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Sleep and the Allocation of Time

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Using aggregated data for 12 countries, a cross section of microeconomic data, and a panel of households, we demonstrate that increases in time in the labor market reduce sleep. Our theory of the demand for sleep differs from standard models of time use by assuming that sleep affects wages by affecting labor market productivity. Estimates of a system of demand equations demonstrate that higher wage rates reduce sleep time among men but increase their waking nonmarket time by an equal amount. Among women the wage effect on sleep is negative but very small.

The study of sleep is wonder. [BURGESS 1982, p. 95]

I. Introduction

Sleeping occupies our scarce time more than any other single activity. Economists have devoted immense effort to studying how consumers allocate time but have almost entirely ignored the empirical study of choices about time spent sleeping.[1] For example, Kooreman and Kap-

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[1] Some humorous notes (e.g., Hoffman 1977) did examine sleep from one economic perspective without developing or testing any predictions. Mullahy (1989) examines alternative econometric techniques using data from a telephone survey of respondents' previous night's sleep.

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teyn (1987) estimate a demand system for seven categories of leisure time use. Sleep is mentioned only once in this study, when it is noted that time spent sleeping is grouped with various waking activities in a "personal *needs* and care" (italics ours) category. Stafford and Duncan (1980) note a negative correlation between wages and time spent sleeping among men but dismiss it as a reflection of unmeasured interpersonal differences. We have essentially banished roughly one-third of humankind's available allotment of time from our analysis of scarcity.

The failure to consider sleep is widespread in other social sciences. A monumental compilation of studies of time use (Szalai 1972) reports briefly on time spent sleeping but devotes none of its analytical effort to this use of time. A recent comprehensive study of the United States (Juster and Stafford 1985) examined a variety of quantitatively less important uses of time but never considered sleep.

Only a very naive view of what determines how long a person sleeps can justify neglecting sleep in an economic model of time allocation. One could assume that sleep time is fixed for reasons unrelated to any of the variables in the economic model. For example, one could assume that the need for sleep is biologically determined. This would leave each person with an endowment of waking time to divide between work and various consumption activities. Even if endowments differed, aggregation across a population would generate a total endowment of waking time that was independent of economic shocks. Many studies of labor supply implicitly assume that the representative consumer has a fixed amount of time to allocate between work and waking leisure. This assumption is explicit in Michael (1973, p. 325) and Heckman and MaCurdy (1980, p. 59).

It seems more plausible to assume that the amount of time at an individual's disposal is variable because time spent sleeping changes from week to week and year to year. More important, some variation in time spent sleeping may result from conscious choice in response to changing economic incentives. These may operate directly, as the price of time and the utility of sleep vary, or indirectly, as other factors that affect the demand for waking leisure change. Some of the variation is beyond the individual's control, but some may respond to variations in labor-leisure choices and in the value of time. If so—if decisions about sleep are not separable from decisions about labor supply—the vast literature on labor supply that ignores sleep contains a difficulty that could have important consequences for understanding the allocation of time between the home and the market.

In this study we use several sets of data to explore whether variations in time spent sleeping represent an important part of people's shifting patterns of time allocation. A more specific question is whether sleep time is under the individual's control and thus is related to the economic variables that affect other decisions about time allocation. In essence, we examine whether an individual's weekly endowment of waking hours is endogenous, a task analogous to the study of the endogeneity of length of life through suicide in Hamermesh and Soss (1974). Section II presents evidence on the distribution and socioeconomic correlates of sleep time and establishes the existence of a relationship between sleep time and market work. In Section III we construct a simple model of time allocation that includes sleep as a choice variable, and in Section IV we present estimates of the demand equation for sleep implied by this model. Section V draws conclusions about the economic implications of our findings.

II. What Do We Know about Sleep, and Is Sleep Economically Important?

The most striking fact that biopsychologists have demonstrated about sleep is its diversity. Kleitman (1963) summarizes evidence on the very wide range of sleep duration among adults. Authenticated examples of nonpathological short sleepers exist (Meddis 1977, chap. 3). "There is no more a 'normal' duration of sleep, for either children or adults, than there is a normal heart rate, or height, or weight" (Kleitman 1963, p. 120). Sleep is clearly a major expenditure of time that exhibits substantial variation within every population that has been studied.

There is remarkably little evidence on the determinants of individual differences in sleep duration. There is some evidence that women sleep more than men (cited in Kleitman [1963]) and still weaker indications that sleep duration declines with age among adults (Morgan 1987). Beyond this and substantial unexplained individual variation, previous studies offer few guidelines about how to begin an empirical examination of sleep duration. One basic indicator of its importance as an economic variable might, however, be its relationship to time supplied to the labor market. As a by-product of examining this relationship, we provide the first comprehensive set of demographic correlates of sleep duration.

Evidence from International Surveys

One source of data on the sleep-work relationship is Szalai (1972, p. 618), who reports average sleep duration from time diaries collected at 15 different sites or sets of sites in 12 countries in the mid-1960s.[2]

[2] Diaries came from sites in Belgium, Bulgaria, Czechoslovakia, France, two from the Federal Republic of Germany, the German Democratic Republic, Hungary, Peru, Poland, two from the United States, the Soviet Union, and two from Yugoslavia.

TABLE 1

SLEEP (Minutes per Day) AND EMPLOYMENT STATUS, 15 STUDIES

	Means and Standard Deviations (1)	Parameter Estimates* (2)
Sleep	503	
	(47)	
Minutes worked	511	−.109
(by workers, on weekdays)	(21)	(.01)
Children	.35	−11.18
	(.48)	(4.15)
Male	.35	17.84
	(.48)	(2.66)
Married	.71	−8.52
	(.46)	(5.83)
Workday	.53	−30.28
	(.50)	(5.37)
$\bar{R}^2$		.70

* Based on data in Szalai (1972). The means and standard deviations are unweighted. The data cover 249 cells. The estimates are from regressions that use the numbers of persons in each cell as weights. Standard errors of the regression parameters are in parentheses here and in tables 3–6.

Average sleep duration is reported by employment and marital status, presence of children, and sex and whether the diary is kept for a weekday or a weekend. Underlying each usable cell are time diaries of at least 10 people.

Column 1 of table 1 presents the means of the variables included in a regression of minutes of sleep per day on control variables and on daily minutes of work in the market.[3] The means are unweighted; the regression coefficients reported in column 2 are based on weights that are inversely proportional to the square root of the number of people in each cell. Average sleep duration is nearly 8½ hours per day, somewhat above the mean durations reported in clinical studies. While this discrepancy is not easily explicable, there is no reason to assume that whatever produced it biases the estimated effect of work time on sleep duration.

Webb (1985) examined differences in mean sleep time within several pairs of demographic categories in these data and showed that people sleep less on workdays and that women sleep less than men on weekends. The regression estimates presented here are mostly consistent with these comparisons and with casual observations (though there is no previous multivariate evidence on sex differences in sleep behavior). Thus the presence of children reduces sleep duration, and

[3] Minutes of work per day are an average for all workers on workdays in the particular country study, not the average for each sex–marital status cell. These latter data were not available. The results were qualitatively the same when a dummy variable measuring employment status, which contains less information, was used instead.

people sleep less on workdays than on weekends. The only inconsistency with the clinical results is the significantly longer sleep duration among men. Since we have controlled for time spent working and the presence of children, this difference may reflect differing allocations of time in household production.

With other factors held constant, each additional hour of work reduces time spent sleeping by about 7 minutes. Alternatively, employed people sleep roughly 1 hour less per day on workdays than those who do not work in the market. At the very least, this aggregate evidence suggests that changes in work-leisure choices are related to changes in the amount of time individuals have available for sleep.

Evidence from the 1975–76 Time Use Study

The 1975–76 Time Use Study obtained data from four days of time diaries kept by 1,519 households. The days were at 3-month intervals, with two being weekdays, one a Saturday, and the fourth a Sunday. The data on time use are combined into "synthetic weeks," which we use in estimating the relation between sleep duration and hours of work. Of the respondents, 421 were excluded because they were above age 65 or below age 23, or because they did not have complete information on main sleep time in each of the interview waves. Others were disqualified if one of the control variables of interest was missing or if there were severe inconsistencies in the data.[4] This left a usable sample of 706 individuals, of whom 400 were men.

The 86 categories of time use in the 1975–76 diaries included night (or main) sleep, naps and resting, and miscellaneous personal activities. This last category does not include washing or dressing, but presumably includes time spent in sexual activities and affection. Since there is some scope for people to include sleep in any one of these categories, we analyze increasingly broad definitions of sleep time that add the last two categories successively to main sleep time. We measure work time as minutes spent in normal work (excluding on-the-job leisure) plus work at a second job.[5]

Table 2 shows descriptive statistics for the three definitions of sleep time and for minutes of market work in the sample and two subsamples. The mean weekly sleep durations imply an average daily main

[4] Thirty-three individuals were excluded who reported earnings in 1974 that exceeded their reported family income.

[5] In these data we define market work as normal work time on the main and the secondary jobs. Leisure time at work and travel to work are excluded. Hamermesh (1990) shows that on-the-job leisure is less than 10 percent of total time spent at the job and that its effects on wages are very small. This suggests that it makes sense to exclude it from time spent working and to include it instead in waking nonmarket time.

TABLE 2

SLEEP AND WORK TIME (Minutes per Week), 1975–76 TIME USE STUDY (Means and Standard Deviations)

	Sleep	Sleep and Naps	Sleep, Naps, and Personal Activities	Work
All respondents	3,266	3,383	3,438	2,122
	(444)	(499)	(520)	(947)
Men	3,252	3,360	3,409	2,435
	(435)	(492)	(505)	(848)
Women	3,285	3,413	3,476	1,715
	(456)	(507)	(539)	(916)

sleep of around 7¾ hours, more consistent with clinical reports than the mean in table 1 was. Adding rest and naps raises the daily average to slightly over 8 hours, while adding miscellaneous personal activities increases the total to nearly 8¼ hours. The standard deviation of sleep time is large; 12 percent of the sample sleep more than 9 hours per night, while 10 percent sleep less than 6½ hours per night on average.

For the average respondent, sleep clearly occupies a larger fraction of the total time endowment than market work. What is more striking is that this is true for a huge majority of the people in the sample: Only 67 of the 400 men report working more than their main sleep time, and only 20 of the 306 women do so.[6] That sleep is the largest single use of time by most people makes it a worthwhile subject for economic analysis.

Consider some of the estimated effects of the variables used as controls in the regressions. To save space, these are presented in table 3 only for the regressions describing time spent sleeping and napping (resting). The dummy variables listed in the table are self-explanatory. The results on the effects of age are mixed. The evidence suggests an inverse U-shaped sleep-age profile among men (with a peak at age 46) but a U-shaped sleep-age profile among women (with a minimum at age 36). For both men and women, including only a linear term in age yields insignificant positive effects. This runs counter to the sparse clinical evidence and may perhaps be due to our multivariate analysis that controls for time spent in the labor market. More interesting, increased educational attainment reduces sleep duration. It is difficult to imagine that greater schooling

[6] Only 58 of the men worked more than their combined time sleeping and resting, and only 55 worked more than their total sleep, rest, and miscellaneous personal time. The comparable figures among the 306 women are 17 and 17.

TABLE 3

Parameter Estimates, Sleep and Naps Equations, 1975–76 Time Use Study

	All Respondents	Men	Women
Work time	−.199	−.219	−.169
	(.02)	(.03)	(.03)
Married	16.04	−43.15	92.50
	(57.27)	(82.71)	(82.20)
Years married	−2.59	2.43	−7.62
	(2.31)	(3.13)	(3.49)
Age	1.86	24.52	−24.81
	(12.80)	(16.20)	(21.17)
Age squared	.02	−.26	.35
	(.15)	(.19)	(.25)
Years of schooling	−14.30	−18.28	−9.09
	(6.71)	(8.55)	(10.83)
Male	99.42	...	...
	(39.07)		
Excellent or	−94.16	−123.79	−59.66
good health	(59.16)	(80.75)	(89.05)
Children < 3	−35.42	39.03	−153.00
years old	(56.44)	(67.72)	(102.60)
Protestant	86.15	90.87	93.97
	(37.45)	(47.99)	(60.04)
Black	−69.17	−110.65	−43.95
	(80.62)	(114.41)	(115.63)
$\bar{R}^2$	.141	.176	.108

reduces the taste for sleep; rather, we interpret this as operating through wages and thus as reflecting a price effect[7] (see Sec. IV). Finally, given their market work time, Protestants sleep more than adherents of other faiths (in this sample, mostly Roman Catholics).

As in the estimates in table 1, men sleep more than women. The difference in mean sleep time (see table 2) is more than accounted for by differences by sex in characteristics, particularly employment status and work hours. An otherwise identical woman sleeps between 3 and 5 percent less than her male counterpart, depending on the definition of sleep that is used, a difference of around 20 minutes per night. (This is remarkably close to the coefficient on the male dummy variable in table 1.) There is some evidence that women who are in the labor market work more hours (in the home and the market) than men (Cain 1984). Our results show that part of the cushion for this sex difference in hours worked is provided by reductions in hours of sleep. It is not clear whether this represents discrimination due to male dominance in household decision making or optimal responses

[7] Mullahy's (1989) data do not measure wages, but yield negative correlations of sleep with age, education, and total income. All these correlations could be due to a negative wage effect on sleep.

TABLE 4

PARAMETER ESTIMATES, OTHER SLEEP MEASURES AND WORK TIME, 1975–76

	Dependent Variable	
	Sleep	Sleep, Naps, and Personal Activities
All respondents	−.164	−.214
	(.018)	(.021)
$\bar{R}^2$	.116	.147
Men	−.184	−.239
	(.025)	(.028)
$\bar{R}^2$	.146	.190
Women	−.134	−.179
	(.028)	(.033)
$\bar{R}^2$	.082	.101

NOTE.—Includes all the variables listed in table 3.

to the differing capacities of men and women to reduce sleep without reducing household and market productivity. Also noteworthy are the various effects on parents' sleep time of having young children in the household.[8] Fathers' sleep duration is essentially unaffected, but young children substantially reduce mothers' sleep time.

Estimates of the relationship between sleep time and work time are presented in the first row of table 3 and in table 4. Each hour of additional work reduces sleep by roughly 10 minutes. The effects on total sleep and nap time are slightly greater than those on sleep alone, and those on all possibly sleep-related time are greater still.[9] None of these coefficients is changed appreciably if we base them on a bivariate regression of minutes sleeping on minutes of market work.

The estimated effect of additional work time on sleep duration is 50 percent larger than what we inferred from the cross-section international averages in table 1. This discrepancy is not explicable by differences in average working hours, nor does it differ if only the control variables in table 1 are used. It may be due to differences in the instructions to the participants in the various studies about keeping their diaries or to greater measurement error in the 1-day diaries in the international samples than in the 4-day diaries in the Time Use Study. Also, the aggregation over individuals that produced the cell means underlying the estimates in table 1 may have removed the

[8] A child is coded as being less than 3 years old if he or she was at most 2 years old.

[9] Tests of sex differences in the response of the sleep measure to additional minutes of market work yield t-statistics of 1.39, 1.33, and 1.50 for the three variables that measure sleep.

correlated extreme values of both the sleep time and work time variables, so that the estimate of their partial correlation was reduced.

Evidence from Panel Data

We have shown that there is a significant negative partial correlation between sleep time and work time that is robust to the location in which the sampling occurs and to the characteristics of the workers sampled. It does not, however, demonstrate a causal relationship. Consider a situation in which sleep has no effect on productivity or utility, provided that the individual satisfies a biologically required need for sleep. Suppose also that this need varies among individuals. Then economic theory predicts that (under most circumstances) individuals requiring less sleep would divide the extra waking time between work and leisure. This would lead to a negative correlation between work and sleep in cross-section data, even though sleep time would be irrelevant to changes in time allocation.

This extreme example illustrates a possible individual-effect bias in the estimates in tables 1, 3, and 4. Consider the equation

$$T_{sit} = \boldsymbol{\alpha} T_{wit} + \boldsymbol{\beta} \mathbf{X}_{it} + \nu_i + \epsilon_{it}, \tag{1}$$

where T_{sit} is the time spent sleeping by individual i in period t, T_{wit} is the time spent working, $\mathbf{X}$ is a vector of control variables, $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are parameter vectors, ν is an unobserved individual-specific effect that is time invariant, and ϵ is a random term that varies across individuals and time. If we interpret ν_i as an individual-specific "need for sleep," then it will be positively correlated with T_{sit} and negatively correlated with T_{wit}. Cross-section estimates of $\boldsymbol{\alpha}$ from equations such as (1) will be negatively biased. Despite the remarkable consistency of our estimates, we may have shown only that there are some people who are innately sleepless workaholics.

To examine this possibility, difference (1) over time:

$$\Delta T_{si} = \boldsymbol{\alpha} \Delta T_{wi} + \boldsymbol{\beta} \Delta \mathbf{X}_i + \Delta \epsilon_i, \tag{2}$$

where Δ denotes a change between times $t - k$ and t. Estimating (2) using a panel of observations on the same people eliminates possible biases in $\hat{\boldsymbol{\alpha}}$ that may be caused by unobserved individual effects that are correlated with both T_w and T_s. Even though total time available is fixed, $\boldsymbol{\alpha}$ is not necessarily negative. There are many other uses of time besides sleeping that can change to compensate for a change in market work time.

Fortunately, a 1981 follow-up study to the 1975–76 Time Use Study allows us to estimate (2). The 1975–81 Time Use Longitudinal Panel Study collected data similar to those collected in the 1975–76 study, so that $k = 6$. Time diaries were kept for 4 days (again, at 3-month intervals) by 620 of the households included in the 1975–76 survey. The same age disqualifier used in the 1975–76 data reduced the sample to 507 observations. Missing data on the variables of interest reduced it to 278 respondents, while inconsistencies between reported incomes and earnings in 1974 or 1980 reduced it to a final size of 239 people, of whom 95 are women.

The 1981 data allowed for 223 separate uses of time, including night sleep (main sleep of the day), naps and resting, sex or making out, personal or private activities, and affection. The first two categories are the same as those in the 1975–76 cross section; the last three can be viewed as subcategories of the group miscellaneous personal time that was used in the 1975–76 cross section. We therefore formed the same three dependent variables that we used in the cross-section analysis. The individuals in this subsample from the panel study did not differ significantly in their sleep or work times from the larger 1975–76 cross-section sample.[10] That there is potentially interesting variation in the panel data is shown by noting that only 93 of the sample participants changed their average main sleep time between the two synthetic weeks by less than 30 minutes, while 81 changed it by more than 1 hour. This is not simply measurement error: The 6-year correlations of sleep time are positive and significant.

We use a "within" estimator (Judge et al. 1980) to produce the consistent estimates of $\boldsymbol{\alpha}$ from (2) that are presented in table 5. Included as control variables are all the measures for which $\Delta \mathbf{X} \neq 0$ for some observations: health status, presence of young children, marital status, years of schooling, and age.[11] These "within" estimates of $\boldsymbol{\alpha}$ are remarkably similar to the cross-section estimates shown in tables 3 and 4. Neither for the sample as a whole nor for men and women separately does the estimate of $\boldsymbol{\alpha}$ differ significantly from the cross-section estimates from the large 1975–76 sample.[12] Again we find that

[10] The means in 1975–76 for the three sleep classifications and work time were 3,246, 3,370, 3,410, and 2,184 minutes for the entire sample of 239 people. Among women they were 3,278, 3,410, 3,458, and 1,750, while among men they were 3,225, 3,343, 3,378, and 2,470. A comparison with table 2 shows that, at least along these dimensions of time use, the individuals in the longitudinal data were remarkably similar to the people included in the sample from the 1975–76 Time Use Study.

[11] Since a quadratic in age is included in eq. (1), a linear term belongs in eq. (2).

[12] The estimates of $\boldsymbol{\alpha}$ from (2) are also very similar to cross-section estimates of $\boldsymbol{\alpha}$ based on this smaller sample. For example, for sleep and naps, $\hat{\boldsymbol{\alpha}}$ estimated over the 239 people in this panel and based on (1) for 1975–76 is $-.212$. Estimating the same equation for these people using 1981 data produces $\hat{\boldsymbol{\alpha}} = -.100$. Among men, the analogous estimates are $-.242$ and $-.129$; among women, they are $-.185$ and $-.065$. With the exception of the (small) subsample of women in 1981, all these estimates differ significantly from zero.

TABLE 5

Parameter Estimates, Sleep Time and Work Time, 1975–76, 1981 (Within Estimates)

	Sleep	Sleep and Naps	Sleep, Naps, and Personal Activities
All respondents	−.175	−.224	−.234
	(.031)	(.037)	(.037)
$\bar{R}^2$	.108	.123	.133
Men	−.154	−.229	−.237
	(.039)	(.045)	(.045)
$\bar{R}^2$	.090	.129	.138
Women	−.210	−.224	−.233
	(.053)	(.064)	(.065)
$\bar{R}^2$	.115	.092	.105

Note.—Includes variables measuring age and change in health status, presence of young children, educational attainment, and marital status.

$\partial T_s/\partial T_w$ increases in absolute value the more broadly we define sleep time.

This replication of the cross-section results on panel data suggests that at the individual level part of any change in time spent in market work is taken from nonmarket work and leisure, while the remainder is taken out of sleep time. For the entire sample the panel results imply that each 1-hour increase in work time results in a 13-minute reduction in sleep duration and a 47-minute decline in waking nonmarket time. In elasticity terms, the sleep–market work elasticity is −.14, while the waking nonmarket time–market work elasticity is −.36. It is certainly not the case that there is a fixed amount of nonsleep time that individuals divide among other uses. It is also clear that the greater part of any increase in market work is met by a reduction in waking nonmarket time, though sleep time is also reduced significantly.

We have not strictly established the direction of causation, if any, between sleep time and labor supply. It may be that variations in individuals' sleep time are beyond their control and that their labor supply changes in response to these variations. For this explanation to be plausible, exogenous changes in sleep would have to be both predictable and persistent enough to engender a labor supply response. It seems reasonable, however, to believe that the correlation between sleep time and work time reflects in part people's ability to alter the time spent sleeping in response to the same economic factors that affect labor supply. Indeed, certain results of this section, particularly our findings of differences in sleeping on workdays and weekends and of the effect of young children on parents' sleep behavior, imply that people are able to adjust their sleep behavior to changing circumstances.

The totality of our results suggests that, at the least, time spent sleeping is changed by the indirect impacts of economic and demographic factors on decisions about work and leisure. We have already seen that education affects sleep duration independently of the amount of time spent working in the market, which may reflect a direct effect of wages on sleep. This finding and the strength of the indirect effects justify constructing and testing a utility-based model with sleep as a choice variable.

III. The Demand for Sleep: A Theoretical Model

Fitting sleep into a model of consumer choice can proceed at the simplest level if we assume that individuals derive no utility from sleep and that it has no impact on their market or household productivity. In that case the consumer's choice is simple: Sleep duration will equal the biological minimum, T^*_{si}; it will be unaffected by other choices about time allocation and by changes in exogenous factors that affect consumer demand. At a more complex level, we can assume that sleep is a completely time-intensive commodity whose consumption yields utility just as other commodities do. In that case, it can be analyzed in the same way as any other commodity. Under this assumption, sleep is the obverse of work: It takes no goods, only time, reducing the amount of time available for producing other commodities or earning a wage.

At the most complex level, we can assume that sleep adds to an individual's productivity. This view is consistent with Becker's (1965, p. 498) argument that some sleep is necessary for efficiency and is required even if the goal is to maximize money income. The idea that sleep and productivity or job performance are related is supported by evidence from sleep researchers. Experimental studies indicate that severe sleep deprivation leads to lapses in efficiency, especially in nontrivial but repetitious tasks (Meddis 1977, pp. 58–59), and that for healthy subjects with normal sleep habits, an increase in nightly sleep enhances alertness and daytime functioning (Roehrs et al. 1989). A committee of the Association of Professional Sleep Societies (Mitler et al. 1988) surveyed studies of performance failures in actual work settings and concluded that "inadequate sleep, even as little as one or two hours less than usual sleep, can greatly exaggerate the tendency for error" (p. 107) during certain times of the day, especially late afternoon. Other sleep researchers have placed at $50 billion the annual reduction in manufacturing productivity as a result of "sleep problems," including irregular work schedules and inadequate rest (*Wall Street Journal* [July 7, 1988], p. 25).

We can model the worker's demand for sleep to allow for the possibility that sleep enhances both productivity and utility. Let the worker's market wage W_m be

$$W_m = W_1 + W_2 T_s, \tag{3}$$

where we have dropped the i subscript, and W_1 and W_2 are positive parameters. Assume that the individual's utility is defined over T_s and a commodity Z,

$$U = U(Z, T_s), \quad U_\iota > 0, U_{\iota\iota} < 0, \tag{4}$$

and that the worker's endowment of time is divided as $T^* = T_z + T_s + T_w$, where $T_z = bZ$ is time spent producing commodity Z. Production of Z also requires the input of goods X such that $X = aZ$.[13] The price of X is P. Thus the individual's goods constraint is the standard $PX = W_m T_w + I$, where I is nonlabor income. Combining this constraint with the individual's time constraint and the technology for producing Z yields

$$(W_1 + W_2 T_s)(T^* - T_s - T_z) + I = aPZ. \tag{5}$$

The individual maximizes (4) subject to (5), which yields

$$\frac{U_1}{U_2} = \frac{aP + bW_m}{W_1 + W_2(T_s - T_w)}. \tag{6}$$

Equation (6) states that the ratio of the marginal utilities of consumption and sleep must equal the ratio of their prices. The price of a unit of Z reflects the cost of the goods required to produce it and the shadow price of the time needed for production. The price of a unit of sleep is the wage rate minus any addition to labor income that occurs as a result of the effect of extra sleep on productivity.

The effect on sleep of a change in nonlabor income is given by

$$\frac{\partial T_s}{\partial I} = \{U_{11}[W_1 + W_2(T_s - T_w)] - U_{12}(aP + bW_m) + bU_1 W_2\}D^{-1}, \tag{7}$$

[13] We adopt a fixed-coefficients specification of household production technology for expositional convenience and also to highlight the fact that consumption activity requires waking as opposed to sleeping leisure. Indeed, this is one important reason for treating the two types of leisure as distinct categories. In the text we discuss certain implications of the perfect complementarity of market goods and waking leisure embodied in the specification. These results should be seen as extreme expressions of tendencies present when there is any complementarity between X and T_z. The basic results are not affected if our assumption that the enjoyment of sleep requires no expenditure on market goods is replaced with the more realistic assumption that it requires some fixed expenditure on goods (e.g., a bed).

where $D < 0$. The first two terms in the expression are standard. If sleep enhances the utility of consumption, as one might expect, both terms exert a positive influence on the effect of income on sleep. The third term, which is present only if sleep raises productivity, works in the opposite direction. Its negative sign results from the assumption that Z is produced using a fixed-coefficients technology. The market goods purchased with an addition to income can enhance utility only if T_z is also increased. The increase in T_z, combined with the tendency for T_s to increase in response to the added income, implies a reduction in T_w. From (6) one can see that, if sleep is productive, a fall in T_w raises the price of sleep. Thus the third term in (7) can be viewed as a second-order substitution effect working against the pure income effect captured by the first two terms.

The demand for sleep is also affected by changes in the parameters of the wage function in (3):

$$\frac{\partial T_s}{\partial W_1} = [(U_1 - bU_2)(aP + bW_m)]D^{-1} + T_w \frac{\partial T_s}{\partial I} \tag{8a}$$

and

$$\frac{\partial T_s}{\partial W_2} = T_s \frac{\partial T_s}{\partial W_1} - (aP + bW_m)U_1 T_w D^{-1}. \tag{8b}$$

Equation (8a) is the Slutzky equation describing the demand for sleep. The first term differs from the usual substitution effect because it includes $-bU_2$. This appears because a change in the wage also changes the price of Z; one can show, though, that $(U_1 - bU_2)$ is always positive. An analogous expression for $\partial T_z/\partial W_1$ can be derived, and it is interesting to note that the substitution effect of a change in W_1 on waking leisure is positive. This results from the complementarity of T_z and X in producing Z. If W_1 increases, the goods purchased with the extra income can be enjoyed only if T_z increases as well. However, the substitution effect of a change in W_1 on total nonmarket time, $T_s + T_z$, is negative, just as in the standard labor supply model. Equation (8b) shows the effect on the demand for sleep of a change in the productivity of sleep. As one would expect, an increase in W_2 has a less negative (more positive) impact on sleep than an increase in W_1.

Note from (6) that the demand for sleep may be affected by changes in any other exogenous factors that could be included as affecting tastes for sleep or the composite commodity Z. This means that, in general, any exogenous factor that shifts the demand for commodities will affect the demand for sleep and the (residual) supply of labor. Whether estimating separate wage effects for T_s and T_z provides different implications for the wage elasticity of the demand for leisure, T_l $(= T_s + T_z)$, compared with what has been produced in the standard work that does not make the distinction between sleep and waking leisure, is an empirical question.

IV. The Demand for Sleep

Estimation of a Complete Model

The theoretical model implies a demand equation for sleep that is analogous to the commodity demand and labor supply equations typically estimated in the literature. The demand for sleep is a function of the individual's wage rate and nonlabor income. We estimate such a demand equation using the subsample of consumers we have extracted from the 1975–76 Time Use Study. Along with it we estimate a similar demand equation for T_z. Market work is the commodity deleted from the system of demand equations. The estimating equations are analogues of equations that have become standard in the literature on labor supply:

$$T_j = \gamma_{1j} + \gamma_{2j} W_m + \gamma_{3j} I + \beta_j \mathbf{X} + \mu_j, \qquad (9)$$

where $j = s$, the sleep equation, or $j = z$, the nonmarket waking time equation; the γ_{ij} are parameters to be estimated; W_m is the logarithm of the wage rate; I is the logarithm of the respondent's household's other income; and μ is an independent and identically distributed error term. Except for its exclusion of years of schooling, which we assume affected the results in table 3 only through its effect on wages, **X** is the same vector of demographic variables whose coefficients were presented in table 3.

We measure W_m as the logarithm of the respondent's self-reported monthly earnings divided by 4.3 times his or her self-reported weekly hours. This hours measure is a response to a question and is not part of the time diaries that yield the measures of T_s and T_z. Any bias induced by error in this wage measure due to errors in reported hours is removed by the use of instrumental variables. Other income I is measured as the logarithm of the difference between the respondent's reported 1974 household income less a spouse's expected 1975 earnings and 12 times the respondent's monthly earnings.

To estimate (9) we need to circumvent the standard problem that the market wage rate is not observed for nonworkers (174 of the 706 sample members). We do this by first estimating a probit over the entire sample of 706 observations, relating the probability of labor force participation to a number of variables that might affect it: age and its quadratic, religious preference, health status, sex, marital status, and the presence of young children.[14] The inverse Mills ra-

[14] This model is basically an extension of what Killingsworth (1983) has called "second-generation" models of labor supply.

tio, $f(-J)/[1 - F(-J)]$, where J is the predicted ordinate of the unit normal distribution for an observation, was then entered into a second-round equation describing the logarithm of wages in the sample of 532 workers. As is common in the labor supply literature, the inverse Mills ratio added little to the wage equation. We abandoned this approach and estimated (9) using the prediction of the logarithm of hourly earnings from wage equations that excluded this ratio.[15]

By using instrumental variables for W_m, we are implicitly viewing the equations for T_s and T_z as part of a simultaneous system, because of the possible impact of both T_s and T_z on the wage rate. The time use equations are identified by their exclusion of several variables used in the wage equation—education, union status, large SMSA, and region—and of the occupation and industry dummy variables.[16]

The estimates of γ_{2_j} and γ_{3_j} for demand equations describing T_s and T_z are shown in table 6. The results are presented for the entire sample and separately for equations estimated for men and women. Before we discuss them, it is worth noting that the responses of T_s and T_z to wages are not really very different from each other. For the entire sample, a test of the hypothesis that $\hat{\gamma}_{2s} = \hat{\gamma}_{2z}$ yields the statistic $\chi^2(1) = 1.38$. For the samples of men and women, the corresponding χ^2-values are 1.46 and 0.61. Except for the hypothesis that the entire vectors of coefficients (including the control variables) in the two equations are equal, none of the hypotheses that impose equal responses of T_z and T_s to the independent variables can be rejected at conventional significance levels. However, the directions of the differences in the parameter estimates, the two χ^2-statistics that exceed unity, and the significant negative $\hat{\rho}$, the contemporaneous correlation of μ_s and μ_z, indicate that this approach to disaggregating nonwork time can be profitable.

If we hold the respondent's other household income constant, people with higher predicted wages sleep less.[17] In the sleep and naps equation for the entire sample, $\hat{\gamma}_{2s}$ is significantly negative at the 95 percent level of confidence. (The sleep-wage elasticity is $-.042$.) Indi-

[15] Wage equations included education and experience and dummy variables for sex; marital, union, and health status; race; region; large standard metropolitan statistical area (SMSA); and one-digit occupation and industry. The $\bar{R}^2$'s were .37 for the full sample, .18 for men, and .28 for women. Complete results are available from the authors and are comparable to those common in the literature.

[16] We explored the possibility that sleep affects productivity by estimating a wage equation that included a measure of sleep. Our model suggests that to do this properly, sleep, waking nonmarket leisure (or hours of work), and wages would have to be treated as endogenous. Unfortunately, our data are not sufficient to allow us to identify convincingly such a wage equation: there are not enough variables that are strongly correlated with sleep time and work time that can be excluded from the wage equation.

[17] Qualitatively similar results on W_m are obtained when the equation systems are reestimated using either sleep or sleep, naps and rest, and personal time as one of the three uses of time.

TABLE 6

Wage and Income Effects, Demand Systems, 1975–76 Time Use Data

Dependent Variable	Wage	Income	$\bar{R}^2$	$\hat{\rho}$
	All Respondents			
Sleep and naps	−141.44	−1.78	.024	
	(77.35)	(4.80)		−.24
Waking nonmarket time	132.18	−1.71	.162	
	(129.37)	(8.09)		
	Men			
Sleep and naps	−181.68	−2.88	.040	
	(120.88)	(5.77)		−.23
Waking nonmarket time	233.34	−6.69	.050	
	(193.67)	(9.30)		
	Women			
Sleep and naps	−64.30	1.55	.018	
	(93.44)	(8.43)		−.27
Waking nonmarket time	−262.42	14.44	.053	
	(166.99)	(14.80)		

Note.—Each equation also includes all the variables listed in table 3. The standard errors are adjusted using the correction of Murphy and Topel (1985)

viduals whose time is more valuable substitute away from the relatively time-intensive commodity sleep, a commodity that yields utility but no direct income. While our results do suggest the existence of this most basic of economic effects on the demand for sleep, they are not overwhelming. We believe that they are strong enough, though, to demonstrate that time spent sleeping is scarce and subject to variations produced by the same economic factors that affect other choices about allocating time.[18]

The wage effect on sleep is especially large for men and mirrors the wage effect on waking nonmarket time. The amount of time that men spend in the market is unaffected by an increase in the wage rate, but that increase induces them to switch time from sleeping to leisure and nonmarket production. This could be a reflection of the complementarity between waking leisure and consumption that we highlighted in Section III. Among women, changes in the value of time have little

[18] Kooreman and Kapteyn (1987), who use the 1975–76 Time Use Study to estimate their time allocation model, report that women "substantially reduce the amount of time spent on personal care if their wage rate goes up" (p. 241). This result, with its counterintuitive implication that highly paid women are less attentive to their health and appearance, makes more sense when one recognizes the importance of sleep in their personal care category. (Our broadest measure of sleep makes up 80 percent of their category.) The decreased time devoted to personal care is recognizable as the wage effect on the demand for sleep that we have found.

effect on sleep but lead to reallocation of time between market and nonmarket work. This sex difference in the response of sleep to wage changes may arise because women have more opportunities than men for substituting between market and nonmarket work.

Taken together, the results of estimating this demand system are consistent with the mass of prior research showing that men's supply of work to the market is much less sensitive to wage rates than women's. The implied labor supply elasticity for men is $-.021$, essentially zero, while for women it is .191, positive but not very large (in this sample in which an unusually large fraction of women are in the labor force).

The standard errors of the estimated income effects $\hat{\gamma}_{3j}$ are too large to permit reliable inferences about their signs, but the effect of income on sleep appears to be economically insignificant. This could be caused by the nonsuperiority of sleep that is induced by the second-order substitution term in (7), or it could merely stem from problems in our measure of other income. In any case, together with the evidence (summarized by Killingsworth [1983]) that income effects on the supply of hours of work are very small, these findings suggest that the receipt of additional unearned income does not affect T_s. Implicitly, the entire impact of extra nonlabor income is to shift the typical consumer to the production of relatively more goods-intensive commodities through purchasing more goods, not through reducing the total time spent producing those commodities.

Additional Evidence on the Income Effect

We failed to find any evidence of income effects in the estimates of the demand system. Contemplating this issue, though, leads to two interesting extensions. The first involves examining the impact of economic development on the demand for sleep. There is a general notion that as the price of time increases and incomes rise, the demand for sleep will fall.[19] This ignores the possibility that sleep yields utility and that the higher incomes produced by rising wages can overcome the pure price effects. This possibility does not seem consistent with the results from the demand system; yet since its obverse is the best way to reconcile cross-section and time-series estimates of variations in labor supply, the argument is surely not outlandish.

We do not have time series on sleep duration. We can, though, use measures of living standards along with the demographic variables in the international data set described earlier to estimate a reduced-form

[19] Linder (1970, p. 47) argues that "many people regard sleep as a waste of time. The greater the demand for time, the more people come to accept this view."

Engel curve for sleep over a diverse sample of economies. Using gross national product per capita in 1966 in that equation and dropping minutes of work produce only minor (less than 10 percent) changes in the coefficient estimates in table 1. Higher GNP per capita is associated, though, with *significantly longer sleep duration.*[20] The effect is small, with an increase in income over the entire range producing only 21 extra minutes per day of sleep time for the average household (and an increase of two standard deviations producing only 14 extra minutes of sleep). Nonetheless, this contradicts the notion that economic development must be associated with less time spent sleeping, and it may provide some evidence for the existence of income effects in the demand for sleep.

A second extension involves examining how people respond to a hypothetical offer of an increase in full income through increased T^*. In three of its monthly polls (in 1978, 1983, and 1988) the Roper Organization asked respondents to list two or three activities that they would engage in if they had an additional 4 hours each day.[21] Sleeping was the seventh most frequently mentioned activity by the 776 people in the samples. Moreover, under the assumption that each activity mentioned occupies the same share of the additional time, the implied estimate of dT_s/dT^* is .045. Participants in the fourth wave of the 1975–76 Time Use Study were asked how they would spend an additional 2 hours per day. Most in our sample listed only one activity; 31 sample members out of the 671 who responded to this question chose sleep. Assuming that these people would spend all this extra time sleeping, we can infer a value of .046 for dT_s/dT^*. Although these two remarkably similar results are based on a hypothetical question, they do suggest that sleep is not inferior.

What sort of people would sleep more if the day were longer? The sleep lovers in our sample sleep 1½ hours more per week than the other sample members and work less, but they are not significantly different with respect to any other variable in the data set. The desire to spend hypothetical surplus hours on sleep may reflect a constraint on time allocation not captured by our model, for example, a minimum hours constraint on the job. To examine this, we respecified (9) to allow those wanting to sleep during the extra 2 hours to have wage and income effects different from the rest of the sample.

[20] The GNP data were constructed from materials in the *United Nations Statistical Yearbook* and the *International Financial Statistics.* The coefficient on GNP per capita, measured in thousands of 1966 U.S. dollars, was 6.14; its standard error was 1.87. The range of GNP per capita in this sample was \$356–\$3,842, with a mean of \$1,609 and a standard deviation of \$1,110.

[21] We thank Sender Hoffmann of the Roper Organization for providing the underlying data.

If a constraint were affecting their behavior, their sleep would be less responsive to wage and income changes. There was no evidence of differential responses. Either these 31 respondents have a pure preference for sleep or sleep enhances their productivity more than it does that of other respondents.

V. Conclusions and Implications

People spend close to one-third of their time sleeping, but it is wrong to view these unconscious hours as a predetermined deduction from their scarce allotment of time. We have shown that at least part of sleep time is a reserve on which people can draw when economic circumstances make other uses of time more attractive. Our results suggest that it is not unusual for people's average daily sleep time to differ by as much as 1 hour at different times in their adult lives. Such variations are economically important, for they respond to economic incentives: Time spent sleeping is inversely related to both the wage and time spent in the labor market. In short, sleep is subject to consumer choice and is affected by the same economic variables that affect choices about other uses of time.

This fact has not been recognized in empirical studies of labor supply and commodity demand. If sleep does not influence productivity, then estimates of labor supply equations and "complete" systems of labor supply and commodity demand (e.g., Abbott and Ashenfelter 1976) that ignore sleep will yield unbiased estimates of income and substitution parameters.[22] The labor supply equation proxies the complement of the demand for all nonmarket time (sleeping and waking); since the price of that time is the wage rate, estimating labor supply equations in standard ways is a legitimate application of the composite commodity theorem. The realization that sleep is a choice variable does lead to a subtle reinterpretation of estimated labor supply elasticities, in that they can no longer be viewed as the negative of elasticities of demand for leisure. For example, a substitution effect on labor supply that is nearly zero may reflect the combination of a positive price effect on waking leisure and a negative effect on the demand for sleep. Indeed, that is what our results suggest is the case for men.

If sleep affects productivity, as evidence from other fields strongly suggests, the issue becomes more complex. The marginal price of sleep differs from the marginal price of other uses of time. The

[22] Estimated demand systems that ignore labor supply will produce biased parameter estimates if sleep is not weakly separable from goods in the utility function, just as they would if waking leisure time were not weakly separable.

impact of sleep on the wage rate makes the wage endogenous in the labor supply function. Demand systems that are derived from parameterizations of the direct or indirect utility function without accounting for the role of sleep will produce biased estimates of the structural parameters. This relationship clearly merits further investigation by economists.

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