ORIGINAL ARTICLE

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Economic Productivity by Age and Sex

2007 Estimates for the United States

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Background: Human capital estimates of labor productivity are often used to estimate the economic impact of diseases and injuries that cause incapacitation or death.

Objectives: Estimates of average hourly, annual, and lifetime economic productivity, both market and household, were calculated in 2007 US dollars for 5-year age groups for men, women, and both sexes in the United States.

Research Design: Data from the American Time Use Survey were used to estimate hours of paid work and household services and hourly and annual earnings and household productivity. Present values of discounted lifetime earnings were calculated for each age group using the 2004 US life tables and a discount rate of 3% per year and assuming future productivity growth of 1% per year.

Subjects: The estimates of hours and productivity were calculated using the time diaries of 72,922 persons included in the American Time Use Survey for the years 2003 to 2007.

Results: The present value of lifetime productivity is approximately $1.2 million in 2007 dollars for children under 5 years of age. For adults in their 20s and 30s, it is approximately $1.6 million and then it declines with increasing age. Productivity estimates are higher for males than for females, more for market productivity than for total productivity.

Conclusions: Changes in hours of paid employment and household services can affect economic productivity by age and sex. This is the first publication to include estimates of household services based on contemporary time use data for the US population.

Key Words: cost-of-illness, human capital, indirect cost, cost-benefit analysis, economics

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Cost-of-illness studies of the economic impact of disease or injury and economic evaluations of health-related policies or interventions frequently include estimates of economic productivity losses resulting from short-term disability, permanent disability, and premature mortality. Although there is a long history in economics and actuarial science of calculating the present value of lifetime earnings, Weisbrod[1] operationalized the human capital concept for use in public health. Under this approach, productivity is calculated as the present value of the sum of earnings and the imputed value of household production over the lifetime, adjusted for survival and discounting. In principle, one could put a monetary value on other uses of time, although in practice this is typically not done. Klarman[2] introduced the practice of adjusting for expected growth in future productivity. It has long been customary in the United States to project future earnings based on a cross-sectional age-earnings profile adjusted for an expected 1% annual increase in real employee compensation, which is consistent with the postwar US experience (eg, Hartunian et al, 1980).[3]

Cost-of-illness studies include both prevalence-based studies, which estimate the economic costs associated with prevalent cases of disease, and incidence-based studies, which estimate the present value of future economic costs associated with newly occurring cases. The latter approach is necessary to estimate the economic benefits of prevention interventions.[4] Incidence-based studies are particularly likely to include estimates of productivity losses. For example, the present value at birth of lifetime productivity has been used in numerous economic analyses to calculate the economic value of the prevention of child deaths.[5,6]

Following the cost-of-illness approach pioneered 4 decades ago by Rice,[7] a distinction is made between direct costs or expenditures and indirect costs, which represent lost economic productivity.[8] Two recent systematic reviews of the peer-reviewed cost-of-illness literature each concluded that approximately half of studies report just direct cost estimates and the other half report either just indirect or both direct and indirect costs.[9,10] In recent years, many economists have discontinued use of the term "indirect" cost and instead refer to productivity losses.[11]

Traditionally, cost-benefit analyses used the human capital approach to put a monetary value on lost life.[2] In recent decades, it has become standard in most regulatory applications in the United States to use willingness-to-pay estimates to value health endpoints, particularly mortality.[12]

Such estimates incorporate the intangible costs of pain and suffering, both to the affected individuals and to surviving family members and friends.[12] Most such estimates, particularly the value of a statistical life based on occupational mortality and compensating wage differentials, are several times higher than human capital estimates.[13]

Nonetheless, productivity estimates continue to be used in many cost-benefit analyses. In particular, it is common for federal agencies to use cost-of-illness methods to value morbidity costs for which willingness-to-pay estimates are lacking.[14] For example, the US Department of Agriculture currently includes estimates of loss of earnings due to disability from foodborne illnesses but values mortality using the value of a statistical life approach.[15] In addition, it is common for environmental health analysts to value the loss of cognitive ability due to environmental exposure to neurotoxins such as lead in terms of a projected loss in future earnings, although not household services.[16] Finally, economists at the Centers for Disease Control and Prevention continue to use the human capital approach to value both morbidity and mortality outcomes in cost-benefit analyses.[5,17]

Older cost-effectiveness analyses, particularly those that restricted health outcomes to loss of life-years, often included productivity costs. However, the US Panel on Cost-Effectiveness in Health and Medicine recommended that reference case cost-effectiveness analyses include only direct costs of care and exclude productivity costs.[11] The rationale offered was that quality-adjusted life-years, the recommended measure of health outcomes, could entail double counting with economic productivity.

Consequently, productivity estimates are primarily of relevance for cost-of-illness and cost-benefit analyses. Incidence-based cost-of-illness estimates can be used as inputs for a cost-benefit analysis, assuming the existence of an effective prevention strategy.[4] Cost-of-illness estimates are also commonly used to highlight the economic impact of a disorder or group of disorders and to advocate for research to develop interventions targeted to those disorders.[4] The validity of their use in this context is debated among health economists.[18,19] In particular, it has been argued that priority setting for research agendas should be guided by the expected improvements in health rather than the magnitude of the health problem.[18]

Previous US Estimates

Rice and Cooper[20] published present value estimates of annual gross earnings tabulated by age, sex, and race in which, following the lead of Weisbrod,[1] female earnings were adjusted for the imputed value of household services. These estimates of annual and lifetime economic productivity have been updated over the years to include household production by both males and females[21–24] and have been very widely used. When Hirth et al[13] looked for published human capital estimates from the United States, 4 of the 6 studies identified were by Rice and colleagues. The other 2 used a hybrid human capital and willingness-to-pay approach[25] or used wage rates rather than gross earnings.[3]

AQ:1

In a report with productivity estimates for the United States in 2000, Max et al[24] combined information on labor force participation from the National Health Interview Survey and mean annual earnings for full-time, full-year workers from the 2001 Current Population Survey March supplement. They assumed that everyone who reported work as their primary activity during the previous week was a full-time, full-year worker. They based their estimates of household services on time allocation studies conducted during 1965 to 1966 and 1975 to 1976.[26] They incorporated assumptions from Rice et al[22] that hours devoted to household activities fall off sharply after ages 65 to 69 to a level less than 10% of their peak value. Hours were valued via the replacement cost method, using wages for low-skilled workers based on a tabulation of 1987 Bureau of Labor Statistics data.

Grosse[27] published estimates of annual and lifetime productivity for the United States in 2000 using a modification of the Rice approach. The first edition of the same text[28] had included productivity tables calculated by Max and Rice. The Grosse estimates have become fairly widely used in recent years.[29] Grosse[27] used the March 2001 Current Population Survey tabulations of mean earnings during 2000 by age and sex and adjusted these by a factor of 1.224 to account for fringe benefits and payroll taxes based on data from the March 2001 Employer Costs for Employee Compensation survey. Grosse[27] used estimates of time spent in household services from a tabulation of the 1992 to 1994 National Human Activity Pattern Survey (NHAPS) prepared by Expectancy Data.[30] Estimates of wages for specific types of services from Expectancy Data included payroll taxes. Weekly hours of household activity recorded in the NHAPS data by adults over age 69 were almost as high as among younger adults. Also, the gap between men and women was much smaller than what had been observed in the 1960s and 1970s.

AQ:2

METHODS

We calculated 2007 dollar based estimates for 2 components of economic productivity, market and household productivity. We estimated hours of household and market labor time using the 2003 to 2007 editions of the American Time Use Survey (ATUS).[31] Unlike previous estimates, which divided annual earnings by assumed annual days and hours of work to calculate the value of a lost day, the present analysis builds up from hourly earnings and household production to derive estimates of first annual, then lifetime productivity.

Market Productivity

Hours Worked

The ATUS[31] collects single 24-hour time diaries recording time spent on over 450 activities from a sample of individuals representing the US noninstitutional population ages 15 and over. Specifically, the sample is a random subset of individuals included in the Current Population Survey, which collects information on earnings and labor force status. The ATUS is conducted by the US Census Bureau for the Bureau of Labor Statistics. Each time diary begins at 4 AM of the previous day and lasts until 4 AM of the survey day. Weekdays and weekend days are weighted to obtain average daily time spent at various activities throughout the year. Using the time diaries of 72,922 persons collected from the

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2003 to 2007 editions of the ATUS, we calculated the average time spent working at a job or performing work for an income-generating activity for all persons ages 15 and over in the US noninstitutional population. In the first data column of Table 1, we show the average daily hours working at a job for males and females in 5-year age increments from ages 15 to 19 through ages 75 to 79 and then for the open age group of 80 and over.

Earnings by Age and Sex

The ATUS updates each respondent's hours of work and earnings information from the Current Population Survey. We calculated average hourly earnings for wage and salary workers as usual weekly earnings divided by usual weekly hours worked. Annual earnings are the product of hourly earnings by the average number of hours of paid work in a day (that includes weekends and holidays) multiplied by 365. Earnings for each year during 2003 to 2006 were inflated to their 2007 dollar equivalence using the Employment Cost Index for the Wages and Salaries of all Civilian Workers.[32] Earnings for self-employed workers, which are reported in the Current Population Survey but not the ATUS, reflect returns to both labor and the capital invested in the business. To avoid overstating the labor productivity of self-employed workers, we assumed that self-employed persons have the same earning capacity as do wage and salary workers of the same age and sex.

Total Compensation

Earning capacity includes both cash wage earnings and employer provided fringe benefits. To obtain average fringe benefits for the civilian worker population, we used the June 2007 Employer Cost for Employee Compensation survey.[33] The employer cost of insurance, retirement, and legally required benefits are divided by cash wages, salaries, and supplemental pay earned per hour work to obtain an average benefit rate of 30.9% of cash earnings. Total compensation is calculated as earnings times 1.309.

Household Productivity

Hours of Household Productivity

Household productivity estimates for this study were based on a definition of household services derived from the tabulations of the 2003 to 2007 ATUS by Expectancy Data.[34] We defined household services as the sum of time spent at household production and time spent caring and helping household children and adults. Household production was defined to include activities such as inside housework, food cooking and clean-up, household management, shopping, obtaining services, and travel for household activity. Caring and helping household members includes direct child care and physically looking out for or helping household children and adults including providing them with transportation for their own personal needs.

Value of Household Productivity

The value of time spent at household productivity was determined using the replacement value method. Household activity is valued using the May 2007 mean hourly market wage of workers whose job is related to household activity (eg, we use wages for cooks, janitors, maids, landscaping workers, taxi drivers, child care workers, home care aides, etc). We found these wages in the Occupational Employment Statistics survey of hourly earnings by occupation in the United States.[35] The average wage applied to household productivity, $10.48, was calculated for occupations with mean hourly earnings ranging from $8.20 to $12.40 per hour. Benefits paid to part-time service occupation workers, including payroll taxes, equaled 18.9% of earnings in the June 2007 Employer Cost for Employee Compensation survey. The replacement cost value of household productivity is therefore $10.48 per hour plus 18.9% of legally required benefits, or $12.46 per hour. Although our estimates could be overstated to the extent that household workers are not necessarily paid legally mandated benefits, more likely the estimates are understated because they do not include the costs of recruiting or supervising household workers to fulfill specific tasks. Finally, the estimates are not equivalent to the opportunity cost of household activities in terms of potential foregone earnings, which varies depending on the characteristics of the individual performing the activities.

Population Adjustment

Our analysis of earnings and household productivity apply to the noninstitutional population of the United States. The latest available estimates of the total population (noninstitutional plus the group quarter population) from the US Census Bureau's American Community Survey for 2006[36] and military group quarters size from the 2000 Decennial Census[37] are used to adjust these estimates to the total population. The group quarters population includes persons in nursing homes and correctional institutions, students in dormitories, persons in emergency, and transitional shelters, etc.

For all persons in group quarters (except military in barracks), we assume that that population does not produce market earnings or household production. For the military in barracks, we assume that they have the same earning capacity of wage and salary workers for 8 daily hours of work, but that they do not produce household services. It could be argued that many prisoners or college students do engage in paid work or housekeeping activities and that therefore our estimates are understated. However, it could also be argued that such individuals do not generate net productivity and rather than their productivity should be subtracted from the costs of housing and caring for them to calculate net costs of care.

In Table 2, we show the sizes of the US noninstitutional and group quarters population used to adjust the Table 1 average daily value of the production of the US noninstitutional population. Total population market compensation is the size of the noninstitutional population times Table 1 daily market compensation value plus military population times 8 hours per day times Table 1 hourly market compensation value. The per person annual market compensation in Table 2 is the previous sum times 365 divided by the size of the population in each age-sex group. Likewise, the per person annual population household production in Table 2 is the size of the noninstitutional population times Table 1 daily house-

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TABLE 1. Daily Production of the US Noninstitutional Population

Gender	Average Daily h Working at a Job	Usual Hourly Compensation ($)	Daily Market Compensation ($)	h of Household Service	Household Service Daily Value (Hours × $12.46) ($)	Daily Production h	Daily Production Value ($)
Males							
15–19	1.47	11.80	17.40	1.07	13.33	2.54	30.73
20–24	4.06	17.45	70.94	1.55	19.25	5.61	90.19
25–29	5.37	23.74	127.43	2.03	25.27	7.40	152.69
30–34	5.41	29.48	159.52	2.52	31.34	7.93	190.86
35–39	5.42	32.50	176.12	2.66	33.12	8.08	209.24
40–44	5.34	33.79	180.41	2.59	32.30	7.93	212.71
45–49	5.29	33.99	179.67	2.57	32.05	7.86	211.71
50–54	5.24	33.81	177.15	2.30	28.71	7.54	205.86
55–59	4.34	33.26	144.25	2.53	31.54	6.87	175.80
60–64	3.17	34.58	109.69	2.66	33.13	5.83	142.82
65–69	1.57	27.87	43.67	2.87	35.73	4.43	79.39
70–74	1.00	26.97	27.04	2.96	36.84	3.96	63.89
75–79	0.49	31.23	15.41	2.84	35.42	3.34	50.83
80 and over	0.37	32.29	11.82	2.42	30.09	2.78	41.91
All	4.06	29.91	121.54	2.29	28.58	6.36	150.12
Females							
15–19	1.28	10.90	14.00	1.70	21.22	2.99	35.22
20–24	3.33	14.64	48.71	2.99	37.25	6.32	85.96
25–29	3.60	21.75	78.23	4.18	52.04	7.78	130.26
30–34	3.26	25.29	82.35	4.97	61.95	8.23	144.31
35–39	3.45	26.95	92.89	4.93	61.35	8.37	154.25
40–44	3.66	27.17	99.48	4.57	56.97	8.24	156.45
45–49	3.86	26.52	102.24	3.97	49.43	7.82	151.67
50–54	3.78	26.94	101.95	3.64	45.28	7.42	147.23
55–59	3.18	26.47	84.07	3.77	46.97	6.95	131.04
60–64	2.30	25.61	58.89	3.92	48.89	6.22	107.77
65–69	0.90	20.23	18.28	4.14	51.56	5.04	69.84
70–74	0.48	17.26	8.20	3.96	49.30	4.43	57.50
75–79	0.24	15.39	3.66	3.81	47.52	4.05	51.17
80 and over	0.10	19.88	2.07	3.30	41.13	3.41	43.19
All	2.74	24.32	66.61	3.85	47.96	6.59	114.57
All							
15–19	1.38	11.34	15.67	1.38	17.20	2.76	32.87
20–24	3.69	15.89	58.67	2.27	28.30	5.96	86.97
25–29	4.49	22.68	101.80	3.10	38.57	7.58	140.36
30–34	4.31	27.28	117.72	3.76	46.89	8.08	164.61
35–39	4.42	29.70	131.35	3.80	47.38	8.23	178.73
40–44	4.49	30.37	136.36	3.60	44.82	8.09	181.18
45–49	4.56	30.03	136.92	3.28	40.88	7.84	177.80
50–54	4.49	30.10	135.10	2.99	37.25	7.48	172.35
55–59	3.74	29.47	110.21	3.17	39.48	6.91	149.69
60–64	2.71	29.39	79.70	3.33	41.45	6.04	121.15
65–69	1.21	23.62	28.63	3.55	44.19	4.76	72.82
70–74	0.71	21.44	15.25	3.51	43.73	4.22	58.98
75–79	0.35	23.36	8.10	3.40	42.38	3.75	50.47
80 and over	0.20	25.30	5.01	2.98	37.14	3.18	42.15
All	3.38	26.94	91.04	3.10	38.60	6.48	129.64

Sources: Hours of production and market wage rate used to calculation compensation: American Time Use Survey (2003 to 2007). Available at: http://www.bls.gov/tus/.

Benefits to calculate compensation: US Department of Labor, Bureau of Labor Statistics. *Employer Costs for Employee Compensation.* June 2007 BLS News Release 07-1434, Tables 1 and 11. Available at: http://www.bls.gov/news.release/archives/ecec_09202007.pdf.

Household service hourly wages in May 2007: Buruea of Labor Statistics, Occupational Employment Statistics. Available at: http://www.bls.gov/oes/current/oes_nat.htm.

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TABLE 2. Daily Production of the US Total Population

Gender	US Noninstitutional Population	US Military Group Quarters Population	US Nonmilitary Group Quarters Population	Per Person Annual Market Compensation of US Population ($)	Per Person Annual Household Production Value of US Population ($)	Per Person Annual Production Value of US Population ($)
Males						
15–19	11,178,644	84,930	596,820	6233	4586	10,819
20–24	9,916,897	155,560	1,311,664	23,252	6121	29,373
25–29	9,742,499	36,703	288,349	45,262	8924	54,186
30–34	9,781,758	15,177	309,876	56,481	11,070	67,551
35–39	10,266,252	9710	285,296	62,576	11,752	74,327
40–44	10,980,328	3573	291,432	64,157	11,481	75,637
45–49	10,869,679	1213	228,236	64,234	11,455	75,689
50–54	9,618,780	343	229,106	63,158	10,233	73,392
55–59	8,166,240	70	133,775	51,805	11,328	63,133
60–64	6,187,718	10	133,835	39,189	11,838	51,026
65–69	4,561,338	5	47,945	15,773	12,904	28,678
70–74	3,754,599	5	47,945	9747	13,278	23,025
75–79	3,471,698	0	97,070	5473	12,576	18,049
80 and over	2,936,225	0	354,364	3849	9800	13,649
All	111,432,655	307,300	4,405,639	42,791	10,010	52,801
Females						
15–19	10,754,387	15,350	322,628	4999	7510	12,509
20–24	10,011,191	24,110	674,868	16,715	12,710	29,425
25–29	9,628,736	5057	149,797	28,134	18,693	46,827
30–34	10,082,407	1930	152,923	29,618	22,270	51,889
35–39	10,497,826	913	139,626	33,464	22,098	55,562
40–44	11,345,832	327	140,212	35,870	20,539	56,409
45–49	11,234,717	137	109,172	36,958	17,869	54,826
50–54	10,221,375	47	109,262	36,819	16,351	53,170
55–59	8,651,357	20	63,743	30,463	17,017	47,480
60–64	6,948,180	0	63,763	21,298	17,682	38,980
65–69	5,276,799	0	117,395	6528	18,408	24,936
70–74	4,623,782	0	117,395	2919	17,550	20,469
75–79	4,709,730	0	237,654	1271	16,510	17,781
80 and over	5,191,327	0	867,581	646	12,862	13,507
All	119,177,646	47,890	3,296,750	23,676	17,029	40,704
All						
15–19	21,933,030	100,280	919,448	5609	5999	11,608
20–24	19,928,089	179,670	1,986,532	19,692	9317	29,009
25–29	19,371,235	41,760	438,146	36,397	13,737	50,134
30–34	19,864,165	17,107	462,799	42,021	16,712	58,733
35–39	20,764,079	10,623	424,921	47,002	16,938	63,940
40–44	22,326,161	3900	431,645	48,835	16,046	64,881
45–49	22,104,396	1350	337,407	49,227	14,694	63,921
50–54	19,840,154	390	338,367	48,486	13,368	61,854
55–59	16,817,597	90	197,518	39,760	14,242	54,002
60–64	13,135,898	10	197,598	28,660	14,905	43,565
65–69	9,838,137	5	165,341	10,276	15,864	26,139
70–74	8,378,381	5	165,341	5459	15,652	21,111
75–79	8,181,428	0	334,724	2839	14,859	17,698
80 and over	8,127,551	0	1,221,945	1590	11,785	13,375
All	230,610,300	355,190	7,702,388	32,225	13,613	45,838

Sources: US Non-institutional population from the American Time Use Survey (2003 to 2007). Available at: http://www.bls.gov/tus/.

All Group Quarters in 2006: American Factfinder Table S2601B: Characteristics of the Group Quarters Population by Group Quarters Type. Available at: http://factfinder.census.gov/.

Military Group Quarters in 2000: US Census Bureau Internet site. Available at: http://www.census.gov/population/www/cen2000/briefs/phc-t26/index.html.

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hold production value times 365 divided by the number of people in each age-sex group.

Expected Lifetime Present Values

The expected lifetime average present value of productivity (earnings and household services) is calculated for each 5-year age group. Estimates for single year ages are available from the authors. We created synthetic population cohorts on the basis of the assumption that each cohort will experience average earnings in the future equivalent to those of previous cohorts in the same age groups during our sample period. The only adjustment is for expected productivity growth. It has long been customary in the US cost-of-illness literature to project future earnings based on a cross-sectional age-earnings profile adjusted for an expected 1% annual increase in labor productivity.[3] This is also consistent with the average annual compound growth in the real compensation paid per hour in the nonfarm business sector over the last 35 years (Economic Report of the President, 2008, Table B-49).[38]

Earnings in future years are adjusted to present values after taking into account the probability of survival on the basis of age-to-age survival probabilities obtained from the 2004 US Life Tables.[39] Table 3 presents present value estimates of remaining lifetime earnings at various age intervals. These sums of discounted future earnings in real (inflation-adjusted) 2007 dollars are presented for 0%, 3%, and 5% discount rates, consistent with the recommendation of the Panel on Cost-Effectiveness in Health and Medicine.[40] The Panel recommended that a 3% discount rate be used for reference case analyses. That approximates the inflation-adjusted yield on US government securities, which over a 40-year period averaged 2.8%.[41] Results for discount rates up to 10% are in an appendix available with the authors. The present value estimates incorporate the assumption that productivity will grow in future decades by an average of 1% per year. Alternatively, the estimates we present in the appendix for a discount rate of 4% are approximately equivalent to a 3% discount rate with no change in future productivity.

RESULTS

Average Hours of Work and Value of Daily Productivity

Although women average fewer daily hours of market work (2.74) than men (4.06), their average hours of home-based production (3.85) exceed those of men (2.29), resulting in slightly higher total hours of work per day. Women devote 68% more daily hours of household services than men with the largest differential occurring during usual child raising years of ages 25 to 44. In contrast, women have average market compensation per hour worked ($24.32) only 81.3% as high as men ($29.91). Moreover, the average productivity value of hours of household services ($12.46) calculated using the replacement cost method is substantially lower, contributing to lower average daily productivity values for women ($114.57) than for men ($150.12). Analysts can also use pooled daily productivity value estimates for men and women ($129.64), which avoids placing a lower value on the time of women.

Figure 1 shows that total daily hours of paid work and household work by age are broadly similar for men and women, although the curve for women mostly lies above that for men. Both curves show an inverted U-shaped association with age. Average daily hours of work for both men and women peak at around 8 hours per day for adults 30 to 49 years of age. Average hours worked at jobs are fairly stable after school years are completed and begin to decline at age group 55 to 59. Hourly compensation fits the classic concave shape except for a late surge in hourly compensation associated with a decrease in average hours of daily work and hence lower daily compensation.

Annual Productivity

The average values of annual compensation, household productivity, and total productivity by age and sex are reported in Table 2. For all males aged 15 and above, these are $42,791, $10,010, and $52,801, respectively. For all females aged 15 and above, the average values of annual compensation, household productivity, and total productivity by age and sex are $23,676, $17,029, and $40,704, respectively. The male–female differences are largest in the childbearing years. Thus, for 30- to 34 year-olds, average market compensation is $56,481 for men and $29,618 for women, and average household productivity is $11,070 for men and $22,270 for women.

Lifetime Total Productivity

The present values of total production and market production for individuals over their remaining expected lifetimes are presented in Table 3 for 0%, 3%, and 5% discount rates. At a 3% discount rate, the present value of productivity for a male child aged 0 to 4 years is 20.6% greater than that of a female child ($1,311,631 vs. $1,087,261). The present value of a child of indeterminate gender is $1,180,796. The inclusion of nonmarket productivity reduces the gender differential, because market work represents 80% of lifetime total productivity for a male child and only 57% of lifetime productivity for a female child. Because infant and child mortality is uncommon, the present value of earnings at birth (exact age 0) is practically indistinguishable from the value for the 0 to 4 age group.

The present value of lifetime productivity for both sexes together rises with age to a peak in the 20s, at approximately $1.6 million using a 3% discount rate. After age 30, productivity decreases steadily with advancing age. Thus, for example, the expected remaining lifetime economic productivity among 30- to 34 year-olds is $1,521,239 overall, or $1,738,369 among men and $1,361,188 among women. Productivity decreases more slowly with increasing age for women than for men. Indeed, beyond age 65, the present value of productivity is higher for women because of higher survival probabilities and because most productivity is accounted for by household services. Thus, expected productivity among 70- to 74-year-olds, calculated with a 3% discount rate, is $191,289 for men and $206,591 for women. Expected market productivity in the same age group is $64,308 and $16,938, respectively.

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TABLE 3. Present Value of Lifetime Production and Market Production of the US Total Population, by Discount Rate, Gender, and Age (2007 Dollars)

	Total Production			Market Production		
Gender	**0%**	**3%**	**5%**	**0%**	**3%**	**5%**
Males						
0–4	4,693,378	1,311,631	628,941	3,642,720	1,055,542	509,777
5–9	4,477,640	1,450,507	765,688	3,475,277	1,167,304	620,615
10–14	4,263,437	1,601,092	930,483	3,309,026	1,288,488	754,187
15–19	4,044,557	1,748,121	1,110,093	3,143,437	1,411,865	905,053
20–24	3,780,128	1,844,798	1,258,288	2,943,468	1,498,868	1,035,988
25–29	3,427,916	1,844,830	1,327,228	2,662,002	1,498,314	1,094,516
30–34	2,990,567	1,738,369	1,300,327	2,305,038	1,404,556	1,068,787
35–39	2,521,845	1,565,688	1,210,037	1,920,278	1,253,824	988,265
40–44	2,057,228	1,354,530	1,078,213	1,535,803	1,067,628	869,329
45–49	1,616,414	1,122,073	918,016	1,168,503	860,435	722,714
50–54	1,206,118	874,833	732,563	823,247	636,629	549,561
55–59	843,765	632,108	538,397	519,056	416,060	366,678
60–64	551,914	421,378	362,170	284,083	231,736	206,489
65–69	352,992	272,429	234,750	139,257	112,185	99,095
70–74	240,568	191,289	167,358	79,092	64,308	57,035
75–79	161,490	131,923	117,009	46,641	35,286	31,434
80 and over	111,999	94,191	84,811	19,654	17,213	15,878
Females						
0–4	3,951,799	1,087,261	525,518	2,104,312	622,653	304,664
5–9	3,768,255	1,201,797	639,475	2,006,576	688,245	370,729
10–14	3,587,568	1,326,408	777,016	1,910,361	759,607	450,467
15–19	3,392,917	1,439,351	918,713	1,810,004	828,706	537,306
20–24	3,140,416	1,491,416	1,015,066	1,678,185	866,123	602,417
25–29	2,816,466	1,460,296	1,039,955	1,496,005	847,313	618,969
30–34	2,447,841	1,361,188	1,002,209	1,286,575	787,753	598,261
35–39	2,076,515	1,229,570	932,905	1,076,076	710,210	560,805
40–44	1,713,660	1,073,246	836,630	861,132	608,829	498,625
45–49	1,372,246	903,964	722,490	648,683	488,452	414,083
50–54	1,057,483	727,693	594,551	443,947	353,119	308,794
55–59	775,575	551,675	458,088	261,424	216,941	194,501
60–64	542,695	394,674	330,738	123,083	104,482	95,083
65–69	375,466	278,664	235,155	45,409	37,681	33,861
70–74	268,487	206,591	177,479	20,589	16,938	15,143
75–79	187,882	149,780	131,025	10,221	7463	6616
80 and over	130,803	107,955	96,140	3781	3265	2988
All						
0–4	4,250,131	1,180,796	568,817	2,797,829	820,892	399,300
5–9	4,053,773	1,305,510	692,331	2,668,568	907,594	486,006
10–14	3,859,627	1,440,960	841,290	2,540,763	1,001,759	590,572
15–19	3,655,929	1,568,602	999,322	2,410,700	1,095,522	706,799
20–24	3,400,833	1,641,026	1,119,137	2,247,367	1,155,188	801,954
25–29	3,066,764	1,624,222	1,164,022	2,018,593	1,143,413	836,799
30–34	2,668,817	1,521,239	1,130,428	1,740,024	1,066,036	811,878
35–39	2,255,431	1,370,828	1,051,137	1,449,007	953,402	753,219
40–44	1,848,231	1,189,228	937,939	1,155,745	811,433	663,233
45–49	1,463,947	991,366	802,484	872,584	650,305	549,054
50–54	1,108,499	783,529	648,498	604,449	474,216	412,136
55–59	793,170	578,492	486,469	367,664	299,707	266,376
60–64	537,375	399,419	338,632	187,398	155,629	140,015
65–69	359,674	271,286	230,954	81,539	66,496	59,168
70–74	252,923	197,093	170,533	42,140	34,404	30,607
75–79	175,067	140,804	123,803	22,951	16,960	15,066
80 and over	122,272	101,525	90,738	8921	7739	7100

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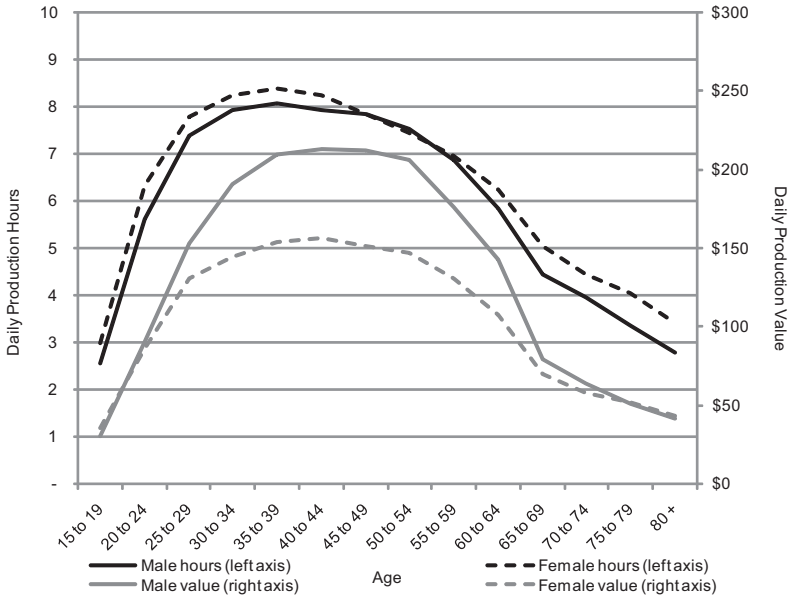

FIGURE 1. Average daily production hours and value of productivity of the US noninstitutional population, by sex and age, 2003 to 2007.

DISCUSSION

To our knowledge, this is the first peer-reviewed publication to present methodologically consistent, empirically based estimates of both earnings and household services by age and sex for the United States population. In particular, this is the first publication to include estimates of household services based on contemporary time use data for the US noninstitutional population. The estimates of earnings include the value of noncash fringe benefits and payroll taxes paid by employers and represent total employee compensation together with reported self-employment earnings.

Changes over time in economic activities, including hours spent in paid employment and in household production and caregiving services, can lead to important variation in economic productivity by age and sex. This can be true even over relatively short periods of time. For example, current dollar earnings grew much more slowly between 2000 and 2005 for younger workers than for older workers, by 0% to 6% for individuals between ages 18 and 34, compared with increases in annual earnings of 43% to 62% among individuals over age 65. The latter increase was associated with large increases in labor force participation and employment among older adults in recent years. Relatively little change in hours spent in directly productive household activities was observed between the 1992 to 1994 NHAPS and the 2003 to 2007 ATUS. However, substantially more hours were recorded by both men and women in caring and helping other household members in the 2003 to 2007 survey than in the 1992 to 1994 survey; approximately twice as much time in the 25 to 44 age groups.

Because of the rapid change in the age-earnings profile observed in recent years, productivity estimates based on year 2000 earnings data understate the productivity of older adults. This understatement is accentuated by the assumption by Max et al that older adults spend very little time in household production.[24] Consequently, the lifetime productivity estimate for women 75 to 79 years of age is $149,780 in 2007 dollars in the present analysis (Table 3), compared with $11,089 in 2000 dollars estimated by Max et al[24] or $86,828 in 2000 dollars estimated by Grosse[27] for 75-year-old women. This is an indication of why the most up-to-date information should be used to calculate estimates of economic productivity for analyses of productivity losses, even though it is unlikely that current patterns will continue indefinitely.

The methods used in the present analysis differ incrementally from the methods that have been used since the 1960s to generate estimates of lifetime economic productivity by age and sex. The primary change, besides the use of recent data on both market and household productivity, is the use of actual data on hours of work rather than annual earnings in combination with assumptions about labor force participation and hours of work.

Other modifications could be made to the methods used in the present analysis. For example, one might assign economic values to other activities, such as volunteer work, personal care, and leisure. There is no theoretical reason not to do so.[42] Indeed, one could argue, as has Becker, that one should incorporate not just the quantity of time spent in activities such as raising children, but their quality in terms of the value of human capital that is generated.[42] The pragmatic question, though, is whether decision makers would find such estimates to be useful.

Finally, the human capital approach is subject to criticism from "friction cost" advocates, particularly in the Netherlands, who believe that human capital estimates overstate the economic impact of death or disability.[43] The friction cost approach attributes productivity costs to disability or death occur only during the period it takes to recruit and train a replacement worker. Not surprisingly, human capital estimates of productivity losses are much higher than friction cost estimates.[44] The friction cost approach is appropriate to

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calculate productivity losses from the employer's perspective. It is valid to estimate productivity losses from the societal perspective only if there is a pool of surplus skilled labor, an assumption that is generally regarded as unrealistic.[45,46] Consequently, the human capital approach remains the dominant approach used in cost-of-illness studies conducted from the societal perspective.

In summary, human capital estimates of economic productivity continue to be widely used in estimating the economic costs of illnesses. The economic impact of disease is 1 factor that influences the potential economic benefit of research to develop interventions to prevent or treat disease. Accurate estimates of the indirect or productivity cost of disease or injury should be based on up-to-date estimates of the expected economic productivity of unaffected individuals. This analysis presents the first set of estimates for the US population that use a single source of data on hours of paid and household work to generate consistent estimates of both market and household productivity for US adults by age and sex.

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