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Effect of Subjective Sleeplessness Symptoms on Japanese Labor Productivity: An Empirical Study

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TOHOKU ECONOMICS RESEARCH GROUP

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Abstract

Sleep is an essential activity for every individual. However, many people suffer from subjective sleeplessness symptoms and insomnia, which affect their daily lives and work. In this study, we focus on the effects of subjective sleeplessness symptoms on labor productivity. Using anonymous data from the 2013 National Survey of Living Conditions in Japan, we find that the respondents' subjective sleeplessness symptoms decrease hourly labor income by about 1% in comparison with those who report no such symptoms. Our findings also show that heterogeneity by gender exists in the estimation, with the effect of sleeplessness observed to be statistically significant only for females.

キーワード：Sleeplessness symptoms, Productivity, Anonymous data, IV

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Effect of Subjective Sleeplessness Symptoms on Japanese Labor Productivity: An Empirical Study

Fengming CHEN[1†], Fusae OKANIWA[2‡]

1. Introduction

The purpose of this study is to statistically examine the effect of insomnia on labor productivity in Japan. The average daily sleep duration of Japanese people is the shortest among OECD countries, with the highest percentage of people sleeping between six and seven hours per day (Ministry of Health, Labor and Welfare, 2018). Meanwhile, Japan's hourly labor productivity of $46.8 has been the lowest among the seven major OECD industrialized countries since 1970 (OECD, 2018a,b). Hafner et al. (2016) found that (1) sleep deprivation reduces workplace productivity, and (2) the associated economic losses (loss as a percentage of the size of each country's economy) are the largest in Japan among OECD countries.

Regarding sleep and productivity, previous medical research has shown that sleep deprivation is associated with lower cognitive ability and performance (Cappuccio et al., 2010; Walker, 2017). In the field of economics, health is considered part of human capital, and many empirical studies have been conducted on the effect of health on labor productivity (Oishi, 2000; Hamaaki and Noguchi, 2009; Iwamoto, 2000; Yuda, 2010; Sato, 2016). Conversely, existing studies in economics, on sleep and labor productivity have treated it exogenously as a leisure activity under budget constraints. Therefore, little

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consideration has been given to elucidating the mechanisms of the relationship between sleep duration and economic performance or the determinants of sleep choice that reflect endogeneity (Giuntella et al., 2015). This points to a lack of evidence on this issue in the field of economics (Gibson and Shrader, 2018).

This study statistically examines the impact of subjective sleeplessness symptoms on worker productivity using anonymous data from the 2013 National Survey of Living Conditions. The findings show that:

1) Subjective sleeplessness symptoms have a significant effect on lowering the labor productivity of respondents.

2) There is a significant difference in the impact of sleeplessness between men and women.

Based on these results, it is necessary to consider the effect of sleeplessness on worker productivity and account for any gender differences when examining the social cost of sleeplessness.

The rest of this paper is organized as follows. Section 2 provides an overview of previous studies. The data used in this study are introduced in Section 3. Section 4 presents the variable definitions and descriptive statistics. Section 5 explains the estimation method and the results. Finally, Section 6 summarizes the study and discusses it limitations.

2. Literature Review

2.1 Health and Productivity

Since 1972, when the economist Grossman first incorporated the concept of health into his theoretical model and developed the health capital investment model, active research has been conducted in Japan and abroad on the relationship between health and labor productivity. Currie and Madrian (1999) and Kuroda (2018) showed that most existing empirical studies support the conclusion that health status significantly affects labor productivity. For example, Sato (2016) used the Keio Household Panel Survey (KHPS) and conducted an analysis using ordinary least squares (OLS) and instrumental variable models with fixed effects (IV-FE), taking endogenous and unobservable personal attributes into account. The results show that among males, worsening health status has a significant negative impact on wage rates.

Subjective health is the most frequently used health indicator to assess overall health status (Oishi, 2000; Kamimura and Komamura, 2017; Sato, 2016; Noguchi, 2014; Yuda, 2010). According to Grossman (1972), as individuals age, their health capital stock declines, and appropriate health investments are necessitated to maintain a certain stock. However, many respondents ignore the decline in health stock due to aging, which may prevent an accurate reflection of individuals' health status through their subjective health level. For example, if they have specific subjective symptoms, they may attribute them to aging and exclude them from their personal health assessment. Therefore, some studies assess respondents' health status by specifically inquiring about subjective symptoms or by using the status of disabilities in daily life, rather than the subjective health level (Iwamoto, 2000).

In addition, while analyzing the relationship between health and labor productivity, there is a need to consider the endogenous nature of health status. Existing studies have used exercise habits, sleep duration, and the history of disease as instrumental variables (Kamimura and Komamura, 2017; Sato, 2016; Hamaaki and Noguchi, 2010; Yuda, 2010). However, the validity of these variables due to the issue of weak correlation remains controversial (Kuroda, 2018).

2.2 Sleep and Productivity

Previous studies have shown that there is a negative correlation between wages and sleep duration for men (Stafford and Duncan, 1980). The introduction of daylight-saving time reduces sleep duration and leads to poor performance, including increased work-related accidents (Barnes and Wagner, 2009); an increase of one hour in average sleep time results in higher productivity than would accrue from a rise of one year of education (Psacharopoulos and Patrinos, 2004). However, these studies do not take the endogenous nature of sleep time into account. One of the first studies to mention the causality between sleep duration and productivity was Biddle and Hamermesh’s work (1990). They conducted a panel data analysis on the effect of working hours on sleep and found that an increase of one working hour was associated with approximately ten minutes of decreased sleep time. However, due to potential reverse causality, the empirical model does not consider the effect of sleep duration on productivity, even though the theoretical model emphasizes this possibility.

In contrast, several economic studies in recent years consider the endogeneity of sleep duration using instrumental variables. These studies typically utilize circadian rhythms as instrumental variables. Living organisms have the ability to change their internal environment (body temperature, hormone secretion, etc.) in concert with changes of day and night (movement of the sun, etc.), and humans are known to follow a circadian rhythm of about 24 hours. Based on physiological evidence that the circadian rhythm induces sleep, the strong relationship between sleep and sunset time is used for estimation.

First, Gibson and Shrader (2018) modeled a sleep production function by extending Becker's (1965) household production function and Gronau's (1977) time-use model to examine the effect of sleep duration on productivity. Using data from the American Time Use Survey, they conducted an empirical analysis using the two-stage least squares (2SLS) method with instrumental variables. The instrumental variables were (1) the annual average sunset time in each region, (2) the declination of each region, and (3) the interaction term between sunset time and declination. They use the difference in sunset time between regions in the U.S., where the sun sets earlier in the east than in the west; hence, the earlier the sunset, the greater the tendency to fall asleep sooner. On the other hand, since work and school start-times are not strongly affected by earlier sunset times (Hamermesh et al., 2008), the estimates were based on the hypothesis that there is no relationship between sunset time and wages. The analysis revealed that increasing the average sleep time by one hour per night increases wages by 1.1% in the short run and by about 5% in the long run. In addition, focusing on the non-linear relationship between sleep duration and wages, the results of quadratic estimation indicate that the optimal sleep duration to maximize wages is about nine hours. However, the analysis does not control for time-invariant unobserved effects. In addition, the problem of a weak instrumental variable exists in some estimations.

Kajitani (2019) also controlled for both time-invariant and time-varying endogenous effects by accounting for the endogeneity of wages and hours of sleep through an instrumental variable model with fixed effects. Data were taken from the Keio Household Panel Survey (KHPS) from 2004 to 2017 to analyze the effect of sleep on the productivity of male workers in Japan. Outside temperature fluctuation was used as an instrumental variable, one of the environmental changes that contribute to circadian rhythms. He used data on the average annual temperature among cities and the average annual sunshine duration as instruments. The results showed that an additional hour of sleep per week increases wages by 3–5%, which is generally consistent with the results of Gibson and Shrader (2018) mentioned above. Note that the statistical validity of the instrumental variables was confirmed by tests of endogeneity and weak instruments. The author also stated that there is no significant long-run relationship between the instrumental variables and the explained variable of productivity, on the basis of Graff et al. (2018). However, from the perspective of environmental economics, there are several studies showing that productivity decreases because of severe temperatures in the agricultural and industrial sectors (Zhang et al., 2018), but no detailed theoretical justification has been provided for this.

2.3 Contributions

It is necessary to consider the endogeneity of sleep and to use instrumental variables for estimation. If the instrumental variable on circadian rhythms adopted in previous studies is used for estimation in the case of Japan, it will likely be difficult to correctly identify appropriate latitudes due to the long vertical shape of the Japanese archipelago. Additionally, as mentioned above, the temperature data used by Kajitani (2019) is undeniably correlated with labor productivity, the explained variable. Therefore, in this study, variables related to sleep duration and exercise habits used in Sato (2016) and Iwamoto (2000 are used as the instrumental variables. Although subjective symptoms of sleeplessness are thought to be correlated with a lack of sleep (short sleep), the symptoms for both are not necessarily identical. For example, people may claim "I can't sleep" even if they have enough sleep time, due to subjective factors such as difficulty falling asleep, waking up many times during the night, and not feeling rested enough due to shallow sleep. In addition, since sleep duration is not believed to affect the hourly wage rate directly, it is a reasonable instrumental variable (Sato, 2016). Furthermore, exercise has a positive effect on sleep quality (Vanderlinden et al., 2020; Glavin et al., 2021).

3. Data

We use anonymous data (Questionnaire B) from the 2013 Comprehensive Survey of Living Conditions (Ministry of Health, Labor and Welfare). This survey is conducted to survey basic matters relating to people's lives, such as health, medical care, welfare, pensions, income, and to obtain the basic data necessary for the planning and operation of the Health and Labor Administration. Large-scale surveys have been conducted every three years since 1986, and the 2013 survey is the 10th large-scale survey. This large-scale survey is known to be one of the most representative surveys in Japan, collecting relevant information from respondents through five questionnaires: household questionnaire, health questionnaire, nursing care questionnaire, income questionnaire, and savings questionnaire.

The anonymous data used in this study are those for which certain confidentiality measures have been taken to protect specific individuals or corporations' privacy, following Article 2, Paragraph 12 of the Statistics Law. The resampling of the anonymous data is done in two stages, census tracts and households, and the weight of each record is adjusted for uniformity.

4. Definitions of Variables

4.1 Indicators of Labor Productivity

According to Kuroda (2018), productivity indicators can be categorized into the individual, firm, and aggregate levels. In this study, we use the logarithm of hourly wages, taking data availability into account. Specifically, based on Yuda (2010), we define the hourly wage rate as equal to employment income (annual income in the previous year)/52 weeks/working hours per week.

4.2 Subjective Sleeplessness Symptoms

Based on survey data, we identify the subjective symptoms of "unable to sleep (a sleep disorder)" and create a subjective sleeplessness symptom dummy. We use a sample of 1,356 respondents who responded to the question of whether they had subjective sleeplessness symptoms; 6.5% of the respondents are found to have a sleep disorder. In this study, we define the subjective sleeplessness symptoms dummy as 1 if the respondents reported having subjective sleeplessness symptoms. Otherwise, this dummy takes the value of zero.

4.3 Control Variables

Based on previous studies (Kamimura and Komamura, 2017; Sato, 2016; Yuda, 2010), our control variables include a male dummy, high school dummy, junior/technical college dummy, university/graduate school dummy, tenure, tenure squared, regular employment dummy, occupation dummies, and firm size dummies. Table 1 shows the descriptive statistics.

Table 1 Descriptive Statistics

	N	Mean	S.D.	Min	Max
ln(Hourly labor income)	1,356	0.363	0.416	0.003	8.750
Sleep fewer than five hours	1,356	0.122	0.328	0	1
Sleeplessness (subjective symptom)	1,356	0.065	0.246	0	1
Male	1,356	0.485	0.500	0	1
High school	1,356	0.434	0.496	0	1
Junior/technical college	1,356	0.226	0.419	0	1
University/Graduate school	1,356	0.271	0.444	0	1
Tenure	1,356	13.515	12.661	0	50
Regular employment	1,356	0.580	0.494	0	1
Administrative and managerial workers	1,356	0.063	0.242	0	1
Specialist professionals	1,356	0.271	0.445	0	1
Clerical workers	1,356	0.157	0.364	0	1

Sales workers	1,356	0.088	0.283	0	1
Service workers	1,356	0.181	0.385	0	1
Security workers	1,356	0.008	0.090	0	1
Agriculture, forestry and fishery workers	1,356	0.003	0.054	0	1
Manufacturing process workers	1,356	0.098	0.298	0	1
Transport and machine operation workers	1,356	0.025	0.156	0	1
Construction and mining workers	1,356	0.023	0.150	0	1
Carrying, cleaning and related worker	1,356	0.046	0.209	0	1
Workers not classified by occupation	1,356	0.038	0.190	0	1
Company size (under 100 persons)	1,356	0.430	0.495	0	1
Company size (100~999 persons)	1,356	0.278	0.448	0	1
Company size (above 1,000 persons)	1,356	0.190	0.393	0	1
Company size (government and municipal office)	1,356	0.102	0.302	0	1

Source: Author’s calculations using data from the 2013 Comprehensive Survey of Living Conditions.

5. Results

5.1 Econometric Model

This study estimates an augmented wage function by adding an explanatory variable for subjective sleeplessness symptoms to the Mincer-type wage function (Mincer, 1974). As mentioned earlier, to take endogeneity into account, a dummy variable is used as the instrumental variable, which takes the value of one for average sleep duration of fewer than 5 hours. The estimation is conducted using a two-stage estimation method. In the first stage, subjective sleeplessness symptoms are the dependent variable. The instrumental and control variables are fed into the regression equation to obtain the predicted value of subjective sleeplessness symptoms. In the second stage, the logarithm of hourly labor income is used as the dependent variable. The predicted value of subjective symptoms and control variables obtained in the first stage are regressed as explanatory variables to estimate the parameters.

5.2 Overall Estimation Results

Table 2 shows the estimation results of subjective sleeplessness symptoms (dummy), on hourly labor income (log). In Table 2, A1 is the estimation result using OLS without considering the endogeneity problem of subjective symptoms. The partial regression coefficient value for the subjective symptom dummy is -0.106, but it is not statistically significant. In other words, the results show that sleeplessness symptoms do not affect labor productivity. Conversely, A2 is the estimation result after correcting the endogenous bias and applying the instrumental variable method. The partial regression coefficient value for the subjective symptom dummy is -0.962, which is statistically significant at the 10% level, indicating a large difference in the significance level and the magnitude (absolute value) of the coefficient compared to the estimation results in A1. This result is consistent with the results of previous studies.

A3 summarizes the results of the first stage of estimation. The partial regression coefficient value for the average sleep time dummy (fewer than 5 hours) is estimated to be significantly positive at the 1% level, indicating that sleep time lower than five hours is highly correlated to the existence of subjective sleeplessness symptoms. In addition, the F-value of the first stage is 37.46, which is larger than the standard value of 10, suggesting that there is no problem of weak correlation.

Table 2 Estimates of the Impacts of Sleeplessness on Labor Productivity（OLS と IV）

	A1	A2	A3
ln(Hourly labor income)	OLS	IV	F-Stage
Sleeplessness (subjective symptom)	-0.106	-0.962*	
	(0.087)	(0.509)	
Sleep fewer than five hours			0.124***
			(0.020)
Male	-0.294***	-0.279***	0.017
	(0.053)	(0.055)	(0.016)
High school	0.174*	0.188*	0.017
	(0.092)	(0.097)	(0.028)

Junior/technical college	0.308***	0.316***	0.005
	(0.102)	(0.107)	(0.031)
University/Graduate school	0.423***	0.406***	-0.018
	(0.103)	(0.108)	(0.031)
Tenure	0.013**	0.016**	0.003
	(0.006)	(0.007)	(0.002)
Tenure squared	0.000	-0.000	-0.000*
	(0.000)	(0.000)	(0.000)
Regular employment	-0.135**	-0.135**	0.001
	(0.058)	(0.059)	(0.016)
Administrative and managerial workers	0.053	0.049	-0.000
	(0.139)	(0.142)	(0.045)
Specialist professionals	-0.186	-0.186	0.001
	(0.130)	(0.133)	(0.037)
Clerical workers	-0.236*	-0.248*	-0.012
	(0.134)	(0.137)	(0.038)
Sales workers	-0.345**	-0.404***	-0.062
	(0.151)	(0.155)	(0.041)
Service workers	-0.123	-0.142	-0.020
	(0.133)	(0.136)	(0.038)
Security workers	-0.425**	-0.509**	-0.104
	(0.198)	(0.206)	(0.082)
Agriculture, forestry and fishery workers	0.208	0.127	-0.073
	(0.296)	(0.301)	(0.126)
Manufacturing process workers	-0.229*	-0.240*	-0.004
	(0.136)	(0.140)	(0.041)
Transport and machine operation workers	-0.344**	-0.264	0.074
	(0.167)	(0.184)	(0.055)
Construction and mining workers	-0.198	-0.220	-0.020
	(0.148)	(0.153)	(0.056)
Carrying, cleaning and related worker	-0.422**	-0.446**	-0.023
	(0.171)	(0.176)	(0.046)
Company size (100~999 persons)	-0.031	-0.051	-0.026
	(0.057)	(0.061)	(0.016)
Company size (above 1,000 persons)	0.071	0.084	0.008
	(0.064)	(0.065)	(0.019)
Company size (government and municipal office)	0.173**	0.193***	0.024
	(0.069)	(0.072)	(0.025)
Constant	-1.359***	-1.310***	0.045
	(0.142)	(0.148)	(0.042)
Adj-R2	0.080	0.018	0.034
N	1,356	1,356	1,356
F-First Stage			37.46
Partial R2			0.027

Note: 1. *, **, and *** represent statistical significance at the 10%, 5% and 1% level, respectively. 2. Figures in parentheses are robust standard errors.

5.3 Estimation Results by Gender

Due to the heterogeneity between men and women, we estimate the impact of subjective sleeplessness on labor productivity by gender. The control variables are the same as those used in section 5.2. Table 3 shows the estimation results. First, regarding the male group results (B1), the partial regression coefficient for the subjective symptom (sleeplessness) dummy is -0.231, but this is not statistically significant. This indicates that sleeplessness does not affect labor productivity. Reviewing the female group results (B3), the sleeplessness dummy is deemed to be significant, indicating that labor productivity is significantly lower for such respondents compared to those without sleeplessness symptoms. Finally, the first-stage F-values of B2 and B4 are both larger than the standard value of 10, indicating that there is no problem of weak correlation.

Table 3 Estimates of the Impacts of Sleeplessness on Labor Productivity by Gender (IV)

	Male		Female	
	B1	B2	B3	B4
	IV	F-Stage	IV	F-Stage
Sleeplessness (subjective symptom)	-0.231 (0.644)		-1.606** (0.769)	
Sleep fewer than five hours		0.106*** (0.031)		0.143*** (0.027)
High school	0.004 (0.114)	-0.021 (0.041)	0.407** (0.170)	0.049 (0.039)
Junior/technical college	0.099 (0.136)	0.000 (0.049)	0.513*** (0.173)	0.021 (0.041)
University/Graduate school	0.220* (0.125)	-0.046 (0.044)	0.582*** (0.195)	0.004 (0.046)
Tenure	0.016** (0.008)	0.001 (0.003)	0.014 (0.011)	0.003 (0.002)
Tenure squared	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Regular employment	0.147* (0.083)	0.032 (0.027)	-0.355*** (0.090)	-0.013 (0.020)
Administrative and managerial workers	-0.144	-0.020	0.148	-0.090

	(0.158)	(0.070)	(0.244)	(0.085)
Specialist professionals	-0.356**	-0.023	-0.037	0.011
	(0.142)	(0.065)	(0.198)	(0.045)
Clerical workers	-0.468***	-0.042	-0.093	-0.000
	(0.165)	(0.070)	(0.194)	(0.045)
Sales workers	-0.525***	-0.103	-0.306	-0.037
	(0.197)	(0.072)	(0.216)	(0.049)
Service workers	-0.229	-0.048	-0.095	-0.012
	(0.166)	(0.068)	(0.192)	(0.044)
Security workers	-0.480**	-0.113		
	(0.218)	(0.101)		
Agriculture, forestry and fishery workers	-0.272	-0.099	0.964***	-0.058
	(0.201)	(0.162)	(0.203)	(0.232)
Manufacturing process workers	-0.368**	-0.026	-0.187	-0.001
	(0.154)	(0.069)	(0.216)	(0.051)
Transport and machine operation workers	-0.542***	0.032	-0.207	0.174
	(0.189)	(0.078)	(0.696)	(0.139)
Construction and mining workers	-0.400**	-0.046	-0.225	-0.065
	(0.163)	(0.079)	(0.195)	(0.166)
Carrying, cleaning and related worker	-0.689***	-0.069	-0.223	0.007
	(0.206)	(0.080)	(0.250)	(0.056)
Company size (100~999 persons)	0.119*	-0.005	-0.187*	-0.038*
	(0.072)	(0.027)	(0.096)	(0.021)
Company size (above 1,000 persons)	0.149**	0.028	0.006	-0.015
	(0.071)	(0.029)	(0.118)	(0.027)
Company size (government and municipal office)	0.230***	0.039	0.181	0.018
	(0.085)	(0.039)	(0.118)	(0.033)
Constant	-1.619***	0.088	-1.415***	0.021
	(0.184)	(0.071)	(0.221)	(0.052)
Adj-R2	0.134	0.015	-	0.042
N	657	657	699	699
F-First Stage		11.61		27.45
Partial R2		0.018		0.039

Note: 1. *, **, and *** represent statistical significance at the 10%, 5% and 1% level, respectively. 2. Figures in parentheses are robust standard errors.

6. Discussion

This study examines the effect of subjective symptoms of sleeplessness on the labor productivity of respondents, using anonymous data from the Comprehensive Survey of Living Conditions. Taking the endogeneity problem of self-reported sleep deprivation into account, we adopt the instrumental variable method. Based on data availability, a dummy variable for sleep duration was used as an instrumental variable, following Sato (2016). The estimation results show that 1) in the analysis using the full sample, sleeplessness (subjective symptom) significantly reduces labor productivity; 2) heterogeneity exists in the estimation by gender, with the effect of sleeplessness observed to be statistically significant only for females.

Two problems exist in the analysis of this study. First, the cross-sectional data do not allow us to take into account the issues of missing variables and measurement bias. Second, in previous studies, the residential area's latitudinal information was collected and used as an instrumental variable. However, in this study, due to the nature of the anonymous data, we are unable to collect data on the respondents' residential areas.

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