and is a nonworker otherwise. Thus, by (97) and (99),

$$v - u > -(Yh - Zk - Rg) \leftrightarrow H > 0, \tag{100a}$$

$$v - u \leq -(Yh - Zk - Rg) \leftrightarrow H = 0, \tag{100b}$$

which are reduced-form expressions for the conditions under which an individual will or will not work, respectively. Likewise, by (96) and (99), the *reduced-form* function for the hours of work *of women who work* is

$$H = Yah + Xb + Rc + [av + e], \tag{101}$$

where the term in square brackets is a composite error term.

Now consider the estimation of (101) using data restricted to working women. The regression function corresponding to (101) is

$$\begin{aligned} &\mathrm{E}\{H \mid Y, X, R, Z, v - u > -(Yh - Zk - Rg)\} \\ &\quad = Yah + Xb + Rc + \mathrm{E}\{[av + e] \mid Y, X, R, Z, v - u > -(Yh - Zk - Rg)\} \\ &\quad = Yah + Xb + Rc + \mathrm{E}\{[av + e] \mid v - u > -(Yh - Zk - Rg)\}, \end{aligned} \tag{102a}$$

where the third line follows from the second because v and e are assumed to be independent of Y, X, R and Z. The last term on the right-hand side of this equality is the expectation of the composite error term $av + e$ *conditional on* positive hours of work (i.e. the mean of $av + e$ for someone with characteristics Y, Z and R who works). Its value depends on the variables Y, Z and R, the structural parameters h, k and g, and the parameters of the joint distribution of the random variables $av + e$ and $(v - u)$. Likewise, the regression function for the wages of workers is

$$\mathrm{E}\{w \mid Y, v - u > -(Yh - Zk - Rg)\} = Yh + \mathrm{E}\{v \mid v - u > -(Yh - Zk - Rg)\}, \tag{102b}$$

where the last term on the right-hand side of (103) is the conditional expectation of v, i.e. the mean value of v among workers.

To proceed further, researchers have typically assumed that the random variables v, e and u are jointly normally distributed (although other distributional assumptions and even nonparametric techniques could be used instead). In this case, it turns out [see, for example, Heckman (1979)] that the conditional mean of $av + e$ in (102a) and the conditional mean of v in (102b) can be written in a relatively simple fashion, i.e.

$$\mathrm{E}\{[av + e] \mid v - u > -(Yh - Zk - Rg)\} = [\sigma_{12}/\sigma_{22}^{0.5}]\lambda, \tag{103}$$

$$\mathrm{E}\{v \mid v - u > -(Yh - Zk - Rg)\} = [\sigma_{v2}/\sigma_{22}^{0.5}]\lambda, \tag{104}$$

where $\sigma_{12} = \mathrm{cov}[av + e, v - u]$, $\sigma_{v2} = \mathrm{cov}[v, v - u]$, $\sigma_{22} = \mathrm{var}[v - u]$, $\lambda = f[-I/\sigma_{22}^{0.5}]/\{1 - F[-I/\sigma_{22}^{0.5}]\}$ and $I = (Yh - Zk - Rg)$. The important thing to note about (103) and (104) is that they express the conditional means of $av + e$ and of v in terms of observed variables and estimable parameters, thereby permitting estimation.

In the approach developed by Heckman (1976b, 1979), estimation proceeds in three steps. In the first, one estimates the parameters governing the decision to work or not to work, as given by eqs. (100), using probit analysis, i.e. by maximizing the probit likelihood function

$$1 = \Pi F[-I/\sigma_{22}^{0.5}]^{1-d}\{1 - F[-I/\sigma_{22}^{0.5}]\}^{d}, \tag{105}$$

where d is a dummy variable equal to one if an individual works, and zero otherwise. This provides estimates of the parameter ratios $h/\sigma_{22}^{0.5}$, $k/\sigma_{22}^{0.5}$ and $g/\sigma_{22}^{0.5}$ which can be used to compute (estimates of) the λ for each working individual [recall the definition of λ in (103)–(104)]. Armed with these measures of working individuals' λ values, one can then estimate the reduced form hours and wage equations by using data for *working* individuals to fit the following functions by, for example, least squares:

$$H = Yah + Xb + Rc + \lambda m + y, \tag{106}$$

$$w = Yh + \lambda n + z, \tag{107}$$

where y and z are random error terms that are uncorrelated with the right-hand side variables in (106)–(107) by (103)–(104), and where, by (103)–(104), estimates of the parameters m and n are estimates of the ratios $\sigma_{12}/\sigma_{22}^{0.5}$ and $\sigma_{v2}/\sigma_{22}^{0.5}$, respectively.

We conclude this abbreviated methodological discussion with one further observation. It should already be clear that the error term plays a much more important role, and has been the focus of much more attention, in second- than in first-generation labor supply research. What may not immediately be clear is that, in general, three kinds of "error terms" (unobservables, measurement errors, etc.) may be relevant to labor supply: one kind has to do with the utility function (or other utility-related function such as the indifference curve, the marginal rate of substitution, etc.); another refers to the budget constraint; the third has to do with the optimum point (e.g. indifference curve–budget line tangency) itself. We refer to these as preference errors, budget constraint errors, and optimization errors, respectively.

Optimization errors (and errors in the measurement of hours of work) refer to discrepancies between optimal and actual (or between actual and *measured*) hours of work. Such discrepancies arise when, for example, individuals are unable to work as many hours as they desire due to unemployment, bad weather or other similar phenomena; or when data on hours of work do not accurately reflect the hours (optimal or not) that individuals are actually working. Preference errors refer to unobservable differences in utility (or utility-related) functions across individuals: for example, Burtless and Hausman (1978) and Hausman (1981) adopt a random-parameter utility function model in which the elasticity of hours of work with respect to exogenous income varies randomly across the population; and Heckman (1976b) assumes that the marginal rate of substitution is affected by unobservables as well as unobservables, as in (97). Finally, budget constraint errors refer to unobservable differences in budget constraints across individuals. For example, most recent work treats the wage as a function of unobserved as well as observed characteristics, as in (99); likewise, observationally identical individuals (with the same observed pretax wage rate, exogenous income, etc.) may not face the same marginal tax rate, meaning that their after-tax budget constraints differ due to unobservable factors (e.g. differences in consumption patterns that lead to different deductions, marginal tax rates, etc.).

4.2. *Estimates of female labor supply elasticities: An overview*

We now turn to estimates of female labor supply elasticities obtained in recent empirical analyses. We focus on the compensated (utility-constant) and uncompensated ("gross") elasticity of hours of work with respect to the wage rate and on the so-called "total-income" elasticity of annual hours (i.e. the difference between the uncompensated and compensated wage-elasticities of hours).[30] Details concerning the samples and variables used in these studies are summarized in Table 2.25; the results of the studies are set out in Table 2.26. All in all, most of the estimates suggest that female labor supply elasticities are large both in absolute terms and relative to male elasticities (on which see Pencavel, Chapter 1 in this Handbook). However, the range of estimates of the uncompensated wage elasticity of annual hours is dauntingly large: Dooley (1982), Nakamura and Nakamura (1981), and Nakamura, Nakamura and Cullen (1979) all report estimates of -0.30 or less, whereas Dooley (1982) and Heckman (1980) obtain estimates in excess of $+14.00$! Since most estimates of the uncompensated wage elasticity are positive and estimates of the total-income elasticity are almost always negative, it is not surprising that the compensated wage elasticities implied by the studies shown in Table 2.26 are generally positive; but even here it is the variability, rather than uniformity, of the estimates that is noteworthy. It is not uncommon for authors of empirical papers on female labor supply to point to results in other studies similar to the ones they have obtained but, as Table 2.26 suggests, such comparisons may not always be informative: it is all too easy to find at least one other set of results similar to almost any set of estimates one may have obtained!

The main exception to these generalizations concerns the results of studies of U.S. and Canadian data by Nakamura and Nakamura (1981), Nakamura, Nakamura and Cullen (1979), and Robinson and Tomes (1985).[31] Here, the uncompensated elasticity of labor supply with respect to wages is negative (so

[30] This discussion omits two kinds of studies: those based on the negative income tax (NIT) experiments, and those based on dynamic models of labor supply of the kind discussed in Section 3.2. One problem with studies based on the NIT experiments is that, as has recently been noted [Greenberg, Moffitt and Friedmann (1981), Greenberg and Halsey (1983)], participants in the experiments may have misreported their earnings and work effort (to an even greater extent than the "controls" who were not receiving experimental NIT payments). For discussions of studies based on the NIT experiments, see Killingsworth (1983, ch. 6), Moffitt and Kehrer (1981, 1983) and Robins (1984). There have been relatively few empirical studies based on formal dynamic labor models [see Altonji (1986), Blundell and Walker (1983), Heckman and MaCurdy (1980, 1982), Moffitt (1984b) and Smith (1977a, 1977b, 1977c, 1980)]; all but one [Moffitt (1984b)] treat the wage as exogenous (in the behavioral sense), and have produced somewhat mixed results. For a brief review, see Killingsworth (1983, ch. 5).

[31] See also Nakamura and Nakamura (1985a, 1985b), which differ from most other studies of female labor supply in that these analyses condition on labor supply in the year prior to the one being considered.

473

Table 2.25
Summary of samples and variables used in selected studies of female labor supply.

Study	Characteristics of sample	Construction of measures of H, W, R
Arrufat and Zabalza (1986)	Wives age < 60, neither unemployed nor self-employed, with working husbands < 65 who were not self-employed – GHS	H = hours of work per week W = hourly earnings, predicted from selection bias-corrected regression R = husband's earnings + rent + dividends + interest + imputed rent (owner-occupiers) – mortgage interest + rent + property tax rebates (after taxes calculated at zero hours of work for wife)
Ashworth and Ulph (1981)	Wives of husbands working ≥ 8 hours/week at salaried job, no other family members working; women with second job excluded if either (i) gross wage at second job > overtime rate on first job or (ii) did not want to work more overtime on first job than actually worked – BMRBS	H = hours of work per week W = marginal net wage (wage at first job, if constrained at first job; or lower of the wages on two jobs, otherwise), inclusive of overtime premium (if any) (linearized) R = net family income excluding own earnings (linearized)
Blundell and Walker (1982)	Working wives with working husbands, husband a manual worker, total weekly expenditures between £35 and £55 – FES	H = hours of work per week W = earnings/H (linearized) R = unearned income (linearized)
Cogan (1980a)	White wives age 30–44 – NLS	H = annual hours of work W = hourly wage R = husband's annual income
Cogan (1980b)	White wives not in school, disabled or retired, self and spouse not self-employed or farmer – PSID	H = annual hours of work W = hourly wage R = husband's earnings
Cogan (1981)	White wives age 30–44, self and spouse not self-employed or farmer – NLS •	H = usual weekly hours × weeks worked in prior year W = earnings in prior year/hours worked in prior year R = husband's earnings
Dooley (1982)	Wives age 30–54 – USC	H = hours worked in survey week × weeks worked in prior year W = earnings in prior year/H R = other income exclusive of earnings of family members, self-employment income, Social Security, and public assistance benefits (separate variables included for husband's predicted income and actual – predicted husband's income)
Franz and Kawasaki (1981)	Wives – M	H = hours worked in survey week W = hourly wage R = income of husband
Franz (1981)	Same as Franz and Kawasaki (1981)	Same as Franz and Kawasaki (1981)
Hanoch (1980)	White wives, husband a wage earner and nonfarmer – SEO	H = hours worked in survey week × weeks worked in prior year W = earnings in survey week/hours worked in survey week R = husband's earnings + property income + transfer payments + other regular non-wage income

Table 2.25 continued

Study	Characteristics of sample	Construction of measures of H, W, R
Hausman (1980)	Black female household heads in Gary Income Maintenance Experiment, observed during experiment (households with preexperiment income > 2.4 times poverty line were excluded from experiment)	H = 1 if worked during middle two years of experiment, = 0 otherwise W = hourly wage R = nonlabor income
Hausman (1981)	Wives of husbands age 25–55 and not self-employed, farmers or disabled – PSID	H = annual hours worked W = hourly wage R = imputed return to financial assets
Hausman and Ruud (1984)	Same as Hausman (1981)	Same as Hausman (1981)
Heckman (1976a)	White wives age 30–44 – NLS	H = weeks worked × average hours worked per week W = usual wage R = assets
Heckman (1980)	White wives age 30–44, husband not a farmer – NLS	H = annual earnings/W W = usual hourly wage R = assets
Kooreman and Kapteyn (1984b)	Households in which both husband and wife are employed wage earners – TUS	H = hours of work per week W = net wage per hour R = "unearned income" per week
Layard, Barton and Zabalza (1980)	Wives age ≤ 60, not self-employed – GHS hours	H = annual weeks worked × usual weekly W = predicted value of annual earnings/H, derived from OLS wage regression (linearized) R = net annual unearned income, including imputed rent, interest and dividends (husband's W, derived as for wife's W, included as separate variable) (linearized)
Mroz (1985)	White wives age 30–60 in 1975 – PSID	H = weeks worked in 1975 × usual hours of work per week W = total earnings in 1975/H R = household income – wife's earnings
Moffitt (1984a)	Wives – NLS	H = hours worked last week W = hourly wage rate R = 0.05 × assets
Nakamura, Nakamura and Cullen (1979)	Wives with no nonrelatives in household – CC	H = hours worked in survey week × weeks worked in prior year W = annual earnings/H R = husband's earnings + asset income
Nakamura and Nakamura (1981)	Wives – CC, USC	H = hours worked in survey week × weeks worked in prior year W = annual earnings/H (linearized) R = husband's earnings + asset income – taxes payable at zero hours of wife's work
Ransom (1982)	Wives of husbands age 30–50 (neither spouse self-employed or working piecework) – PSID	H = hours of work per week W = predicted wage, derived from selection bias-corrected wage regression (linearized) R = income other than earnings (linearized)
Renaud and Siegers (1984)	Wives age < 65 with husbands age < 65 and holding paid job – AVO	H = hours of work per week W = predicted net hourly wage rate derived from selection bias-corrected regression R = net weekly income

Table 2.25 continued

Study	Characteristics of sample	Construction of measures of H, W, R
Robinson and Tomes (1985)	Single and married women reporting earnings on a per-hour basis ("hourly wage sample") or saying they were paid per hour ("hourly paid sample") - QLS	H = hours of work per week W = earnings per hour R = annual income of husband
Ruffell (1981)	Wives working ≥ 8 hours per week, no other working family members except husband - BMRBS	H = hours of work per week W = hourly wage, inclusive of overtime (if any) (linearized) R = nonemployment income + other family members' earnings (linearized)
Schultz (1980)	Wives, husband not full-time student or in armed forces - SEO	H = hours worked last week × weeks worked last year W = last week's earnings/last week's hours of work (adjusted for regional cost of living differences) (linearized) R = nonemployment income (linearized)
Smith and Stelcner (1985)	Wives age 20-54, not self-employed or family worker - CC	H = hours in survey week × weeks worked last year W = earnings last year/H (linearized) R = net nonlabor income + husband's earnings (linearized)
Stelcner and Breslaw (1985)	Wives age 20-54, Quebec residents, nonfarm, not new immigrant or full-time student or unpaid family worker or self-employed or permanently disabled - MDF	H = weeks worked in 1979 W = earnings last year/H (linearized) R = other family income (linearized)
Stelcner and Smith (1985)	Same as Smith and Stelcner (1985)	Same as Smith and Stelcner (1985)
Trussell and Abowd (1980)	Wives age 25-45 who between age 12 and 30 delivered at least one child - NSFG	H = annual hours of work W = hourly wage R = other family income
Yatchew (1985)	Same as Hausman's (1981) data for wives	Same as Hausman (1981)
Zabalza (1983)	Wives age < 60, not self-employed, with working husband age < 65 and not self-employed - GHS	H = hours worked in survey week (in intervals according to value of marginal tax rate) W = tax rate hourly earnings, net of taxes R = husband's earnings + unearned income

Notes:
AVO = *Aanvullend Voorzieningsgebruik Onderzoek 1979*, Social and Cultural Planning Bureau, the Netherlands.
BMRBS = British Market Research Bureau survey, United Kingdom.
CC = Census of Canada, Statistics Canada.
FES = Family Expenditure Survey, Office of Population Censuses and Surveys, United Kingdom.
GHS = General Household Survey, Office of Population Censuses and Surveys, United Kingdom.
M = Microcensus, Statistiches Bundesamt, Federal Republic of Germany.
MDF = 1979 Micro Data File, Census Families Survey of Consumer Finances, Statistics Canada.
NLS = National Longitudinal Survey, Center for Human Resource Research, Ohio State University.
NSFG = National Survey of Family Growth, National Center for Health Statistics.
PSID = Panel Study of Income Dynamics, Survey Research Center, University of Michigan.
QLS = Quality of Life Survey, Institute for Behavioural Research, York University, Canada.
SEO = Survey of Economic Opportunity, U.S. Office of Economic Opportunity.
TUS = Time Use Survey, Survey Research Center, University of Michigan.
USC = U.S. Census, Bureau of the Census, U.S. Department of Commerce.
"Linearized" indicates that budget line is linearized at equilibrium hours of work and equilibrium marginal tax rate; linearized wage rate denotes wage rate × (1 − equilibrium marginal tax rate); linearized R = height of budget line when budget line is projected from equilibrium hours of work back to zero hours of work using linearized wage rate.

474

Table 2.26
Summary of labor supply estimates for women implied by results of selected studies of female labor supply.

Study	Sample, procedure used	Wage elasticity: Uncompensated	Wage elasticity: Compensated	Total-income elasticity
	Data for United States			
Heckman (1976b)	White wives age 30–44:			
	Procedure IV	1.46	1.48	−0.02
	Procedure VI	4.31	4.35	−0.04
Cogan (1980a)	White wives age 30–44:			
	Procedure II	1.14	1.17	−0.03
	Procedure III	3.50	3.60	−0.10
	Procedure VI	2.83	2.91	−0.09
Schultz (1980)	White wives age 35–44 (lbc):			
	Procedure I	0.16	0.21	−0.05
	Procedure II	0.13	0.19	−0.05
	Procedure III	0.65	0.83	−0.18
	Black wives age 35–44 (lbc):			
	Procedure I	0.60	0.34	0.26
	Procedure II	0.42	0.41	0.01
	Procedure III	1.04	0.56	0.48
Trussell and Abowd (1980)	White wives age 25–45 (Procedure VI)	4.50	n.a.	−0.41*
	Black wives age 25–45 (Procedure VI)	2.93	n.a.	≈ 0*
Heckman (1980)	White wives age 30–44:			
	Procedure IV	2.26	2.26	≈ 0
	Procedure VII	1.47	1.47	≈ 0
	Procedure IV(a)	14.79	14.79	≈ 0
	Procedure VII(a)	6.62	6.62	≈ 0
	Procedure V(a)	4.47	4.47	≈ 0
Hanoch (1980)	White wives age 30–44 (fc):			
	weeks worked < 52 (no "corner" in weeks worked)	0.64	0.81	−0.17
	weeks worked = 52 (with "corner" in weeks worked)	0.42	0.54	−0.13
Cogan (1980b)	White wives age 30–44:			
	Procedure VI	2.45	2.64	−0.19
	fixed costs of labor market entry model:			
	OLS	0.89	0.93	−0.04
	conditional ML	1.14	1.19	−0.05
Cogan (1981)	White wives age 30–44:			
	Procedure VI	2.10	2.18	−0.08
	fixed costs of labor market entry (conditional ML)	0.65	0.68	−0.03
Nakamura and Nakamura (1981)	Wives – Procedure VIII (lbc):			
	age 30–34	−0.27	0.11	−0.36
	age 35–39	−0.31	−0.12	−0.19
	age 40–44	−0.09	0.18	−0.27
Dooley (1982)	Wives – Procedure VII:			
	Whites: age 30–34	3.66	4.14	−0.48
	age 35–39	15.24	15.35	−0.11
	age 40–44	4.28	4.73	−0.45
	Blacks: age 30–34	0.67	1.01	−0.35
	age 35–39	−0.34	−0.17	−0.17
	age 40–44	−0.89	−1.06	0.18
Ransom (1982)	Wives, husband age 30–50 – ML, lbc (quadratic family duf)	0.40 to 0.42	0.46 to 0.50	−0.05 to −0.09

Table 2.26 continued

Study	Sample, procedure used	Wage elasticity		Total-income elasticity
		Uncompensated	Compensated	
Hausman (1980)	Black household heads – ML, fc, cbc (ep, eh) (linear lsf)	0.05	0.16	−0.11
Hausman (1981)	ML, fc, cbc (ep, eh) (linear lsf):			
	wives	0.91 to 1.00	n.a.	n.a.
	female household heads	0.46 to 0.53	0.58 to 0.77	−0.12 to −0.24
Moffitt (1984)	ML, cbc (eh) (linear lsf):			
	linear budget constraint	0.78	n.a.	−0.04*
	wage rate a quadratic function of hours worked:			
	response to change in wage at sample means	0.43	n.a.	−0.28*
	response to upward shift in entire budget constraint	0.21	n.a.	−0.18*
Hausman and Ruud (1984)	ML, cbc (eh) (iuf yielding lsf's quadratic in wages)	0.76	n.a.	−0.36*
Kooreman and Kapteyn (1984b)	first-stage ML for leisure times of husband and wife (eh), second-stage selection bias-corrected WLS regression of household ds (translog iuf)	0.27***	0.31***	0.00****
Yatchew (1985)	Wives – ML, cbc (ep) (translog iuf)	0.47	n.a.	−0.89*
	Data for Great Britain			
Layard, Barton and Zabalza (1980)	Wives age ≤ 60:			
	No allowance for taxes:			
	Procedure I (evaluated at overall means)	0.43	0.49	−0.06
	Procedure II (evaluated at workers' means)	0.08	0.09	−0.02
	Procedure III evaluated at overall means	0.78	0.97	−0.19
	Procedure III evaluated at workers' means	0.44	0.63	0.19
	Lbc (eh, eb): Procedure II (evaluated at worker's means)	0.06	0.06	0.10
Blundell and Walker (1982)	Wives – ML, lbc (family ds using Gpf, corrected for selection bias in requiring wife's $H > 0$):			
	Husband's H unrationed: No children	0.43	0.65	−0.22
	One child	0.10	0.32	−0.22
	Two children	0.19	0.03	−0.22
	Husband's H rationed: No children	0.64	0.83	−0.19
	One child	0.09	0.28	0.19
	Two children	0.30	0.11	0.19
Zabalza (1983)	Wives – ML (ordered probit analysis), cbc (ep) (CES duf)	1.59	1.82	0.23
Arrufat and Zabalza (1986)	Wives – ML (modified ordered probit analysis), cbc (ep, eh) (CES duf)	2.03	n.a.	−0.21*
Ashworth and Ulph (1981a)	Wives, husband < 65:			
	OLS – lbc (quadratic lsf)	−0.09 to −0.21	−0.04 to −0.23	0.02 to −0.05
	ML – lbc: CES iuf	−0.19	0.29	−0.48
	restricted generalized CES	0.57	0.81	−0.24
	iuf generalized CES iuf	0.32	0.55	−0.23

Table 2.26 continued

Study	Sample, procedure used	Wage elasticity		Total-income elasticity
		Uncompensated	Compensated	
Ruffell (1981)	Wives, husband < 65 (quadratic lsf):			
	OLS – lbc	−0.00	0.04	−0.04
	ML – cbc (eh)	0.43	0.51	−0.08
	MD – cbc (eh, eb)	0.72	0.77	−0.05
	Data for Canada			
Nakamura, Nakamura and Cullen (1979)	Wives – Procedure VII:			
	age 30–34	−0.17	0.00	−0.17
	age 35–39	−0.20	−0.16	−0.04
	age 40–44	−0.05	0.14	−0.19
Nakamura and Nakamura (1981)	Wives – Procedure VIII (lbc):			
	age 30–34	−0.27	0.23	−0.50
	age 35–39	−0.17	−0.12	−0.05
	age 40–44	−0.05	0.14	−0.19
Robinson and Tomes (1985)	Unmarried and married women: "hourly wage" sample:			
	Procedure II (actual wage used in lsf)	−0.22	−0.22	≈ 0
	Procedure II (instrument used for wage in lsf)	−0.85	−0.85	≈ 0
	Procedure II (actual wage used in lsf; selection biased-correction term, derived from probit analysis, included)	−0.23	−0.23	≈ 0
	Unmarried and married women: "hourly paid" sample:			
	Procedure II (actual wage used in lsf)	−0.19	−0.19	≈ 0
	Procedure II (instrument used for wage in lsf)	−0.44	−0.44	≈ 0
	Procedure II (actual wage used in lsf; selection bias-correction term, derived from probit analysis, included)	−0.20	−0.20	≈ 0
Smith and Stelcner (1985)	Wives: Procedure VII (lbc):			
	age 20–54	0.08	0.21	0.13
	age 20–34	0.21	0.41	0.20
	age 35–54	0.04	0.06	0.09
Stelcner and Smith (1985)	Wives: ML (probit analysis), ep (CES duf):			
	age 20–54	0.03	0.04	0.01
	age 20–34	0.02	0.05	−0.03
	age 35–54	0.02	0.02	0.00
Stelcner and Breslaw (1985)	Wives in Quebec: Procedure VIII (lbc):			
	OLS with selection bias correction (no "tax illusion")	0.40	0.49	−0.09
	GLS with selection bias correction (no "tax illusion")	0.97	1.17	0.20
	OLS with selection bias correction and "tax illusion"	0.40	0.49	0.09
	GLS with selection bias correction and "tax illusion"	1.28	1.52	0.24
	Data for Federal Republic of Germany			
Franz and Kawasaki (1981)	Wives – Procedure VII	1.08	1.28	−0.20
Franz (1981)	Wives – modified Procedure VII	1.37	1.66	−0.29
	Data for the Netherlands			
Renaud and Siegers (1984)	Wives – Procedure III	1.79	1.83	−0.04

Table 2.26 continued

Notes:

a = instrumental variable used for wife's work experience to allow for potential endogeneity of this variable.

* = elasticity of hours of work with respect to exogenous income (R).

** = elasticity of leisure with respect to wage rate (uncompensated).

*** = elasticity of leisure with respect to wage rate (compensated).

**** = elasticity of leisure with respect to exogenous income (R).

All elasticities are evaluated at sample means (reported by author(s)) of entire population of women, or are as reported (if available) directly by author(s). n.a. = not available (not enough information available to permit computation of elasticity). Total-income elasticity is defined as $W(dH/dR)$, equal to the difference between uncompensated and compensated elasticity of labor supply with respect to own wage rate. All calculations use structural labor supply parameters and therefore refer to labor supply response of a given individual (as opposed to, e.g., calculations using expected value of labor supply such as the Tobit expected-value locus).

Estimation technique:
- OLS = ordinary least squares
- GLS = generalized least squares
- WLS = weighted least squares
- ML = maximum likelihood
- MD = minimum distance

Basis of specification:
- Gpf = Gorman polar form of expenditure function
- duf = direct utility function
- iuf = indirect utility function
- ds = demand system
- lsf = labor supply function
- fc = allowance for fixed costs of labor market entry

Treatment of taxes:
- lbc = linearized budget constraint
- cbc = complete budget constraint

Error structure in cbc models:
- ep = variation (error term) in preferences (e.g. utility function or marginal rate of substitution function)
- eh = variation (errors of optimization and/or measurement) in hours of work
- eb = errors of measurement of budget constraint (e.g. wage rate or marginal tax rate)

Estimation procedure:
- I = Obtain predicted wage for all individuals from OLS estimates of wage equation using data on workers only; use predicted wage in OLS estimation of labor supply schedule with data on all individuals (nonworkers' labor supply set at zero).
- II = Obtain predicted wage for workers from OLS estimates of wage equation using data on workers only; use predicted wage in OLS estimation of labor supply schedule with data on workers only.
- III = Obtain predicted wage for all individuals from OLS estimates of wage equation using data on workers only; use predicted wage in Tobit estimation of labor supply schedule with data on all individuals.
- IV = Estimate wage equation by OLS using data for workers only; estimate reduced form labor supply equation using data on all individuals (with nonworkers' H set at zero); identify structural labor supply equation using reduced form estimates and estimates of wage equation.
- V = Estimate reduced form labor supply equation by Tobit; use Tobit estimates to compute a selection bias correction variable (inverse of Mills' ratio); include selection bias correction variable in estimation of wage equation by OLS (or GLS, etc.); identify structural labor supply equation using reduced form estimates and estimates of wage equation.
- VI = ML estimation of joint determination of wages and hours of work (extension of Tobit to simultaneous equation system).
- VII = "Heckit" for exactly-identified labor supply function: estimate reduced form equation for labor force participation by probit; use probit coefficients to compute a selection bias correction variable (inverse of Mills' ratio); include selection bias correction variable in estimation of wage and reduced form hours of work equations; identify structural labor supply equation using reduced form estimates and estimates of wage equation.
- VIII = "Heckit" for overidentified labor supply function: estimate reduced form equation for labor force participation by probit; use probit coefficients to compute a selection bias correction variable (inverse of Mills' ratio); include selection bias correction variable in estimation of wage equation; use estimates of structural wage equation to compute a predicted wage for working individuals; include predicted wage in OLS (or GLS, etc.) estimation of structural labor supply equation.

much so that even the implied compensated elasticity is also negative in some instances). Similarly, Smith and Stelcner (1985) and Stelcner and Smith (1985) obtain uncompensated (and compensated) elasticities that, although positive, are very small in magnitude.

It is tempting simply to dismiss such results as mere anomalies, particularly because the procedures used in these studies differ in some potentially important respects from those adopted in prior work.[32] The most useful evidence on female labor supply elasticities is likely to come from studies that conduct detailed sensitivity analyses, thereby highlighting the consequences of adopting different procedures for the same dataset. The one such analysis currently available is that of Mroz (1985), which offers some surprising and – to those[33] who heretofore thought that female labor supply elasticities were generally rather large – somewhat unsettling results that make it hard to dismiss out of hand results such as those of Nakamura et al.

Begin by considering the first line of Table 2.27, which summarizes results obtained by Heckman (1980) for data on white wives age 30–44 in the 1966 National Longitudinal Survey (NLS). The uncompensated wage elasticities shown there are higher (sometimes appreciably so) than those obtained by other authors, but they are certainly consistent with the notion that the uncompensated wage elasticity of female labor supply is greater than 0.50 or even 1.00.[34]

The second and third lines of Table 2.27 present the results of Mroz's (1985) replication of the Heckman (1980) paper using the same variables and statistical procedures (and alternative definitions of annual hours of work) for a different dataset: white wives age 30–60 in the 1976 Panel Study of Income Dynamics (PSID). The elasticities are uniformly lower in Mroz's (1985) results than in Heckman's (1980), especially when work experience is treated as statistically endogenous. Adding new variables (number of children age 7 or older and wife's age) to the labor supply equation results in larger implied elasticities (again, especially when work experience is treated as statistically endogenous), as shown

[32] For example, Robinson and Tomes (1985) include both single and married women in their analysis, whereas most other studies of female labor supply have considered married women separately; and the studies by Nakamura and Nakamura (1981) and Nakamura and Cullen (1979) do not include an education variable in the labor supply function, whereas many other studies have such a variable. Finally, in both the Robinson–Tomes and Nakamura et al. studies the labor supply function is overidentified (in the sense that more than one variable that does appear in the wage equation does not appear in the structural labor supply equation), whereas in most other work the labor supply function is exactly identified (in the sense that exactly one variable – usually, work experience – that does appear in the wage equation does not appear in the labor supply equation); hence Robinson–Tomes and Nakamura et al. use Procedure VIII, whereas much other work uses Procedure VII (see Table 2.26 for definition of these terms).

[33] See, for example, Heckman, Killingsworth and MaCurdy (1981, esp. pp. 107–109) and Killingsworth (1983, esp. p. 432).

[34] Recall the uncompensated elasticities shown in Table 2.26 that are implied by the results of other studies, e.g. 0.65 in Schultz (1980); 1.14 in Cogan (1980b); 0.65 in Cogan (1981); and 0.90–1.00 in Hausman (1981).

477

Table 2.27
Uncompensated wage elasticities of married women's labor supply implied by alternative estimates of Heckman (1980) model.

	Procedure IV	Procedure VII	Procedure IV[a]	Procedure VII[a]	Procedure VII[b]
Original Heckman (1980) results (white wives age 30–44, NLS)	2.49	2.00	2.93	6.61	n.a.
Mroz (1985) replication (white wives age 30–50, PSID)					
original Heckman variables					
H: definition 1	1.25	0.11	0.17	1.43	0.48
definition 2	1.33	0.22	0.24	0.62	0.63
with new variables added					
H: definition 1	1.51	1.09	1.75	1.68	1.60
definition 2	1.57	1.35	1.97	1.94	1.89

[a]Instrumental variables used for wife's work experience and (when applicable) selection bias-correction variable λ (which includes wife's work experience) to correct for possible endogeneity of wife's work experience.

[b]Instrumental variables used for wife's work experience in both labor supply function and (when applicable) estimation of probit equation for labor force participation (which is used in construction of selection bias variable λ) to correct for possible endogeneity of work experience.

Definitions of hours of work:
1 = (1975 earnings)/(hourly wage in 1976), if available; otherwise, definition 2.
2 = weeks worked in 1975 × usual hours worked per week.

Variables:
Wage equation = education, years of schooling, years of work experience.
Labor supply equation = years of work experience, years of schooling, husband's wage, nonlabor income, number of children age 6 or less.
New variables: age, number of children age 7 or more.

All elasticities evaluated at $H = 1300$ [= approximate mean of hours of work of working women in Heckman (1980) and Mroz (1985) data]. Elasticities obtained as in Heckman (1980), by computing ratio of coefficient on experience variable in labor supply equation to coefficient on experience variable in wage equation (the latter is set at 0.015 in all calculations) and dividing the result by 1300.

For a definition of the statistical procedures used, see Table 2.26.

in the last two lines of Table 2.27. However, the standard errors of the point estimates underlying this third set of elasticities are appreciably larger than those of the point estimates derived using the original Heckman variables. Moreover, it is hardly reassuring to find that (i) one can get to within hailing distance of the original Heckman (1980) results only by departing from the original Heckman (1980) specification or (ii) inclusion of the older children and age variables should have such a pronounced effect on the implied labor supply elasticity.[35]

There remains the possibility that the Heckman and Mroz results differ because they are derived from different data and somewhat different populations: labor supply of white wives age 30–60 in the 1976 PSID (Mroz) may differ substantially from that of white wives age 30–44 in the 1966 NLS (Heckman) because of life-cycle and/or cohort effects. However, at this point it would be mere conjecture to make statements even about the existence of such effects, much less about whether their magnitude is sufficient to provide an explanation of the difference in results. Furthermore, any such explanation would also have to account for the difference between Mroz's results (1985) and those of Cogan (1980b). Cogan (1980b) gets an implied elasticity of 1.14 using conditional maximum likelihood – much higher than Mroz's (1985) results with the original Heckman variables – even though he, like Mroz (1985), uses the 1976 PSID (albeit for essentially all white wives regardless of age, versus Mroz's smaller group of white wives age 30–60).

The main contribution of Mroz's (1985) study is that it provides formal tests of a variety of propositions that were not subjected to serious scrutiny in previous work. Among the most important of his findings are the following: (i) there is

[35]One other consideration has to do with details about what wage equation parameter and what level of hours of work are used in calculation of the elasticities. In Table 2.27, we use 0.015 as "the" coefficient on the wife's experience variable in the wage equation, and use $H = 1300$, the approximate mean annual hours worked by *working* wives. However, one might argue that, in a given calculation, one should instead use (i) the coefficient on the experience variable in the wage equation that corresponds directly to the labor supply equation actually estimated and (ii) the *population* mean annual hours worked (by working and nonworking wives, with the latter's hours set equal to zero); indeed, most of the elasticities shown in Table 2.26 are in fact calculated in precisely this fashion [see especially the figures reported there for Heckman (1980)]. Changing either of these will in general change the implied elasticity. For example, the population mean value of H is about 740 in Mroz's (1985) data, and is 600 in the Heckman data [Heckman (1980, p. 244)]. Thus, other things being equal, using $H = 600$ or 740 rather than $H = 1300$ would increase the wage elasticity figures shown in Table 2.27 by a factor of between $1300/600 = 2.17$ and $1300/740 = 1.75$. That would certainly bring the Mroz replication results "with new variables added" closer to the original Heckman (1980) results shown in Table 2.26; but it would not change the Mroz "original Heckman variables" results very much. Note also that the difference in population mean values of H implies quite different employment rates (0.362 for the Mroz data, 0.468 for the Heckman data) coexisting alongside virtually identical mean values of hours of work for *working* women (1303 for the Mroz data, 1289 for the Heckman data). This highlights the possible importance of cohort and/or life cycle effects noted in the text.

little or no evidence that the wife's work experience is statistically endogeneous in the labor supply equation *provided* selection bias is taken into account [e.g. by inclusion of a λ variable in expressions such as (106)]; and (ii) the hypothesis of no selection bias in analyses of the labor supply of working women is rejected *provided* the wife's work experience is included in the labor supply equation [so that ignoring selection bias, e.g. omitting the λ variable in expressions such as (106), will generally lead to inconsistent estimates of labor supply parameters if work experience is included in the labor supply equation]. Conversely, (iii) if work experience is excluded from the supply equation, the hypothesis of no selection bias in the supply equation cannot be rejected; and (iv) if a selection bias term is excluded from the supply equation, the hypothesis that experience is exogenous in the supply equation is rejected. (Thus, the selection bias problem appears to manifest itself primarily through the work experience variable.) Finally: (v) the conventional Tobit specification of labor supply can be rejected in favour of the generalized Tobit ("Heckit") specification,[36] (106), with the former yielding inflated wage elasticity estimates relative to the latter; (vi) there is little or no evidence that "exogenous" income, R (defined to include husband's earnings and property income), is statistically endogenous; and (vii) correcting for taxes has a trivial effect on wage elasticity estimates, and has varying but generally small effects on estimated elasticities with respect to nonwork income.

Mroz also finds that estimated wage elasticities tend to be higher in exactly-identified labor supply functions than in overidentified labor supply functions,[37] and presents evidence favoring the latter kind of specification. Estimates of labor supply models that embody these findings (e.g. generalized Tobit estimation of overidentified labor supply equations, with or without allowance for taxes, but with correction for selection bias) generally imply a very low or even negative elasticity of labor supply with respect to wages, as shown in Table 2.28.

478

Six years ago, Heckman, Killingsworth and MaCurdy (1981, p. 108) commented that elasticity estimates obtained using recently developed econometric techniques had increased the mean of what might be called the "reasonable guesstimate" of the wage-elasticity of female labor supply. Work since then seems to have reduced the mean and substantially increased the variance of this

[36] The Tobit specification (in terms of Table 2.26, Procedures III, V or VII) implicitly assumes that hours of work vary continuously from zero (at a wage equal to the reservation level) to progressively larger positive amounts (at wages greater than the reservation level), with no jumps or discontinuities. In contrast, the generalized Tobit specification (in terms of Table 2.26, Procedures VII or VIII, sometimes called "Heckit") implicitly allows for a discontinuity in labor supply at the reservation wage such that hours worked are zero below the reservation level and some large amount above the reservation level. The latter approach has sometimes been characterized as a means of allowing for the labor supply discontinuities that may be induced by fixed costs of labor market entry. [For further discussion, see Cogan (1980b) and Killingsworth (1983, esp. pp. 141–148).]

[37] See footnote 32.

Table 2.28
Alternative estimates of uncompensated wage elasticity of wives' labor supply in Mroz's (1985) sensitivity analyses.

Model	Estimated elasticity (standard error)
Procedure VIII (a) – no allowance for taxes	0.09 (0.17)
Procedure VIII (b)	
no allowance for taxes	−0.02 (0.15)
with allowance for taxes (lbc)	−0.05 (0.15)

Notes:
a = Variables in probit equation = age, education, exogenous income, number of children age (i) 6 or less, (ii) 5 or less, (iii) age 5–19, (iv) age 7–19, background variables (county unemployment rate, schooling of wife's parents, etc.), wife's experience, wife's experience squared, quadratic and cubic terms in wife's age and education.
Variables in wage equation = same as probit equation.
Variables in structural labor supply equation = logarithm of wife's wage, exogenous income, children (i) age 6 or less and (ii) 7–19, wife's age, wife's education.
b = Variables in probit equation = as for (a), with addition of cubic and quadratic terms in husband's age and education, family property income (family income exclusive of spouses' earnings), logarithm of husband's average hourly wage.
Variables in wage equation = same as probit equation.
Variables in structural labor supply equation = same as for (a).
lbc denotes linearized budget constraint.
For definition of Procedure VIII, see Table 2.26.
All elasticities evaluated at $H = 1300$ [= approximate mean of hours worked by working women in Mroz's (1985) sample]; see Table 2.27.

guesstimate. Regarding future research, we borrow from Samuel Gompers' characterization of union objectives, and advocate "more". Additional sensitivity analyses using a single behavioral specification, along the lines of Mroz (1985), will help identify some of the factors underlying the substantial diversity of elasticity estimates. However, as implied by our brief reference to life-cycle and/or cohort issues, studies based on alternative behavioral models – notably, life-cycle models, which have been used relatively little in empirical studies – are also likely to provide important insights. Pencavel (Chapter 1 in this Handbook) is critical of the emphasis on mere calibration – as opposed to hypothesis testing – in studies of male labor supply; if only because female labor supply elasticities have been calibrated so imprecisely, most readers are likely to agree that his comments apply just as much to female as to male labor supply.

References

Allen, R. G. D. (1938) *Mathematical analysis for economists*. London: Macmillan Press.

Altonji, J. (1986), "Intertemporal substitution in labor supply: evidence from micro data", *Journal of Political Economy*, 94 (Supplement): S176–S215.

Arrow, K. J. and M. Kurz (1970) *Public investment, the rate of return, and optimal fiscal policy*. Baltimore: Johns Hopkins University Press.

Arrufat, J. L. and A. Zabalza (1986) "Female labor supply with taxation, random preferences, and optimization errors", *Econometrica*, 54:47–64.

Ashenfelter, O. (1979) "Comment [on Manser and Brown, 1979]", in: Cynthia B. Lloyd, Emily S. Andrews and Curtis L. Gilroy, *Women in the labor market*. New York: Columbia University Press, 37–42.

Ashenfelter, O. and J. J. Heckman (1974) "The estimation of income and substitution effects in a model of family labor supply", *Econometrica*, 42:73–85.

Ashworth, J. S. and D. T. Ulph (1981) "Household models", in: C. V. Brown, ed., *Taxation and labour supply*. London: Allen & Unwin, 117–133.

Atkinson, A. B. and N. H. Stern (1981) "On labour supply and commodity demands", in: A. Deaton, ed., *Essays in the theory and measurement of consumer behaviour in honour of Sir Richard Stone*. Cambridge: Cambridge University Press, 265–296.

Atrostic, B. K. (1982) "The demand for leisure and nonpecuniary job characteristics", *American Economic Review*, 72:428–440.

Barten, A. P. (1977) "The system of consumer demand functions approach: a review", *Econometrica*, 45:23–51.

Basemann, R. (1956) "A theory of demand with variable consumer preferences", *Econometrica*, 24:47–58.

Becker, G. (1965) "A theory of the allocation of time", *Economic Journal*, 75:493–517.

Becker, G. (1974) "A theory of marriage", in: T. W. Schultz, ed., *Economics of the family*. Chicago: University of Chicago Press, 293–344.

Ben-Porath, Y. (1973) "Labor-force participation rates and the supply of labor", *Journal of Political Economy*, 81:697–704.

Bergstrom, T. (1984) "Remarks on public goods theory and the economics of the family", unpublished manuscript, Department of Economics, University of Michigan, Ann Arbor, Michigan.

Bjorn, P. A. and Q. H. Vuong (1984) "Simultaneous equations models for dummy endogenous variables: a game theoretic formulation with an application to labor force participation", unpublished manuscript, Department of Economics, California Institute of Technology, Pasadena, California.

Bjorn, P. A. and Q. H. Vuong (1985) "Econometric modeling of a Stackelberg game with an application to labor force participation", unpublished manuscript, Department of Economics, California Institute of Technology, Pasadena, California.

Blundell, R. and I. Walker (1982) "Modelling the joint determination of household labour supplies and commodity demands", *Economic Journal*, 92:351–364.

Blundell, R. and I. Walker (1983) "Estimating a life-cycle consistent model of family labor supply with cross section data", unpublished manuscript, Department of Economics, University of Manchester, Manchester, England.

Boothby, D. (1984) "The continuity of married women's labour force participation in Canada", *Canadian Journal of Economics*, 17:471–480.

Bourguignon, F. (1984) "Rationalité individuelle ou rationalité stratégique: le cas de l'offre familiale de travail", *Revue Economique*, 35:147–162.

Bourguignon, F. (1985) "Women's participation and taxation in France", in: R. Blundell and I. Walker, eds., *Unemployment, job search and labour supply*. Cambridge: Cambridge University Press.

Bowen, W. and T. A. Finegan (1969) *The economics of labor force participation*. Princeton, N.J.: Princeton University Press.

Brown, C. (1985) "An institutional model of wives' work decisions", *Industrial Relations*, 24:182–204.

Brown, A. and A. Deaton (1972) "Models of consumer behaviour: a survey", *Economic Journal*, 82:1145–1236.

Browning, M., A. Deaton and M. Irish (1985) "A profitable approach to labor supply and commodity demands over the life-cycle", *Econometrica*, 53:503–543.

Burtless, G. and D. Greenberg (1983) "Measuring the impact of NIT experiments on work effort", *Industrial and Labor Relations Review*, 36:592–605.

Burtless, G. and J. Hausman (1978) "The effect of taxation on labor supply: evaluating the Gary negative income tax experiment", *Journal of Political Economy*, 86:1103–1130.

Cain, G. (1966) *Married women in the labor force*. Chicago: University of Chicago Press.

Cain, G. (1982) "The economic analysis of labor supply: developments since Mincer", unpublished manuscript, Department of Economics, University of Wisconsin, Madison, Wisconsin.

Clark, K. B. and L. H. Summers (1981) "Demographic differences in cyclical employment variation", *Journal of Human Resources*, 16:61–79.

Clark, K. B. and L. H. Summers (1982) "Labour force participation: timing and persistence", *Review of Economic Studies*, 49 (Supplement):825–844.

Cogan, J. (1980a) "Married women's labor supply: a comparison of alternative estimation procedures", in: J. P. Smith, ed., *Female labor supply*. Princeton, N.J.: Princeton University Press, 90–118.

Cogan, J. (1980b) "Labor supply with costs of labor market entry", in: J. P. Smith, ed., *Female labor supply*. Princeton, N.J.: Princeton University Press, 327–364.

Cogan, J. (1981) "Fixed costs and labor supply", *Econometrica*, 49:945–964.

Cohen, M. S., S. A. Rea and R. I. Lerman (1970) *A micro model of labor supply*. BLS Staff Paper No. 4, U.S. Department of Labor. Washington, D.C.: U.S. Government Printing Office.

Coleman, T. (1984) "Essays on aggregate labor market business cycle fluctuations", unpublished Ph.D. dissertation, University of Chicago, Chicago, Illinois.

Corcoran, M. (1979) "Work experience, labor force withdrawals and women's wages: empirical results using the 1976 panel of income dynamics", in: C. B. Lloyd, E. S. Andrews and C. L. Gilroy, eds., *Women in the labor market*. New York: Columbia University Press.

Deaton, A. (1974) "A reconsideration of the empirical implications of additive preferences", *Economic Journal*, 84:338–348.

Deaton, A. (forthcoming) "Demand analysis", in: Z. Griliches and M. Intriligator, eds., *Handbook of econometrics*. New York: North-Holland, Vol. 3, forthcoming.

Deaton, A. and J. Muellbauer (1980) *Economics and consumer behavior*. New York: Cambridge University Press.

Deaton, A. and J. Muellbauer (1981) "Functional forms for labour supply and commodity demands with and without quantity restrictions", *Econometrica*, 49:1521–1532.

Dixit, A. (1976) *Optimization in economic theory*. Oxford: Oxford University Press.

Dooley, M. D. (1982) "Labor supply and fertility of married women: an analysis with grouped and individual data from the 1970 U.S. census", *Journal of Human Resources*, 17:499–532.

Douglas, P. H. (1934) *The theory of wages*. New York: Macmillan.

Duesenberry, J. (1952) *Income, savings and the theory of consumer behavior*. Cambridge, Mass.: Harvard University Press.

Durand, J. D. (1948) *The labor force in the U.S.* New York: Social Science Research Council.

Fisher, F. and K. Shell (1971) "Taste and quality change in the pure theory of the true cost of living index", in: Z. Griliches, ed., *Price indexes and quality change: studies in new methods of measurement*. Cambridge, Mass.: Harvard University Press.

Franz, W. (1981) "Schatzung Regionaler Arbeitsangebotsfunktionen mit Hilfe der Tobit-Methode und des Probit-verfahrens unter Berucksichtigung des sog. 'Sample Selection Bias'", Discussion Paper No. 171-81, Institut für Volkswirtschaftslehre und Statistik, University of Mannheim, Mannheim, Federal Republic of Germany.

Franz, W. and S. Kawasaki (1981) "Labor supply of married women in the Federal Republic of Germany: theory and empirical results from a new estimation procedure", *Empirical Economics*, 6:129–143.

Friedman, M. (1957) *A theory of the consumption function*. Princeton, N.J.: Princeton University Press.

Fuchs, V. (1984) "His and hers: gender differences in work and income, 1959–1979", Working Paper No. 1501, National Bureau of Economic Research, Cambridge, Massachusetts.

Goldin, C. (1980) "The work and wages of single women, 1970 to 1920", *Journal of Economic History*, 40:81–88.

Goldin, C. (1983a) "The changing economic role of women: a quantitative approach", *Journal of Interdisciplinary History*, 13:707–733.

Goldin, C. (1983b) "Life cycle labor force participation of married women: historical evidence and implications", Working Paper No. 1251, National Bureau of Economic Research, Cambridge, Massachusetts.

Goldin, C. (1984) "The historical evolution of female earnings functions and occupations", *Explorations in Economic History*, 21:1–27.

Goldin, C. (1986) "Monitoring costs and occupational segregation by sex: a historical analysis", *Journal of Labor Economics*, 4:1–27.

Goldin, C. and K. Sokoloff (1982) "Women, children, and industrialization in the early republic: evidence from the manufacturing censuses", *Journal of Economic History*, 42:741–774.

Graham, J. and C. Green (1984) "Estimating the parameters of a household production function with joint products", *Review of Economics and Statistics*, 66:277–282.

Greenberg, D. and H. Halsey (1983) "Systematic misreporting and effects of income maintenance experiments on work effort: evidence from the Seattle-Denver experiment", *Journal of Labor Economics*, 1:380–407.

Greenberg, D., R. Moffitt and J. Friedmann (1981) "Underreporting and experimental effects on work effort: evidence from the Gary income maintenance experiment", *Review of Economics and Statistics*, 63:581–589.

Gronau, R. (1977) "Leisure, home production and work—the theory of the allocation of time revisited", *Journal of Political Economy*, 85:1099–1124.

Grossbard-Shechtman, A. (1984) "A theory of allocation of time in markets for labour and marriage", *Economic Journal*, 94:863–882.

Hanoch, G. (1980) "A multivariate model of labor supply: methodology and estimation", in: J. P. Smith, ed., *Female labor supply*. Princeton, N.J.: Princeton University Press, 249–326.

Hausman, J. (1980) "The effects of wages, taxes and fixed costs on women's labor force participation", *Journal of Public Economics*, 14:161–194.

Hausman, J. (1981) "Labor supply", in: H. Aaron and J. Pechman, eds., *How taxes affect economic behavior*. Washington, D.C.: The Brookings Institution, 27–72.

Hausman, J. (1983) "Taxes and labor supply", Working Paper No. 1102, National Bureau of Economic Research, Cambridge, Massachusetts. (Forthcoming in: A. Auerbach and M. Feldstein, eds., *Handbook of public finance*. New York: North-Holland.)

Hausman, J. and P. Ruud (1984) "Family labor supply with taxes", *American Economic Review*, 74(2):242–248.

Heckman, J. (1971) "Three essays on the supply of labor and the demand for goods", unpublished Ph.D. dissertation, Department of Economics, Princeton University, Princeton, N.J.

Heckman, J. (1976a) "A life cycle model of earnings, learning and consumption", *Journal of Political Economy*, 84:S11–S44.

Heckman, J. (1976b) "The common structure of statistical models of truncation, sample selection, and limited dependent variables and a simple estimator for such models", *Annals of Economic and Social Measurement*, 5:475–492.

Heckman, J. (1978) "A partial survey of recent research on the labor supply of women", *American Economic Review*, 68 (Supplement):200–207.

Heckman, J. (1979) "Sample selection bias as a specification error", *Econometrica*, 47:153–162.

Heckman, J. (1980) "Sample selection bias as a specification error", in: J. Smith, ed., *Female labor supply*. Princeton, N.J.: Princeton University Press, 206–248.

Heckman, J., M. R. Killingsworth and T. MaCurdy (1981) "Empirical evidence on static labour supply models: a survey of recent developments", in: Z. Hornstein, J. Grice and A. Webb, eds., *The economics of the labour market*. London: Her Majesty's Stationery Office, 73–122.

Heckman, J. and T. MaCurdy (1980) "A life cycle model of female labour supply", *Review of Economic Studies*, 47:47–74.

Heckman, J. and T. MaCurdy (1982) "Corrigendum on a life cycle model of female labour supply", *Review of Economic Studies*, 49:659–660.

Heckman, J. and T. MaCurdy (1984) "Labor econometrics", in: Z. Griliches and M. Intriligator, eds., *Handbook of econometrics*. New York: North-Holland, vol. 3, forthcoming.

Heckman, J. and R. Willis (1977) "A beta-logistic model for the analysis of sequential labor force participation by married women", *Journal of Political Economy*, 85:27–58.

Heckman, J. and R. Willis (1979) "Reply to Mincer and Ofek [1979]", *Journal of Political Economy*, 87:203–211.

Hicks, J. R. (1946) *Value and capital*, 2nd ed. Oxford: Oxford University Press.

Hicks, J. R. (1965) *The theory of wages*, 2nd ed. London: Macmillan.

Hill, M. A. (1983) "Female labor force participation in developing and developed countries: consideration of the informal sector", *Review of Economics and Statistics*, 65:459–468.

Hill, M. A. (1984) "Female labor force participation in Japan: an aggregate model", *Journal of Human Resources*, 19:280–287.

Hill, M. A. (1985) "Female labor supply in Japan: implications of the informal sector for labor force participation and hours of work", unpublished manuscript, Department of Economics, Rutgers University, New Brunswick, N.J.

Horney, M. J. and M. B. McElroy (1978) "A Nash-bargained linear expenditure system", unpublished manuscript, Department of Economics, Duke University, Durham, N.C.

Hotz, J., F. Kydland and G. Sedlacek (1985) "Intertemporal preferences and labor supply", unpublished manuscript, Department of Economics, Carnegie-Mellon University, Pittsburgh, Pennsylvania.

Johnson, J. L. (1983) "Unemployment as a household labor supply decision", *Quarterly Review of Economics and Business*, 23(2):71–88.

Johnson, T. and J. Pencavel (1984) "Dynamic hours of work functions for husbands, wives and single females", *Econometrica*, 52:363–390.

Joshi, H. (1985) "Participation in paid work: multiple regression analysis of the women and employment survey", in: R. Blundell and I. Walker, eds., *Unemployment, job search and labour supply*. Cambridge: Cambridge University Press, forthcoming.

Joshi, H. and S. Owen (1984) "How long is a piece of elastic? The measurement of female activity rates in British censuses 1951–1981", Discussion Paper No. 31, Centre for Economic Policy Research, London.

Joshi, H. and S. Owen (1985) "Does elastic retract? The effect of recession on women's labour force participation", Discussion Paper No. 64, Centre for Economic Policy Research, London.

Kalachek, E. D., W. Mellow and F. Q. Raines (1978) "The male labor supply function reconsidered", *Industrial and Labor Relations Review*, 31:356–367.

Kalachek, E. D. and F. Q. Raines (1970) "Labor supply of lower-income workers", in *President's Commission on Income Maintenance Programs, Technical studies*. Washington, D.C.: U.S. Government Printing Office, 159–186.

Kapteyn, A., P. Kooreman and A. van Soest (1985) "Non-convex budget sets, institutional constraints and imposition of concavity in a flexible household labor supply model", unpublished working paper, Department of Econometrics, Tilburg University, Tilburg, The Netherlands.

Killingsworth, M. R. (1983) *Labor supply*. New York: Cambridge University Press.

Killingsworth, M. R. (1985) "A simple structural model of heterogeneous preferences and compensating wage differentials", pp. 303–17 in: R. Blundell and I. Walker, eds., *Unemployment, job search and labour supply*. Cambridge: Cambridge University Press, 303–317.

Kniesner, T. (1976) "An indirect test of complementarity in a family labor supply model", *Econometrica*, 44:651–659.

Kooreman, P. and A. Kapteyn (1984a) "Estimation of rationed and unrationed household labor supply functions using flexible functional forms", Research Memorandum 157, Department of Econometrics, Tilburg University, Tilburg, The Netherlands.

Kooreman, P. and A. Kapteyn (1984b) "A disaggregated analysis of the allocation of time within the household", Research Memorandum 153, Department of Econometrics, Tilburg University, Tilburg, The Netherlands.

Kooreman, P. and A. Kapteyn (1985) "Estimation of a game theoretic model of household labor supply", Research Memorandum 180, Department of Econometrics, Tilburg University, Tilburg, The Netherlands.

Kosters, M. (1966) "Income and substitution effects in a family labor supply model", Report No. P-3339, The Rand Corporation, Santa Monica, California.

Kosters, M. (1969) "Effects of an income tax on labor supply", in: A. C. Harberger and M. J. Bailey, eds., *The taxation of income from capital*. Washington, D.C.: The Brookings Institution, 301–324.

Layard, R., M. Barton and A. Zabalza (1980) "Married women's participation and hours", *Economica*, 47:51–72.

Layard, R. and J. Mincer, eds. (1985) "Trends in women's work, education, and family building", *Journal of Labor Economics*, 3(special edition):S1–S396.

Leibowitz, A. (1974) "Production within the household", *American Economic Review Proceedings and Papers*, 62(2):243–250.

Lewis, H. G. (1957) "Hours of work and hours of leisure", in *Industrial Relations Research Association, Proceedings of the ninth annual meeting*. Madison, Wisconsin: Industrial Relations Research Association, 195–206.

Leuthold, J. (1968) "An empirical study of formula income transfers and the work decision of the poor", *Journal of Human Resources*, 3:312–323.

Lillard, L. A. (1978) "Estimation of permanent and transitory response functions in panel data: a dynamic labor supply model", *Annales de l'INSEE*, 30:367–394.

Long, C. D. (1958) *The labor force under changing income and employment*. Princeton, N.J.: Princeton University Press.

Lundberg, S. (1985) "The added worker effect", *Journal of Labor Economics*, 3:11–37.

Manser, M. and M. Brown (1979) "Bargaining analyses of household decisions", in: C. B. Lloyd, E. Andrews and C. Gilroy, eds., *Women in the labor market*. New York: Columbia University Press, 3–26.

Manser, M. and M. Brown (1980) "Marriage and household decision-making: a bargaining analysis", *International Economic Review*, 21:31–44.

Marshall, A. (1920) *Principles of economics*. New York: Macmillan, 8th ed.

Martin, J. and C. Roberts (1984) *Women and employment: a lifetime perspective*. London: Her Majesty's Stationery Office.

McCabe, P. J. (1983) "Optimal leisure-effort choice with endogenously determined earnings", *Journal of Labor Economics*, 1:308–329.

McElroy, M. and M. Horney (1981) "Nash-bargained household decisions: toward a generalization of the theory of demand", *International Economic Review*, 22:333–349.

Mincer, J. (1962) "Labor force participation of married women: a study of labor supply", in *Aspects of labor economics*. Princeton, N.J.: National Bureau of Economic Research, Princeton University Press, 63–97.

Mincer, J. (1963) "Market prices, opportunity costs and income effects", in: C. F. Christ, M. Friedman, L. A. Goodman, Z. Griliches, A. C. Harberger, N. Liviatan, J. Mincer, Y. Mundlak, M. Nerlove, D. Patinkin, L. G. Telser and H. Theil, eds., *Measurement in economics*, Stanford, Calif.: Stanford University Press, 67–82.

Mincer, J. (1966) "Labor force participation and unemployment: a review of recent evidence", in: R. A. Gordon and M. S. Gordon, eds., *Prosperity and unemployment*. New York: Wiley, 73–112.

Mincer, J. and H. Ofek (1979) "The distribution of lifetime labor force participation of married women: comment", *Journal of Political Economy*, 87:197–201.

Mincer, J. and S. Polachek (1974) "Family investments in human capital: earnings of women", in: T. W. Schultz, ed., *Economics of the family: marriage, children and human capital*. New York: Columbia University Press, 397–429.

Moffitt, R. (1984a) "The estimation of a joint wage-hours labor supply model", *Journal of Labor Economics*, 2:550–566.

Moffitt, R. (1984b) "Profiles of fertility, labour supply and wages of married women: a complete life-cycle model", *Review of Economic Studies*, 51:263–278.

Moffitt, R. and K. C. Kehrer (1981) "The effect of tax and transfer programs on labor supply: the evidence from the income maintenance programs", in: R. G. Ehrenberg, ed., *Research in labor economics*. Greenwich, Conn.: JAI Press, vol. 4, 103–150.

Moffitt, R. and K. C. Kehrer (1983) "Correction", in: R. G. Ehrenberg, ed., *Research in labor economics*. Greenwich, Conn.: JAI Press, vol. 6, 452.

Mroz, T. A. (1985) "The sensitivity of an empirical model of married women's hours of work to

economic and statistical assumptions", unpublished manuscript, Department of Economics, University of Chicago, Chicago, Illinois.

Mueller, D. (1981) *Public choice*. New York: Cambridge University Press.

Nakamura, A. and M. Nakamura (1981) "A comparison of the labor force behavior of married women in the United States and Canada, with special attention to the impact of income taxes", *Econometrica*, 49:451–490.

Nakamura, A. and M. Nakamura (1985a) "Dynamic models of the labor force behavior of married women which can be estimated using limited amounts of past information", *Journal of Econometrics*, 27:273–298.

Nakamura, A. and M. Nakamura (1985b) *The second paycheck: a socioeconomic analysis of earnings*. New York: Academic Press.

Nakamura, A., M. Nakamura and D. Cullen (1979) "Job opportunities, the offered wage, and the labor supply of married women", *American Economic Review*, 69:787–805.

Olsen, R. (1977) "An econometric model of family labor supply", unpublished Ph.D. dissertation, Department of Economics, University of Chicago, Chicago, Illinois.

Owen, J. (1969) *The price of leisure*. Rotterdam: Rotterdam University Press.

Owen, J. (1971) "The demand for leisure", *Journal of Political Economy*, 79:56–76.

Owen, J. (1985) *Working lives: the American work force since 1920*. Lexington, Mass.: D. C. Heath.

Pigou, A. C. (1946) *The economics of welfare*, 4th ed. London: Macmillan.

Pollak, R. (1985) "A transactions cost approach to families and households", *Journal of Economic Literature*, 23:581–608.

Pollak, R. and M. Wachter (1974) "The relevance of the household production function and its implications for the allocation of time", *Journal of Political Economy*, 83:255–277.

Ransom, M. (1982) "Estimating family labor supply models under quantity constraints", Working Paper No. 150, Industrial Relations Section, Princeton University, Princeton, New Jersey.

Ransom, M. (1985a) "The labor supply of married men: a switching regressions model", Working Paper No. 191, Industrial Relations Section, Princeton University, Princeton, New Jersey.

Ransom, M. (1985b) "A comment on consumer demand systems with binding non-negativity constraints", Working Paper No. 192, Industrial Relations Section, Princeton University, Princeton, New Jersey.

Renaud, P. S. A. and J. J. Siegers (1984) "Income and substitution effects in family labour supply", *De Economist*, 132:350–366.

Robins, P. K. (1984) "The labor supply response of twenty-year families in the Denver income maintenance experiment", *Review of Economics and Statistics*, 66:491–495.

Robinson, C. and N. Tomes (1985) "More on the labour supply of Canadian women", *Canadian Journal of Economics*, 18:156–163.

Ruffell, R. J. (1981) "Endogeneity II: direct estimation of labour supply functions with piecewise linear budget constraints", in: C. Brown, ed., *Taxation and labour supply*. London: Allen & Unwin, 101–116.

Samuelson, P. A. (1947) *Foundations of economic analysis*. Cambridge, Mass.: Harvard University Press.

Samuelson, P. A. (1956) "Social indifference curves", *Quarterly Journal of Economics*, 70:1–22.

Samuelson, P. A. (1960) "The structure of a minimum equilibrium system", in: R. W. Pfouts, ed., *Essays in economics and econometrics in honor of Harold Hotelling*. Chapel Hill, N.C.: University of North Carolina Press, 1–33.

Schoenberg, E. and P. Douglas (1937) "Studies in the supply curve of labor: the relation between average earnings in American cities and the proportion seeking employment", *Journal of Political Economy*, 45:45–62.

Schultz, T. P. (1980) "Estimating labor supply functions for married women", in: J. P. Smith, ed., *Female labor supply*. Princeton, N.J.: Princeton University Press, 25–89.

Smith, J. B. and M. Stelcner (1985) "Labour supply of married women in Canada, 1980", Working Paper No. 1985-7, Department of Economics, Concordia University, Montreal, Quebec.

Smith, J. P. (1977a) "The convergence to racial equality in women's wages", unpublished paper, The Rand Corporation, Santa Monica, California.

Smith, J. P. (1977b) "Assets, savings and labor supply", *Economic Inquiry*, 15:551–573.

Smith, J. P. (1977c) "Family labor supply over the life cycle", *Explorations in Economic Research*, 4:205–276.

Smith, J. P. (1980) "Assets and labor supply", in: J. P. Smith, ed., *Female labor supply*. Princeton, N.J.: Princeton University Press.

Smith, J. P. and M. Ward (1984) "Women's wages and work in the twentieth century", Report R-3119-HICHD, The Rand Corporation, Santa Monica, California.

Smith, J. P. and M. Ward (1985) "Time-series growth in the female labor force", *Journal of Labor Economics*, 3(Supplement):S59–S90.

Smith, R. E., ed. (1979) *The subtle revolution*. Washington, D.C.: The Urban Institute.

Smith, R. (1979) "Compensating wage differentials and public policy: a review", *Industrial and Labor Relations Review*, 32:339–352.

Smith, S. (1983) "Estimating annual hours of labor force activity", *Monthly Labor Review*, 106(2):13–22.

Sorrentino, C. (1983) "International comparisons of labor force participation, 1960–81", *Monthly Labor Review*, 106(2):23–36.

Stelcner, M. and J. Breslaw (1985) "Income taxes and the labor supply of married women in Quebec", *Southern Economic Journal*, 51:1053–1072.

Stelcner, M. and J. B. Smith (1985) "Labour supply of married women in Canada: non-convex budget constraints and the CES utility function", Working Paper No. 1985-9, Department of Economics, Concordia University, Montreal, Quebec.

Stewart, M. and C. Greenhalgh (1984) "Work history patterns and the occupational attainment of women", *Economic Journal*, 94:493–519.

Takayama, A. (1985) *Mathematical economics*, 2nd ed. New York: Cambridge University Press.

Tinbergen, J. (1956) "On the theory of income distribution", *Weltwirtschaftliches Archiv*, 77:155–173.

Trussell, T. J. and J. M. Abowd (1980) "Teenage mothers, labour force participation and wage rates", *Canadian Studies in Population*, 7:33–48.

van der Veen, A. and G. H. M. Evers (1984) "A labour-supply function for females in the Netherlands", *De Economist*, 132:367–376.

Veblen, T. (1973) *The theory of the leisure class*. Boston: Houghton Mifflin Co.

Wales, T. and A. D. Woodland (1977) "Estimation of the allocation of time for work, leisure and housework", *Econometrica*, 45:115–32.

Wales, T. and A. D. Woodland (1980) "Sample selectivity and the estimation of labor supply functions", *International Economic Review*, 21:437–468.

Wales, T. and A. D. Woodland (1983) "Estimation of consumer demand systems with binding non-negativity constraints", *Journal of Econometrics*, 21:263–285.

Watts, H., D. Poirier and C. Mallar (1977) "Sample, variables and concepts used in the analysis", in: H. Watts and A. Rees, eds., *The New Jersey income-maintenance experiment: Labor-Supply Response*, New York: Academic Press, vol. 2, 33–56.

Yamada, T. and T. Yamada (1984) "Part-time employment of married women and fertility in urban Japan", Working Paper No. 1474, National Bureau of Economic Research, Cambridge, Massachusetts.

Yamada, T. and T. Yamada (1985) "Part-time work vs. full-time work of married women in Japan", Working Paper No. 1608, National Bureau of Economic Research, Cambridge, Massachusetts.

Yamada, T., T. Yamada and F. Chaloupka (1985) "A multinomial logistic approach to the labor force behavior of Japanese married women", Working Paper No. 1783, National Bureau of Economic Research, Cambridge, Massachusetts.

Yatchew, A. (1985) "Labor supply in the presence of taxes: an alternative specification", *Review of Economics and Statistics*, 67:27–33.

Zabalza, A. (1983) "The CES utility function, nonlinear budget constraints and labour supply: results on female participation and hours", *Economic Journal*, 93:312–330.

Zabalza, A. and J. Arrufat (1983) "Wage differentials between married men and women in Great Britain: the depreciation effect of non-participation", Discussion Paper No. 151, Centre for Labour Economics, London School of Economics, London.