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Juan Du
Old Dominion University

Takeshi Yagihashi
Old Dominion University, tyagihas@odu.edu

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Goods-time Elasticity of Substitution in Health Production

Juan Du[1] and Takeshi Yagihashi[2]
Department of Economics, Old Dominion University, Norfolk, VA

Abstract

We examine how inputs for health production, in particular, medical care and health-enhancing time, are combined to improve health. The estimated elasticity of substitution from a CES production function is significantly less than one for the working-age population, rejecting the unit elasticity of substitution used in previous studies.

Key words: elasticity of substitution, health production, medical spending, leisure

[1] Corresponding author. Address: Department of Economics, Old Dominion University, 5115 Hampton Boulevard, Norfolk, VA 23529; phone (757) 683-3543; email: jdu@odu.edu.
[2] Address: Department of Economics, Old Dominion University, 5115 Hampton Boulevard, Norfolk, VA 23529; phone (757) 683-3512; email: tyagihas@odu.edu.

1. Introduction

Health care spending in the US has grown rapidly over the last several decades, but population health has not improved at a corresponding pace. According to Grossman (1972), health production involves both medical care and time input. Many studies have examined the effectiveness of each input on health outcomes, but little is known about the relationship of the two inputs, in particular whether medical care and time work as substitutes or complements in health production.

It is *a priori* hard to predict what the goods-time elasticity of health production is at the general level. For instance, it is widely reported that regular physical activity reduces the risk of various diseases (USDHHS, 1996), which should help in lowering the monetary cost of health care. On the other hand, treating illness apparently requires both money and time (e.g., doctor visits), suggesting that the two variables are complements.

The purpose of this paper is to empirically assess the goods-time substitutability for health production. Solid understanding of this relationship is important because it likely impacts our discussions related to the future course of medical spending (Hall and Jones, 2007), health-related behavior over the life-cycle (Scholz and Seshadri, 2013), and the relationship between health and the business cycle (Ruhm, 2000, 2005). In the past, studies often assumed unit elasticity between health-related goods and time (e.g., Scholz and Seshadri, 2013) or adopted specifications (such as the translog) that do not directly deal with such substitutability (e.g., Sickles and Yazbeck, 1998). To our knowledge, this paper is the first to estimate the elasticity of substitution using a structural model of health production.

We begin by formulating a cost minimization problem with medical spending and *health-enhancing* (HE) time as the two inputs. The optimality condition derived from the cost minimization problem is used to pin down the elasticity parameter.[3] We construct the time measure from the time use diary of the American Time Use Survey (ATUS). This time use information is matched with out-of-pocket medical expenditure data obtained from the Current Population Survey Annual Social and Economic Supplement (CPS ASEC) for the same individual.

We find that for the working-age population the elasticity ranges between 0.190 - 0.427 across different model specifications, strongly rejecting the null hypothesis of unit elasticity. An immediate caveat of our finding is that time and money input are complements in health production. It suggests that promoting physical activities and improving access to medical care are both needed to improve health outcomes.

2. Empirical Strategy and Data Issues

We assume that health is produced by combining medical spending (*M*) and HE time (t_{he}) in the Constant Elasticity of Substitution (CES) production function. Following the literature (Hamermesh, 2007; Baral et al., 2011), we also assume the price of time is the wage rate (*W*) and the price of medical goods is normalized to one. Solving the standard cost-minimization problem yields the following estimating equation for the relative demand of goods and time in health production:

$$\ln\left(\frac{M}{t_{he}}\right) = constant + \sigma \ln(W). \quad (1)$$

Unfortunately, there are no data that provide details on both time use and medical expenditure. One approach often adopted in the literature is to use one data source for

[3] Applications of the same method to other commodities include Hamermesh (2008) for food and Rupert et al. (1995) for home production.

time use and another for expenditure, which comes with the obvious limitation that goods and time are not for the same person. In this paper, medical expenditure is not available in the ATUS, but we can match medical expenditure from the CPS ASEC (available since 2011) with time use in ATUS for the same individual. This is possible because the ATUS sample is randomly drawn from the sample that completed the last round of the CPS. The advantage of this approach is that both time use and expenditure are for the same individual, but this approach is also associated with two unavoidable problems. One is that medical expenditure is collected for the year before the ATUS interview. The other is that the resulting matched sample is smaller than the original ATUS sample.[4]

Medical spending was defined as out-of-pocket expenditure in the previous year, including medical care (hospital, medical providers, dental services, prescription medicine, vision aids), medical equipment, over-the-counter products, and health insurance payments. It was available at the individual level.

The wage rate was measured as per-hour earnings for hourly workers. For non-hourly workers, we used their weekly earnings divided by the hours worked. We note that this wage rate most likely reflects the opportunity cost of time during weekdays rather than during weekends because the earnings reported in ATUS are for the respondent's main job. Jobs on the weekend may have a different wage rate. Therefore in this study we focused on the weekday sample.[5] To account for the endogeneity of wages, we used a Heckman selection equation to predict wages and used the predicted wages in estimation.

[4] The link procedure follows the American Time Use Survey User Guide, Appendix K. To achieve matching, we needed to restrict the ATUS sample to those interviewed in March, April, May, and June of the interview year. The resulting sample was 60% smaller than the original ATUS sample. Since most of the sample we lost was based on the interview month, it should not have caused any selection bias.

[5] In ATUS, each participant is randomly assigned a day of the week to complete a time diary. About 50% of the sample is assigned to weekdays and 50% to weekend days. In alternative regressions (not shown), we included the weekend sample, and the estimates are similar to our baseline estimates.

Identification of the sample selection equation was through the higher order of age and years of education, an interaction between age and years of education, marital status, spouse earnings, and number of children at several age ranges (0-2, 3-6, and 7-18 years old). Identification of wages in equation (1) required variables that affect individuals' wages but not medical care and/or time use directly. We followed the literature and used the state-level labor force participation rate, unemployment rate, and the minimum wage.

Defining time input for health production is not straightforward. A common approach used by many studies is to include all nonmarket time as an input for health, but nonmarket time also includes activities that could be detrimental to health. In this paper, we considered three definitions of HE time. HE1 includes sports, exercises, medical and personal care. HE2 additionally includes socialization and relaxation, such as spending quiet time alone, doing fun things and eating with others, participating in clubs and religious groups, and hobbies. These activities can serve as "breathers" and "restorers" that lower stress and induce positive emotions (Pressman et al., 2009). Passive activities, such as watching TV and computer use, were excluded because screen-based media use is generally linked to a sedentary lifestyle and an increased likelihood of obesity. HE3 additionally includes sleep time. The corresponding codes in ATUS are presented in Appendix A.

Following the literature, we dropped observations of those who were younger than 25 or older than 65 years, those enrolled in school, active military members, the unemployed, and individuals having emergencies on the diary day. The final sample size was 2,289 for four years (2011-2014).

3. Results

Table 1 presents the elasticity estimates for three specifications across the three HE definitions. The baseline estimates are shown in Column (a). For HE1, the elasticity of substitution is estimated to be 0.306. For HE2, the estimate drops a little to 0.304. Since socialization and relaxation are more relevant to mental health, this fall in estimate suggests that time input (particularly relaxation and socialization) may be more important for mental health than for physical health. The elasticity becomes 0.325 when sleep time is added (HE3). When we use total nonmarket time, the estimate becomes larger (0.392), suggesting it may be easier to find market substitutes for non-health-related time than for health-related time. We conducted a hypothesis test with the null H_0: $\hat{\sigma} = 1$, and we strongly rejected the null hypothesis in all specifications.

In Column (b), alternative specifications including individual's insurance status, self-reported health, and state insurance premiums as additional control variables are shown.[6] The estimates become somewhat smaller and range from 0.190 to 0.245, and we again strongly rejected the null hypothesis of H_0: $\hat{\sigma} = 1$.

In Column (c), we present the specification with annualized HE time. Recall that medical spending is reported on an annual basis, whereas leisure time is measured on a daily basis. This timing mismatch could lead to biased estimates if HE time on a given day does not represent time use of the entire year. To address this issue, we constructed a weekly estimate by predicting HE time on the non-sampling days and aggregating it with time use on the sampling day. Details of the procedure are presented in Appendix B. We find that the elasticity estimate using the annualized leisure is around 0.395 for HE1, a

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[6] Insurance status and self-reported health are available in the CPS ASEC. State insurance premium is obtained from the Kaiser Family Foundation.

little larger than using the daily measure, reflecting easier adjustment of leisure / work time in the long run.

Our estimates are close to those in Hamermesh (2008) and Baral et al. (2011), who estimated the goods-time elasticity of substitution for food production to be in the range of 0.2-0.5. Our estimates are much smaller than the elasticity of substitution for home production, which is estimated to be above one (Aguiar and Hurst, 2007; Rupert et al., 1995).[7] As one may expect, it is difficult to outsource health-enhancing activities (such as exercise), whereas people can often find market substitutes for house cleaning and childcare.

4. Conclusions

This paper provides empirical estimates for the elasticity of substitution between goods and time input of health production. Our estimate is significantly less than one, thus rejecting the unit elasticity of substitution assumed in previous studies. This result indicates that goods and time in health production are gross complements, suggesting that improved access to medical care through public policy (e.g., Affordable Care Act of 2010) needs to be accompanied by time devoted to health-enhancing activities in order to be effective.

The complementary nature of goods and time inputs also has implications for how health moves along the business cycle. During economic expansions, individuals can afford more medical goods (spending), but less time is available for health-enhancing activities and medical care. During recessions, more time is devoted to health-enhancing

[7] Aguiar and Hurst (2007) find the elasticity of substitution estimate to be 1.8 and they measure the opportunity of cost using observed shopping behavior. Rupert et al. (1995) find the elasticity estimate to be 1.8 for single women and close to 1 for single men.

activities and medical care, though the eventual health outcome will depend on the relative change in total spending and time. In addition, fiscal policies often implemented during economic turbulence, such as changes in labor income tax, could also alter input compositions. A lower labor income tax would effectively raise the wage rate, which increases the ratio of money over time.

One limitation of this study is that there may be considerable heterogeneity in health production because technology and medical care accessibility could differ by age, gender, education, and geographic location. The advantage of using time diary data is that it allows us to pin down specific time spent on health improvement, but time diary data are often associated with measurement errors and nonresponses.[8] Future studies may further explore the heterogeneous nature of health production and better data for time use.

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[8]Abraham, Maitland, and Bianchi (2006) find that ATUS respondents have stronger community ties than non-respondents (about 45% of the eligible persons), which may lead to an overstatement of socialization. If relaxation is a close substitute of socialization, then by aggregating them we can reduce the potential bias caused by nonresponses.

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Table 1. Estimates of elasticity of substitution between goods and time for health production

	Time use definition	(a) Baseline	(b) With controls	(c) Baseline, annualized HE
HE1 (baseline)	Exercise, personal care, and medical care	0.306 (0.066)	0.196 (0.066)	0.395 (0.059)
HE2	HE1 plus socialization and relaxation	0.304 (0.064)	0.190 (0.065)	0.386 (0.060)
HE3	HE2 plus sleep time	0.325 (0.062)	0.194 (0.062)	0.369 (0.060)
Nonmarket time	24 hours minus work time	0.392 (0.062)	0.245 (0.063)	0.427 (0.061)

Note: Data are from ATUS 2011–2014. Sample size is 2,289. The samples include those with positive medical expenditure and positive HE time. The estimates are based on OLS regressions. In Column (b), we additionally include the individual's insurance status, self-reported health, and state-level insurance premiums. Column (c) replaces daily HE time with annualized HE estimates. All coefficients are statistically significant at the 5% level.

Appendix A: Activity Categories and Corresponding ATUS Codes

Activity category	HE definition	Codes in ATUS
Exercise	Included in HE1, HE2, and HE3	130101-130104, 130106-130128, 130130-130199
Medical care + Personal care	Included in HE1, HE2, and HE3	010201, 010299, 010301, 010399, 010401, 010499, 010501, 010599, 019999, 080401-080403, 080499, 080501, 080502, 080599, 160105, 180101, 180199, 180804, 180805, 180899
Relaxation	Included in HE2 and HE3	020501, 020599, 020602, 030103-030105, 040103-040105, 060102, 110101, 110199, 119999, 120301, 120304-120307, 120309-120313, 120399, 120401-120404, 120499, 130105, 130129, 130201-130232, 130299, 139999, 150102, 150103, 150105, 150199, 150201, 150202, 150299, 150301, 150302, 150399, 150801, 150899, 160101, 160102, 181205
Socialization	Included in HE2 and HE3	060201-060203, 120101, 120199, 120201, 120202, 120299, 129999, 140101, 140102, 140105, 149999, 150104, 150106, 050201-050203, 150204, 150401, 150402, 150499, 150501, 150599, 150601, 150602, 150699, 150701, 150799, 159999
Travel & waiting time associated with relaxation and socialization	Included in HE2 and HE3	060204, 110201, 110299, 120501-120504, 120599, 130301, 130399, 140103, 180205, 180602, 181101, 181199, 181201-181204, 181299, 181301, 181302, 181399, 181401, 181499, 181501, 181599
Sleep	Included in HE3	010101, 010199

Note: Codes 050201-050203 are socializing, relaxing, eating, drinking, sports and exercise as part of a job. We include them in the socializing category, considering that these activities serve as breaks from work. The travel time categories were coded with a starting number of “17” before 2005 and “18” after 2005.

Appendix B: Construction of Annualized Health-Enhancing (HE) Time

Medical spending is measured annually and leisure time is recorded on a daily basis. To match the frequency, we converted the daily time use measure into an annual estimate.

The ATUS interview occurs either on a weekday or weekend, hence we do not observe weekday *and* weekend time use for the same individual. To convert daily time use to weekly time use, our strategy is to estimate time use on the days that the individual was not interviewed. This is possible because ATUS randomly assigns individuals to one day either during the week or the weekends.

For an individual *i* who was interviewed on weekdays, hours spent on HE time over a given week (5 weekdays and 2 weekends) are calculated as,

$$t_{HE,week,i} = \left(\frac{5\mu_{wd,i} + 2\hat{\mu}_{we,i}}{7}\right)(168 - h_i)$$

where μ_{wd} is the fraction of nonmarket time spent on HE activities on weekdays, $\hat{\mu}_{we}$ is the "predicted" fraction of nonmarket time spent on HE activities on weekends, and h is the usual hours worked per week ("TEHRUSLT" in ATUS). A fractional logistic regression (Papke and Wooldridge, 1996) is used to estimate $\hat{\mu}_{we}$ from the weekend sample. The conditional mean of HE time is specified as,

$$E\left(\mu_{we,i} \middle| \mathbf{x}_i\right) = G(\mathbf{x}_i\beta),$$

where $G(\cdot)$ is the logistic function and the vector **x** consists of gender, age, age squared, race, education dummies (high school, less than high school), marital status, self-employed, number of children (0-2, 3-6, 7-18 years old), regional dummies, a summer indicator, and year indicators.

Similarly, for an individual *j* interviewed on weekends, the weekly HE time is calculated as,

$$t_{HE,week,j} = \left(\frac{5\hat{\mu}_{wd,j} + 2\mu_{we,j}}{7}\right)(168 - h_j),$$

where μ_{we} is the actual fraction of nonmarket time spent on HE activities on weekends and $\hat{\mu}_{wd}$ is the predicted fraction of nonmarket time spent on HE activities on weekdays. $\hat{\mu}_{wd}$ is predicted using the same fractional regression model specified above.

Finally, annual HE time is calculated by assuming the following temporal aggregation process,

$$t_{HE,year} = 52 \times t_{HE,week}.$$

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