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# ABSTRACT

## The Labour Market Returns to Sleep*

The proportion of people sleeping less than the daily-recommended hours has increased. Yet, we know little about the labour market returns to sleep. We use longitudinal data from Germany and exploit exogenous variation in sleep duration induced by time and local variations in sunset time. We find that a 1-hour increase in weekly sleep increases employment by 1.6 percentage points and weekly earnings by 3.4%. Most of this earnings effect comes from productivity improvements, while the number of working hours decreases with sleep time. We identify one mechanism driving these effects, namely the better mental health workers experience from sleeping more hours.

**JEL Classification:** I18, J12, J13

**Keywords:** sleep, employment, productivity, mental health, sunset times

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# 1 Introduction

There is a widespread concern that average sleep duration has decreased over the past 50 years, and that insufficient sleep has become a major public health issue (Roenneberg, 2013).[1] The adverse effects of sleep deprivation have potentially important consequences for economic activity. Insufficient sleep can impair cognitive abilities (Nuckols et al., 2009) and brain plasticity (Saper et al., 2005). It can give rise to errors in judgment, influencing organizational capacities (Barnes and Hollenbeck, 2009) as well as risk taking (Harrison and Horne, 1998). Sleep deprivation can also predict higher rate of workplace accidents (Barnes and Wagner, 2009) and a higher prevalence of heart attacks and chronic diseases (Moore et al., 2002; Giuntella and Mazzona, 2019; Jin and Ziebarth, 2020). Yet despite such detrimental consequences, little attention has been paid on the economic consequences of sleep deprivation, especially its impact on labour market performance.

To estimate the causal effects of sleep on work performance, it is important to control for individual heterogeneity in sleep routines (Jansson-Fröjmark et al, 2019), genetic predispositions in sleep time (Shi et al, 2019) or ability to deal with sleep deprivation, which are likely to be correlated with both sleep duration and labour market outcomes.[2] While some of these factors may vary over time, they are likely to be fixed across individuals. In order to deal with such omitted variables, it is therefore essential to rely on longitidunal data and include individual fixed-effects to estimate the causal effect of sleep on work performance. Existing studies have relied on repeated cross-sections (Gibson and Shrader, 2018; Giuntella and Mazzona, 2019). In this paper, we are the first to use longitudinal data and rely on the German Socio-Economic Panel between 2008 and 2019 to measure individual sleep and labour market performance. To get exogenous individual variations in sleep duration and avoid reverse causality, we combine these longitudinal data with an instrumental strategy using time and local variations in sunset time to instrument for sleep. The intuition behind this first-stage relationship is straightforward: earlier sunset times induce workers to go to bed earlier, and because work schedules do not respond as strongly to variation in sunset times (Hamermesh et al., 2008), earlier bedtimes encompass

[1] Although a recent Gallup survey in the US shows that the hours of sleep have not changed from 1990s, there is an hour difference in sleep compared to 1942.

[2] One could also imagine that individuals who have bias in reporting sleep duration may also have consistent bias in reporting labour market outcomes.

more sleep (Gibson and Shrader, 2018; Giuntella and Mazzona, 2019).

We make several contributions to the literature. First, we identify the effect of sleep duration on a range of outcomes including labour force participation, hours worked, and earnings - using a large-scale longitudinal dataset. Second, we dig into the specific mechanisms through which sleep affects labour market performance through the detailed analysis of workers' self-reported efficiency, stress, psychological well-being and health. This allows us to provide novel insights into how sleep can boost workers' productivity. Finally, we investigate the extent to which labour market returns to sleep are heterogeneous across different subgroups. This allows us to identify who are the individuals most likely to suffer from sleep deprivation and to opt out from the labour market/decrease their working hours due to sleep problems.

Providing empirical evidence on the causal impact of sleep on labour market performance requires large and exogenous variations in sleep duration. Our methodology relies on two sources of variation. First, within a location, earlier sunset times during the year can be associated with longer sleep. Using the interview date and respondent's region of residence, we assign daily local sunset time to each observation in the dataset and exploit the differences in interview days between survey waves for each respondent to capture the effect of daily local sunset time on respondent's sleep. Second, respondents living further east experience on average earlier sunset times than respondents living further west. We observe a bit less than 10% of individuals relocating to different regions between two survey waves in our dataset. We thus also rely on these geographical variations to capture the effect of sunset time on sleep duration. To the best of our knowledge, we are the first to capture exogenous variations in sleep duration relying on within-individual variations in interview days and region of residence (movers). This research designs allows us to get as close as possible to a quasi-natural experiment dealing with important confounders (such as sleeping routines, ability to deal with sleep deprivation or reporting bias) that are likely to affect results from cross-sectional estimates. By restricting our sample to non-movers, we can also disentangle how much of the sleep effects come from seasonal versus geographical variations.

Some clear results emerge from our analysis. We find that later sunset times significantly reduce sleep duration conditional on individual fixed effects. In fact, a 1-hour increase in sunset time reduces weekly sleep duration by 0.08-0.11 hours (roughly 5-7

minutes). 50% of our sample experience more than 30 minutes variations in sunset times over two consecutive interviews (among whom 20% experience more than 2 hours). And there are about 40 minutes differences in sunset times between east and west residents in Germany. For comparison, using cross-sectional variations in weekly sleep, Gibson and Shrader (2018) find that a 1-hour increase in sunset time reduces weekly sleep by 20 minutes. We then assess the impact of sleep variations induced by sunset times on respondent's labour market outcomes. We find that sleep exerts a positive effect on employment. An increase by 1 hour in sleep duration increases labour force participation by 1.6 percentage points. The effects are large in economic terms. At the intensive margin, we also find that sleep increases workers' earnings. Among full-time workers, a 1-hour increase in sleep would increase weekly earnings by 3.4%.

Changes in earnings may reflect changes in productivity or changes in the number of hours spent at work. Our dataset uniquely allows us to provide evidence on both channels. We find that a 1-hour increase in sleep is associated with significant increases in hourly wages. In contrast, a 1-hour increase in sleep reduces working hours by 0.8% among full-time workers. These results suggest that respondents who sleep more hours tend to be more productive at work. They also tend to spend less time on the labour market.

Investigating potential mechanisms, we find that an increase in sleep duration substantially increases worker's self-reported efficiency in completing tasks. We also document evidence that an increase in sleep duration increases (i) worker's ability to deal with stress, (ii) decreases the probability to experience negative emotions during the day and, (iii) is associated with better self-reported health. These results suggest that workers sleeping longer are more efficient and experience a better mental health. In quantitative terms, a 1-hour increase in sleep duration increases workers' mental health by 0.18 points on a 1-5 scale. This is equivalent to the mental health effects of having an increase in autonomy or security at work of about 50% (Clark et al., 2018). Under competitive markets, our results suggest that this increase in productivity through better mental health ultimately results in higher wages.

Importantly, we find that women and in particular mothers are those who are more likely to benefit from longer sleep. Women who sleep 1-hour more per week are 6.4 percentage points more likely to work, and when they work, their weekly earnings increase

by 4.6%. This increase in labour market participation is twice as much as that observed for men. Moreover, the increase in weekly earnings experienced by women from sleeping 1-hour more is 20% higher for women compared to men. This suggests that women would be those who would benefit the most from policies promoting sleep and encouraging individuals to allocate more time to sleep. Such policies would ultimately help reduce gender inequalities. Moreover, there is evidence that a 1-hour increase in sleep would not decrease women's working hours (compared to a 2% decrease for men). In addition, we find that parents are those who benefit the most from longer sleep. A 1-hour increase in sleep would increase parents' earnings by 6.9% on average (compared to 2.2% for non-parents). These are large differences consistent with the idea that parents and in particular mothers are more likely to suffer from sleep deprivation and to opt out from the labour market or experience lower earnings due to sleep deprivation (Costa-Font and Fleche, 2020).

Our findings are robust to a number of robustness checks, e.g. including individuals' socio-demographic controls, job characteristics, as well as housing characteristics, day temperature and other environmental factors. The identification assumption underlying our sunset time instrument is that there are enough variations in time and local sunset times within individuals and that these variations are exogenous to labour market performance (that is, they only affect respondents' labour market performance through sleep, conditional on our control variables). We provide support for this assumption by restricting our baseline specification to non-movers – using only seasonal variations to identify our sleep effects. We use this specification to test if endogenous sorting of respondents across locations could not bias our results. We also test that our results are not driven by seasonal confounders which would co-vary with both daily sunset time and labour market performance.

Our paper contributes to several strands of literature. First, it relates to the scarce literature on the relationship between sleep and labour in economics. Standard economic models of time allocation (Becker, 1965; Gronau, 1977) focus on "productive time" and "leisure time" and do not tend to model "sleep time" (Dunn, 1979). In a seminal work, Biddle and Hamermesh (1990) extend the analysis and consider a model where individuals optimize over sleep and other time uses (e.g. work, leisure and home production). While their model allows sleep to affect productivity at work, they do not test this re-

lationship in their empirical analysis. Instead, Biddle and Hamermesh provide evidence for the opposite relationship, that is the impact of wages on sleep duration. They find that individuals, whose time is more valuable, tend to substitute away time from sleep. Consistently, Szalontai (2006), Grandner et al. (2010), Bonke (2012) et Brochu et al. (2012) estimate a negative relationship between wages and sleep duration.

Our study most closely relates to Kamstra et al. (2000), Gibson and Shrader (2018) and Giuntella and Mazzona (2019). Using Daylight Saving Time as an exogenous variation in sleep duration, Kamstra et al. (2000) provide evidence that insufficient sleep impairs how individuals process information and negatively affects performance of stock market participations. Using cross-sectional time use data from the United States, Gibson and Shrader (2018) investigates sleep changes induced by variations in sunset times. They provide evidence that a 1-hour reduction in weekly sleep decreases earnings by 1.1% in the short run and 5% in the long run. Similarly, Giuntella and Mazzona (2019) use US time zone variations and provide evidence that later sunset times induce a reduction in income per capita by roughly 3% across commuting zones spanning across a time-zone boundary. Other studies focus on the relationship between insomnia, work accidents and absenteeism (see Metlaine et al., 2005 for a review), or cyberloafing (Wagner et al., 2012). Our approach differs from theirs in that we use longitudinal data and consider only differences in sleep patterns within individuals through time, rather than between individuals. This is important as it allows us to take into account genetic effects on sleep which are time invariant unobserved characteristics alongside sleep routines formed in early life which are likely to be correlated with both sleep and future labour market outcomes. Indeed, sleep routines can influence individuals' educational attainment as well as the ability to deal with sleep reduction, alongside the amount of sleep needed to stay alert. Following the same individuals over time is rare in observational studies investigating the relationship between sleep and labour market performance, one exception being Costa-Font and Fleche (2020) which rely on birth cohort data and focus on children-related sleep deprivation. They provide evidence that sleep disruptions induced by children negatively affect mothers' labour market performance. However, the effect is restricted to mothers, and therefore is not extensive to the entire active population.

This paper also complements recent work by Bessone et al. (2021). In their paper, the authors conduct a randomized three-week sleep intervention in India. They find that

increased night-time sleep exerts no effects on participants' cognition, productivity, decision making or wellbeing but lead to small decreases in labour supply. These results stand at odds with previous findings from the medical literature showing that sleep reduces mistakes (Ulmer et al., 2009), increases students' tests (Taras and Potts-Datema, 2005), or improve cognitive performance (Van Dongen et al., 2003) and depend on the experimental setting.[3] Our study allows us to investigate how sleep affects workers 'self-reported efficiency, decreases stress and improves psychological wellbeing using large-scale observational data. To capture the mechanisms through which sleep can affect labour market performance, it is important to study all these effects within the same sample of individuals. To the best of our knowledge, we are the first to provide evidence on these mechanisms using large-scale observational data and to show that these productivity effects are significantly related to mental health improvements.

Finally, our study relates to another important literature, which investigates the determinants of workers' productivity. The finding that sleep boosts workers' productivity relates to a recent stream of research, which have begun to incorporate insights from health and the psychology literature to consider further aspect of work like cognitive functioning, mood and affective states to understand workers' productivity (e.g., Krueger et al., 2009; Oswald et al., 2005; Bellet et al., 2021). It also relates to the growing literature that estimates the effect of environmental factors on workers' productivity. Relative to these studies, our paper focuses on sleep duration and how longer sleep can improve workers' productivity.

The remainder of the paper is organized as follows. Section II presents the data and the empirical strategy. Section III describes the central results of the paper and robustness checks. Section IV tests for underlying mechanisms and heterogeneous effects. Section V concludes.

[3]Other studies have also found a relationship between sleep and workplace accidents (Barnes and Wagner, 2009), car accidents (Smith, 2016), health (Jin and Ziebarth, 2020), depression or emotional states (Hansen et al., 2017).

# 2 Data and Empirical Strategy

This section describes the data, explains how we identify exogenous variations in sleep duration, and presents the empirical specification.

## 2.1 Data

To evaluate the labour market returns to sleep, we rely on the German Socio-Economic Panel (SOEP), which is a longitudinal survey of households and individuals produced by the German Institute for Economic Research (DIW Berlin) and which includes information on household composition, demography, employment, health, income, education, satisfaction indicators, among others. One of the main advantages of the German SOEP is its longitudinal dimension, which allows us to follow the same individuals over time and control for unobserved heterogeneity. Respondents are interviewed annually and most interviews occur between February and June (about 82%).

Although the SOEP began in 1984, we only use data from 2008 to 2019, which includes information on respondents' sleep duration and labour market outcomes. As we are interested in labour market effects of sleep, our final sample is restricted to those individuals aged between 15 and 64 and who are not self-employed. This gives us a sample size of roughly 20,200 individuals, for a total of approximately 86,000 observations. Additionally, for the analysis of employed individuals, we restrict our sample to individuals aged between 15 and 64 who report not being self-employed, who report receiving positive weekly earnings and who work full-time, as in Gibson and Shrader (2018). This sample contains about 15,300 respondents for a total of approximately 63,800 observations.

**Sleep Data**. The SOEP data include rich information on sleep. In particular, the dataset provides precise information on the number of hours slept. We use the individuals' answers to the following question: "How many hours of sleep do you have on average on a normal day during the working week? How many hours on a normal weekend day?" All these answers are given in complete hours. From these variables, we have also created another sleep variable, "weekly sleep", which measures the hours of sleep on a normal week, and allows us to match the frequency of our earnings variable:

Weekly sleep = (5*Sleep hours on workdays + 2*Sleep hours on weekends)

Table 1 reports the descriptive statistics. In our sample, respondents sleep on average 6.73 hours on a normal workday and 7.89 hours on weekends. This amounts to 49.46 hours on a normal week. The sleep information in SOEP relies on the cognitive ability of respondents to be able to estimate the average time they devote to different activities. One concern lies in that the sleep information refers to an average sleep duration, which may not vary with daily sunset times if respondents average it over the year. This issue means that our estimates relying on seasonal variations in sleep duration would be attenuated. An alternative to measuring sleep is time diaries and focuses on a restricted number of days where respondents are asked to fill their diaries. Unfortunately, this is not how sleep data are collected in SOEP. Reassuringly, Sonnenberg et al. (2011) find large associations between experience sampling time use questions and the standard survey questions of the SOEP for long lasting and externally structured activities such as sleep. We also provide evidence that within year, earlier sunset times are associated with longer sleep duration (see Section II.B.). We also find that average sleep responses vary with interview days in a meaningful way. This suggests that the average reference period used by SOEP respondents to report their sleep duration allows to capture meaningful seasonal (daily) variations.[4]

**Labour Market Outcomes**. We use several variables to capture the labour market effects of sleep. Table 1 provides the descriptive statistics for these outcomes. The first employment variable is a measure of employment status (whether the respondent is currently working). In our sample, 98% of respondents work and 75% declare working full-time. We also have information on weekly hours of work. The question included in SOEP refers to the actual hours currently work per week by respondent. The second-to-last row gives information on weekly earnings (i.e., the net monthly income reported by

[4]The SOEP data also include questions on sleep satisfaction and sleep disorder. Sleep satisfaction is assessed using the following question: "How satisfied are you today with your sleep?". Possible answers range from 0 (completely satisfied) to 10 (completely satisfied). Appendix Table A1 in the Online Appendix examines the correlation between the different measures of sleep used in this paper. Overall, we find significant correlations that suggest that sleeping more hours increases sleep satisfaction and having sleep disorder reduces sleep duration and sleep satisfaction.

respondent multiplied by 12 and divided by 52). The last employment-related outcome gives information on hourly wages (that is the weekly earnings reported by respondent divided by the number of actual hours currently worked per week). In our sample, full-time workers work on average 43.71 hours per week. They earn 498.08 euros on average per week and 11.34 euros per hours of work. Comparisons with other data sources suggest that these figures capture employment and earnings accurately in Germany.[5]

**Work Efficiency, Stress, Psychological Well-being, and Health**. Insufficient sleep may impair worker's performance at work by decreasing their alertness and their ability to process information (Kamstra et al., 2000; Killgore, 2010; Kahn et al., 2014; Wagner et al., 2012). It can also increase the risk of mental impairment and depression as well as workplace injuries (Barnes and Wagner, 2009). To test for these mechanisms, the SOEP data collect detailed information on worker's self-reported efficiency (e.g., whether worker is thorough; efficient and effective in completing tasks), stress (e.g., feeling of being rushed by time; whether respondent is nervous), emotional states (eg., frequency of being angry; worried; sad or happy), mental and physical health (using the SF-12 questionnaire or whether state of health affects daily activities). Detailed definitions of all these variables from the SOEP questionnaire can be found in the online Appendix.

## 2.2 Empirical Strategy

The main empirical issue in estimating the causal effect of sleep on labour market outcomes is that sleep and labour market performance may be endogenous. First, individuals who spend more time on the labour market and earn higher wages may sleep less on average. Second, both sleep and labour market performance may result from unobserved characteristics, which are not included in the model. Third, sleep duration on a normal week may be imperfect proxy of sleep quantity. Due to these issues, OLS estimates may be biased.

To overcome these issues, it is essential to rely on longitudinal data which allow to identify the effect of sleep on labour market performance by exploiting within-individual variations in sleep quantity and to deal with unobserved heterogeneity likely to affect both sleep duration and labour market outcomes. Furthermore, to account for omitted

[5]See https://www.destatis.de/

variables and deal with reverse causality, we implement an instrumental strategy based on time and local variations in sunset times within individuals to instrument for sleep variations using information from sunset map logs.[6]

**First-stage**. Using the interview date and respondent's region of residence, we assign sunset time to each observation in the dataset and begin by estimating the following first-stage equation:

$$Sleep_{irt} = \lambda_1 S_{rt} + X_{irt}\beta_1 + \delta_{1,t} + \mu_{1,r} + \eta_{1,i} + \epsilon_{1,irt} \tag{1}$$

where $Sleep_{irt}$ is our measure of sleep duration of individual $i$ at time $t$, in region (länder) $r$. $S_{rt}$ is the sunset time (in hour) at time $t$ in region $r$ that individual $i$ experiences. $X_{irt}$ is a vector of covariates that includes respondents' age group dummies and occupation dummies. $\delta_{1,t}$ are time fixed effects (i.e., day of week fixed effects and a dummy for being interviewed during summer).[7] $\mu_{1,r}$ are region fixed effects and $\eta_{1,i}$ are individual fixed effects. Standard errors are clustered at the region level.

Our source of identification corresponds to deviations in respondents' sleep duration through time. Sleep, and especially sleep time, evolves across the individuals' life cycle. Indeed, middle-aged individuals appear to sleep less than both older and younger counterparts (Bonke, 2012). Therefore, it is important to control for age. Similarly, occupation and job characteristics are likely to be related to both respondent's sleep and labour market performance (Mezick et al., 2008; Antillon et al., 2014). We therefore control for occupation dummies. Finally, individual fixed effects allow us to control for any unobserved heterogeneity across respondents, including genetic propensity for interrupted sleep, ability to deal with sleep deprivation, time-invariant environmental triggers (such as the presence of curtains, bed quality, or insulation at home, etc.) and respondent specific persistent reporting bias in sleep duration.

The relevance of sunset time as an instrument for sleep comes from a large medical

[6]https://sunrise.maplogs.com/ This website uses google maps to search and choose a location on earth. Then the location is send to a back-end server to perform sunrise and sunset time calculations. It provides sunrise and sunset times for a number of country and regions worldwide.

[7]Sleep may vary across time due to temperature or holidays. We therefore control for a summer dummy to capture some of these effects.

literature, which has demonstrated that the human body reacts to environmental light. As such, human circadian rhythm is synchronized with sunrise and sunset times. Based on this idea, Roenneberg et al. (2007) provide evidence using Germany data that later sunset times induce individuals to go to bed later and reduce sleep duration. Similarly, Gibson and Shrader (2018) and Giuntella and Mazzona (2019) demonstrate using time use data in the United States that a 1-hour increase in sunset time is associated with a reduction in sleep duration of roughly 20 minutes per week. Note that if people were able to compensate later sunset time by waking up later, we would not observe any effect on sleep duration. But because work schedules often tend to be rigid, many individuals are not able to compensate in the morning by waking up one hour late (Hamermesh et al., 2008).

Using sunset time as a source of exogenous variations actually provides two types of variation: (1) within a location, earlier sunset time during the year induces longer sleep duration. (2) comparing two locations, respondents living further east will experience earlier average sunset time than respondents living further west. As a consequence, respondents of the eastern location will sleep longer. We rely on these two types of sunset variations to estimate our sleep effects. More specifically, conditional on individual fixed effects, we first rely on differences in interview days between survey waves for each respondent to capture the seasonal effect of sunset time on respondent's sleep. By focusing on within-individual variations in interview days, our estimation strategy allows us to reduce the possibility that individual confounders correlated with seasonal effects (e.g. individuals with consistent reporting bias being systematically interviewed in Summer) would affect our estimates. Second, relying on individuals who relocate to different regions across survey waves, we also capture sunset time effects through spatial differences in sunset times for movers and their impacts on sleep duration. In contrast with cross-sectional estimates, this allows us to deal with geographical factors that would be systematically correlated with individual unobserved heterogeneity.

However, one important assumption underlying this strategy is that there are enough variations in time and local sunset times within individuals in our dataset. To provide evidence for this, we first compute within-individual variations in sunset times across two interview dates in our sample. We then plot the distribution in Figure 1. We see that 50% of our sample experience more than 30 minutes variations in sunset times over

two consecutive interviews (among whom 20% experience more than 2 hours). 20% of our sample experience between 15- and 30- minutes variations in sunset times and 30% less than 15 minutes variations.[8] This suggests that there are significant variations in interview dates (or regions of residence) between interviews in our dataset.[9], [10] Note however that the distribution is not uniformly distributed over days of the year, which suggests that the timing of interviews is not unconditionally random.

We also graphically examine the relationship between within-individual variations in sunset times and within-individual variations in sleep duration to provide evidence that these variations are meaningful. To construct Figure 2, we first average within-individual variations in weekly sleep between two interviews by within-individual variations in sunset times (in quarter of an hour). We then plot the means of the y-variable within each sunset time changes. The solid line shows the linear fit estimated. As expected, there is a strong relationship between variations in sunset times and variations in weekly sleep. Consistent with our hypothesis and previous findings from Gibson and Shrader (2018) and Giuntella and Mazzona (2019), this indicates that later sunset times reduces sleep duration on average. To interpret the magnitude, a 1-hour increase in sunset time decreases the average duration of sleep by 6 minutes within-individuals.[11]

**2SLS estimates**. We build on this first-stage relationship and examine the effect of sleep on respondents' labour market outcomes using sunset time as an instrument for sleep. More specifically, the 2SLS empirical specification we estimate is the following:

$$Sleep_{irt} = \lambda_1 S_{rt} + X_{irt}\beta_1 + \delta_{1,t} + \mu_{1,r} + \eta_{1,i} + \epsilon_{1,irt}$$

$$Y_{irt} = \alpha_2 Sleep_{irt} + X_{irt}\beta_2 + \delta_{2,t} + \mu_{2,r} + \eta_{2,i} + \epsilon_{2,irt} \quad (2)$$

[8]Note that 10.5% of respondents are observed only once in our sample.

[9]Only 10% of our sample were interviewed in the exact same week between two interviews (see Appendix Figure A1).

[10]There are a bit less than 10% movers in our sample. This means that most of our identification comes from seasonal variations.

[11]For comparison purpose, we can also replicate Figure 2 using cross-sectional variations in weekly sleep and sunset times. Consistent with Gibson and Shrader (2018), we find that a 1-hour increase in sunset time would increase weekly sleep duration by 15 minutes. See Appendix Figure A2.

where $Y_{irt}$ is the employment status, the number of hours worked, weekly earnings or hourly wages of individual $i$ at time $t$ in region $r$. $Sleep_{irt}$ is our measure of sleep duration instrumented by $S_{rt}$ the daily sunset time at time $t$ in region $r$. $X_{irt}$ is the same set of covariates in both equations (1) and (2), and $\delta_{2,t}$, $\mu_{2,r}$ and $\eta_{2,i}$ are time, region, and individual fixed effects. Standard errors are clustered at the regional level. Our coefficient of interest, $\alpha_2$, is the labour market effect of 1-hour increase in sleep duration.

The validity of our instrumental strategy relies on the idea that variations in sunset times affect respondents' labour market performance only through sleep – conditional on our control variables. While we control for individual, time, and region fixed effects, one could still be concerned about potential correlations between sunset times and labour market performance.

The primary threat to this identification strategy is seasonal confounders which would covary with labour market outcomes and sunset times within a location. We provide evidence that our results are robust to a wide range of seasonal confounders. We also provide evidence that our results are insensitive to the inclusion of individuals' socio-demographic characteristics, job characteristics, and housing characteristics. We can also make use of the amount of selection on observables as a guide to the amount of selection on unobservables (see Oster, 2017). Overall, the insensitivity of the results to our controls and the "modest" association between observables that determine the respondents' labour market outcomes allow us to conclude that the exclusion restriction is reasonable.

There is one identification issue we cannot address: seasonal variation in sunset time is almost perfectly correlated with sunrise and daylight duration. Therefore, all our results could be interpreted in terms of sunrise or daylight variations. Our exclusion restriction could be violated if variations in daylight duration affect mood, which itself influences labour market performance – and this mood effect will not go through sleep.

A residual source of variation relies on movers and geographical variations in sunset times. Endogenous sorting of respondents across locations could be correlated with unobserved characteristics related to both sunset times and labour market performance. In particular, if more productive individuals are more likely to move and to move to regions with earlier sunset time, that could violate the exclusion restriction. To avoid potential endogeneity, we provide evidence that our results remain similar when including region*individual fixed effects or restricting our sample to non-movers (that is, focusing

on seasonal variations in sunset times to estimate our effects).

# 3 Results

## 3.1 Baseline Results

Table 2 presents the central results of this paper and report two-stage least square (2SLS) estimates of the labour market returns to sleep. Appendix Table A2 reports control coefficients. We focus on respondent's weekly sleep duration – although robustness checks for workday and weekend sleep duration are reported in Appendix Tables A10 and A11.

First-stage regressions for the IV estimates are reported at the bottom of Table 2. The coefficients on sunset times are negative and significant, which confirms that an increase in sunset time decreases respondent's sleep duration. Quantitatively, a 1-hour increase in sunset times reduces respondent's weekly sleep duration by 0.08-0.11 hours (roughly 5-7 minutes). The weak identification tests produce large Kleibergen-Paap statistics (F>10) that compare favourably to the statistics reported in Stock and Yogo (2005). This allows us to reject the hypothesis of weak instruments for all regressions.

The coefficients on the instrumented sleep variable suggest large labour market returns to sleep. Column (1) is estimated on the full sample of respondents aged between 15 and 64, and who are not self-employed. The result shows a positive and significant relationship between respondent's sleep duration and employment probability. In terms of magnitude, the estimate in column (1), 0.016, indicates that a 1-hour increase in weekly sleep duration would increase the employment probability by 1.6 percentage points. In columns (2), (3) and (4), we then restrict the sample to full-time workers. We first test the effect of respondents' sleep duration on the number of hours worked (column (2)). The coefficient on respondent's sleep is negative and significant, indicating that a 1-hour increase in weekly sleep would reduce working hours by 0.8% on average. In column (3), we then use the log of weekly earnings as the dependent variable. The coefficient on respondent's sleep duration is statistically significant. The estimate in column (3) indicates that a 1-hour increase in weekly sleep would increase weekly earnings by 3.4%. Note that weekly earnings are a function of the number of hours worked per week times the hourly wage earned by respondent. Hence, if the number of hours worked per week decreases with

sleep but weekly earnings increase, this may suggest that most of the increase in weekly earnings is due to an increase in hourly wages. To test for this, column (4) presents the effect of respondent's sleep duration on the log of hourly wages (which we expect to pick up productivity effects). The effect is statistically significant and indicates that a 1-hour increase in weekly sleep would increase hourly wages by 4.2%, consistent with a productivity-enhancing role of sleep.

Overall, the results in Table 2 are consistent with the existence of large labour market returns to sleep. They suggest that respondents who sleep more hours on average tend to be more productive at work. They also tend to spend less time on the labour market. Does the magnitude of the 2SLS make sense? Overall, our results are consistent with available evidence from the sleep-labour literature. For example, Gibson and Shrader (2018) find that a 1-hour increase in weekly sleep increases earnings by 1.1% in the short run (using seasonal variations) and 5% in the long run (using geographical variations). Similarly, Costa-Font and Fleche (2020) find that a 1-hour increase in mother night-time sleep is associated with a 6.2% increase in household income. In practice, the estimates might be biased by measurement errors. But overall, they imply not implausibly large effects of sleep on respondent's labour market performance conditional on individual fixed-effects.

These results have large policy implications. They suggest that employers and firms aiming to increase their workers' productivity should consider adopting work schedules that allow them allocating enough time to sleep. Long working hours have been associated with sleep disturbances (short sleep, difficulty falling asleep, frequent waking) and sacrifying sleep for work can become an exhausting cycle. Our results suggest that allocating enough time to sleep could be an important step toward productivity. The effects are equivalent to the earnings effect of 6 additional months of schooling (Angrist and Krueger, 1991). This is substantial. Sleeping more hours is not only beneficial for workers' productivity, it also increases the probability of working. Individuals who are sleep deprived are more likely to remain out of the labor force. As a result, policies aiming to reduce unemployment should consider taking sleep deprivation into account. As an illustration, fatigue has been estimated to cost employers around $1,967 annually per employee (Rosekind et al., 2010) and up to 3 percent of GDP (Hafner et al., 2016).

## 3.2 Robustness checks

The previous results show that respondent's sleep increases labour force participation, decreases the number of hours worked and boost weekly earnings. However, several biases could affect our estimates. Therefore, this section is devoted to test whether our results are robust to several robustness checks and specification tests.

We begin by including various additional controls which are likely to be correlated with sunset times, respondent's sleep, and labour market performance, such as socio-demographic characteristics, job characteristics, house characteristics and environmental factors. Overall, we find that our results remain remarkably stable when including those controls. In Panel A of Table 3, we first examine the effects of additional socio-demographic controls such as education, marital status, the presence of children in the household, citizenship, and health status. Indeed, the existing literature on sleep has shown that groups of individuals with specific socio-economic characteristics tend to suffer more from sleeping problems (Arber et al., 2009; Asgeirsdottir  Olafsson, 2015; Grandner et al. 2010). For instance, adults with more education report fewer sleeping problems. Other salient individual's characteristics include the fact that partnered individuals exhibit better sleep quality (Grandner et al., 2010). One of the most common disruptions to sleep comes from new-born arrival (Costa-Font and Fleche, 2020). A recent study using British data finds that children reduce sleep by 4.2 minutes a day, single people sleep 4.8 minutes less and separated people 6.5 minutes less on average (Hafner et al, 2016). When including those controls in our baseline specifications, we find little effect on our 2SLS estimates. For example, the estimate of the effect of sleep duration on employment is 0.015 (s.e.= 0.005) with these additional socio-demographic controls. The effects on hours worked and earnings are now -0.0108 (s.e. = 0.003) and 0.029 (s.e. = 0.009), respectively.

Similarly, job characteristics can influence respondent's sleep and labour market performance. Work stress and the social situation at work are strongly linked to disturbed sleep and impaired awakening (Metlaine et al., 2005). To control for this, in Panel B, we include controls for the type of contract (temporary versus permanent), the number of years spent at current firm, and whether respondent is a civil servant or not. Again, including these controls has small quantitative effects on our 2SLS estimates. The coefficient on employment is now 0.012 (s.e.= 0.005). The coefficient on hours worked is

-0.006 (s.e.= 0.003) and the one on weekly earnings is now 0.027 (s.e.= 0.009).

Finally, house characteristics such as home insulation, the presence of curtains, as well as bed quality are likely to influence sleep quantity. The individual fixed effects capture most of these effects. However, in Panel C, we control for whether there is air conditioning in respondent's house. This may help respondents to deal with excessive temperatures at night. Our estimates of the effect of sleep on labour market performance do change but remain statistically significant. Overall, some deviations from our baseline estimates emerge after controlling for socio-demographic characteristics, job characteristics and house characteristics (Panel D). But overall, they remain remarkably similar and we can reject the null hypothesis that the coefficient on sleep is zero, with little effects from socio-demographic, job and house characteristics.[12]

Despite the inclusion of a wide range of controls, our estimates could still be biased by unobservable factors correlated with both sunset times and respondent's labour market performance. We try to assess this issue by implementing a strategy proposed by Oster (2017). In Panel D, we run two sets of regressions. We first run unconditional 2SLS regressions of respondent's labour market performance on weekly sleep duration (Appendix Table A4). We use the same instrumental strategy as before but only control for individual fixed effects. Our full regressions are those presented in Panel D of Table 3. Comparing the R-squared from these two set of regressions and computing the ratios suggested by Oster (2017), we find that none of the ratios associated with employment, the number of hours worked, weekly earnings and hourly wages (reported in Table 3), are less than 1. Their values which range from 14.88 to 59.25 suggest that selection on unobservables would have to be at least 15 times that on observables and on average over roughly 35 times as strong to account for the full effect of sleep on labour market performance. As additional evidence, Panel E reports the reduced-form effects of respondents' labour market performance on sunset times. All the relationships are statistically significant and have the expected signs. This suggests economically important effects of

[12]Still, it could be argued that if there are measurement errors in the controls, this could bias the control coefficients towards zero, and mechanically implies that including the controls does not affect our coefficients of interest. To deal with this issue, we run additional regressions where the additional individual variables, job and house characteristics variables are included as dependent variables in the baseline regressions. The regressions are presented in Appendix Table A3 and indicate positive and significant effects of respondent's sleep duration on these variables.

sunset times on labour market performance without requiring any exclusion restriction.

One might still argue that seasonal effects and selective migration may affect our results. One can try to further deal with seasonal effects by including daily minimum temperatures (Panel F) and quarter fixed effects (Panel G). Temperature data are derived from the European Climate Assessment Dataset (ECA D). They are merged using information on date of interview and location of respondent. Including deviations in daily minimum temperature barely change our estimates. The coefficient on employment is 0.016 (s.e.= 0.005). The coefficient on the number of working hours is now -0.008 (s.e.= 0.003). Further, the effect on earnings is 0.031 (s.e.= 0.010).[13] The estimates including quarter fixed effects do change. The coefficient on employment is 0.010 (s.e.= 0.006) and is not significant anymore. The coefficient on the number of working hours is now -0.007 (s.e.= 0.006). However, the effect on earnings remains very similar, at 0.030 (s.e.=0.017) and significant at the 10% level.

Finally, Panel H replicates our baseline estimates including individual*location fixed effects. This restricts our source of identification to within individual within location variation in sunset times. Our estimates slightly increase and remain statistically significant. Alternatively, in Appendix Tables A6-A7-A8-A9, we replicate our baseline estimates (i) restricting our sample to non-movers, (ii) including quarter fixed effects and individual*location fixed effects, (iii) individual*quarter fixed effects to restrict our source of identification to spatial differences in sunset time within individuals, and (iv) only movers. Our results remain qualitatively the same, which suggests that neither selective migration nor seasonal confounders fully explained our estimates. However, they suggest some interesting findings. When restricting our source of identification to spatial differences in sunset time within individuals (that is, focusing on movers), our coefficients on earnings increase by almost 50% at 0.049 (s.e.=0.036) (although they are barely significant). These results are consistent with Gibson and Shrader (2018) who find that a 1-hour increase in sleep duration would increase earnings by 5% in the long run (relying on geographical variations to identify their effects) compared to only 1.1% in the short run (using seasonal variations).[14]

[13] In Appendix Table A5, we control for maximum temperature instead of minimum temperature. The coefficients largely increase but remain significant.

[14] These tests also allow us to disentangle how much of our sleep effects on labour market performance are identified through seasonal variations and geographical variations. Relying on within individual

As additional robustness checks, in Appendix Tables A10 and A11, we also estimate our baseline results using sleep duration during a normal weekday and a normal weekend day as endogenous variables. Arguably, sleep deprived people may catch up with their sleep during weekends; hence sleep on workdays may have a larger impact on labour market performance than sleep during weekends. Our estimates confirm that insufficient sleep during workdays has larger negative effects on respondent's labour market performance than insufficient sleep experienced during weekends. We also replicate our findings controlling for sleep satisfaction (Appendix Table A12) and sleep disorder (Appendix Table A13). This allows us to control for sleep quality in addition to sleep quantity. Finally, in Appendix Table A14, we instrument respondent's sleep by deviations in minimum night temperature in addition to sunset time and in Appendix Table A15, we instrument respondent's sleep by sunrise time instead of sunset time. Similar results are obtained.

One could argue that for these results to be valid, there should be some wage flexibility, such that when sleep increases hourly wages could increase. In other words, we would expect those results to depend on how much workers are able to influence their hourly wages - within a week (or a month). If we expect some wage rigidity, by contrast, it is possible that most of the effects comes from the fact that people sleep more in the winter and are more likely to get pay rises then (in the new year). To test for this, Appendix Table A16 controls for a new year dummy (January month effect) in our baseline specifications. Our results remains very similar. Finally, we replicate our results on all workers (not only full-time workers) and include part-time workers (Appendix Table A17). We find that when increasing our sample size, our coefficients increase. The coefficient on weekly earnings is now 0.064 (s.e.=0.017) and the one on hourly wages is now 0.072 (s.e.=0.020). This could suggest that productivity (and wage) gains from longer sleep are higher among part-time workers, who might have more opportunities to adjust their hourly wages.

# 4 Potential Mechanisms and Heterogeneity

The previous section has shown that respondents are more likely to work, work fewer hours and earn higher salaries when they sleep more hours on average per week. These

changes in sunset time, it appears that most of our identification comes from seasonal variations.

results are robust to various tests. If sleep affects labour market performance, one might expect that one mechanism through which these relationships occur is via the positive effect sleep exerts on cognitive functioning and attention to work (Lim and Dinges, 2010; Killgore, 2010). Another mechanism would be the effect of sleep on worker's ability to deal with stress and mental wellbeing. Arguably, if workers are more focused and less stressed, they are more likely to report better health, which in turn increases their productivity at work. In this section, we document the impact of sleep on alternative outcomes and test for these underlying mechanisms. We then focus on the existence of heterogeneous effects across respondents.

**Work Efficiency, Stress, Psychological Well-being and Health**. One advantage of the SOEP data is the inclusion of several variables, which allow us to contribute to the literature by providing unique insights on the potential mechanisms through which sleep affects labour market performance. The first potential explanation advanced for the increase in productivity is that workers are more efficient at work. To test for this, we examine the effect of sleep duration on the worker's probability to report (i) being a thorough worker, and (ii) being effective and efficient in completing tasks. Self-reported measures of worker's efficiency at work are not necessarily a high-quality measure of productivity. Yet, we believe that this provides a first piece of evidence of whether workers sleeping more hours on average tend to be more efficient at work. Table 4, Panel A, reports the results. The estimated coefficients reveal that a 1-hour increase in weekly sleep duration is associated with a 2.5 percentage point increase in the probability of being a thorough worker and a 4.3 percentage point increase in the probability of being effective and efficient in completing tasks. The coefficient is only significant on the latter.

The second explanation invoked was that sleep duration reduces worker's stress and increases psychological wellbeing. In other words, workers are more productive because they feel more relaxed and less under pressure. In SOEP, respondents are asked whether they feel (i) nervous, and (ii) rushed by time. Columns (3) and (4) of Panel A indicate that a 1-hour increase in weekly sleep duration decreases the probability of being nervous by 2 percentage points and significantly reduces the probability of feeling rushed by time by 17.3 percentage points. This latter estimate reveals meaningful effects of sleep duration on worker's stress – equivalent to a decrease of roughly 50% in worker's stress, relative

to a sample mean of 41%. Arguably, if workers feel more relaxed, they are more likely to enjoy working and be more productive at work.

We provide further evidence for this mental health channel, by investigating the effects of sleep on worker's affective states and self-reported mental health. In the SOEP data, respondents are asked "during the last four weeks, how often did they feel: (i) angry, (ii) worried, (iii) sad, and (iv) happy". Possible answers range from (1) very rarely to (5) always. Sleep deprivation is likely to affect worker's mood. In our sample, 25% declare being very often or always angry, 5% worried, 10% sad and 60% happy. If respondents who sleep less on average, are also respondents who report more negative emotions, they may experience more problems at work or be less productive. Panel B of Table 4 report the results. The estimates reveal that workers who sleep more hours tend to be less angry and less sad on average. We do not find any significant effect on the frequencies of being worried or happy. We also investigate the effects of sleep duration on respondent's mental health using a summary measure of the SF-12 questionnaire. We replicate the baseline regression with this variable as alternative outcome. Interestingly, a 1-hour increase in sleep duration increases respondent's mental health by 0.18 points on 1-5 scale.

Finally, if workers are less under pressure and experience higher wellbeing, this might translate into better health. To examine such health effect, we study the effect of sleep duration on workers' probability of reporting that (i) their state of health affects their ability to perform tiring tasks and (ii) a composite measure of respondent's general health from the SF-12 questionnaire. In our sample, 13% of workers declare being limited in their activities due to health problems. Panel C reports the results. The estimates reveal a (non-significant) negative effect of weekly sleep duration on the probability that workers report being affecting in their ability to perform tiring tasks. We do however find significant and positive effects on worker's general health. In terms of magnitude, a 1-hour increase in weekly sleep duration would increase respondent's general health by 0.16 points on a 1-5 scale. These results are consistent with the idea that better sleep reduces absenteeism and workplace accidents. If workers are in better health, then they tend to be more productive.

Overall, these results are important – they provide a first attempt to explore potential mechanisms through which sleep can affect worker's productivity using large-scale longitudinal data. They highlight the influence of sleep on worker's efficiency, stress, psy-

chological wellbeing, and health and allow to shed new lights on previous findings from the literature (Bessone et al., 2021). However, our results are also somewhat hindered by the quality of the data and the small sample size.

**Other activities**. While more hours of sleep improve productivity at work, it can also increase productivity in other day-to-day activities. In other words, it is likely that longer sleep affect market work but also non-market activities such as leisure and home production. In the SOEP data, we have information on respondent's satisfaction with several times allocations, including leisure, home production and family life. We replicate our baseline regressions with these variables as alternative outcomes in Appendix Table A18. Interestingly, a 1-hour increase in sleep duration substantially increases housework satisfaction. The effects are large and meaningful, which suggests that the productivity effects of sleep duration are pervasive and go beyond work effects. We do not find any significant effects on leisure, family or life satisfaction though.

**Heterogeneity**. In Table 5, we also investigate heterogeneous effects with respect to: (i) gender, (ii) education, (iii) age, and (iv) parenthood. We find evidence of significant differences across these different subgroups. We see that the employment effects - on the extensive margins - are concentrated among women and respondents aged below 42 (the median age in our sample). This suggest that young women experiencing sleep deprivation are the ones who are more likely to opt out from the labour market. We also find that the productivity effects (looking at hourly wages for instance), are more pronounced for respondents with children and respondents aged above 42. Again, these results are important and suggest that women and in particular mothers would be those who would benefit the most from policies promoting sleep and encouraging firms to pay attention to sleep issues allowing to reduce gender inequalities.

# 5 Conclusions

To estimate the causal effects of sleep duration on labour market performance, it is important to rely on longitudinal data that allow considering within-individual variations in sleep duration and control for specific sleep routines, genetic predisposition to cope with

sleep deprivation or reporting bias that would be correlated with both sleep duration and labour market outcomes. In this paper, we rely on the German Socio-Economic Panel and exploit daily variations in local sunset times as an instrument for sleep duration. Importantly, our dataset allows us to investigate the causal effects of sleep on a range of labour market outcomes, including labour force participation, hours worked and earnings, and to provide unique evidence on the mechanisms through which sleep affects labour market performance.

We find that an increase in sleep duration significantly increases labour force participation and weekly earnings. We document that a 1-hour increase in sleep duration increases labour force participation by 1.6 percentage points and weekly earnings by 3.4%. Moreover, we find that the number of working hours slightly decreases with sleep duration; that is, most of the earnings effects come from productivity changes. Interestingly, women and in particular mothers are more likely to experience an increase in labour force participation and earnings when allocating more time to sleep. These results are consistent with sleep playing an important role in preventing women with young children to go back to work and could be an additional explanation to the child wage penalty experienced by women.

Investigating potential mechanisms, we find that an increase in weekly sleep duration increases worker's efficiency in completing tasks and substantially decreases the feeling of being rushed by time. Although other mechanisms are likely to be at work, we find that the mental health effects associated with sleep seem to play a key role in shaping the labour market returns to sleep. In return, we find beneficial effects on worker's physical health.

The results of our study are important because they highlight how sleep can exert economically significant productivity gains. They can also help us shed light on the returns to interventions attempting to address sleep deprivation. For instance, we find that workers who sleep 1 hour longer are more efficient at work by 4.3 percentage points; they are more productive within shorter hours of work (0.8% reduction in weekly working hours). Therefore, if a policy is introduced that allows workers to sleep 1 hour more per week then our results suggest that they are more likely to work by 1.6 percentage points and to earn higher salaries by 3.4% in response to this change.

One promising avenue for policy could be to engage workers in training and informa-

tion campaigns in which the idea is conveyed that sleep is productivity-enhancing and enough time should be allocated to sleep per night. Another avenue for policy could be to encourage firms to recognise the importance of sleep and to adopt flexible working hours allowing workers to have enough time to sleep. However, whether such interventions would be successful in improving sleep and labour market performance is beyond the scope of this article and is an open question that future research should address.

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# 7 Figures and Tables

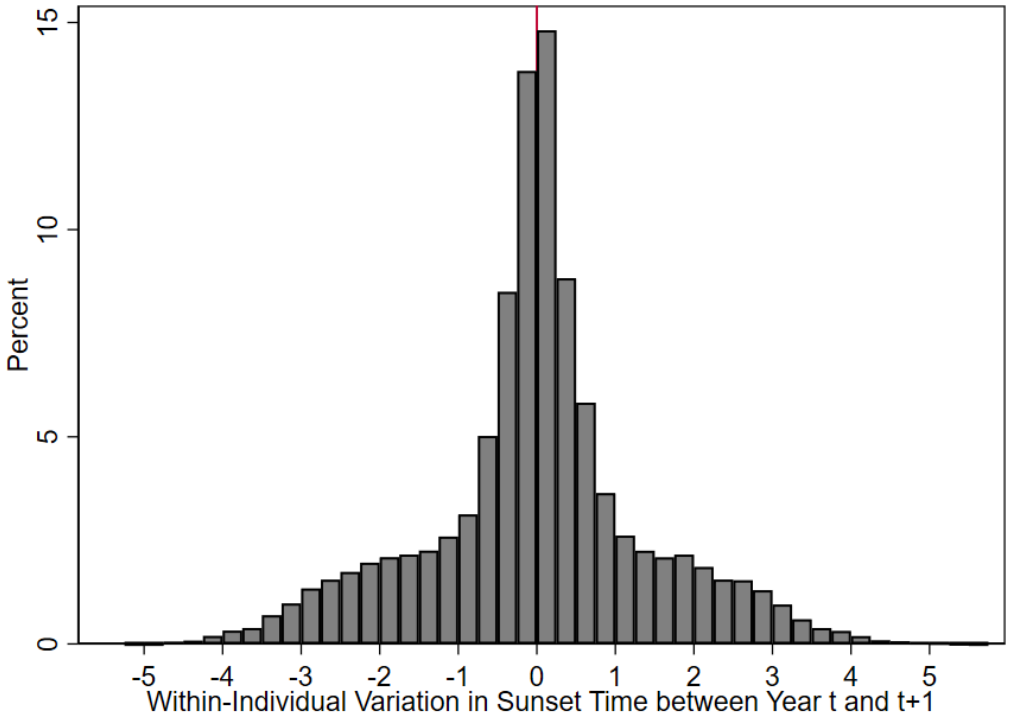
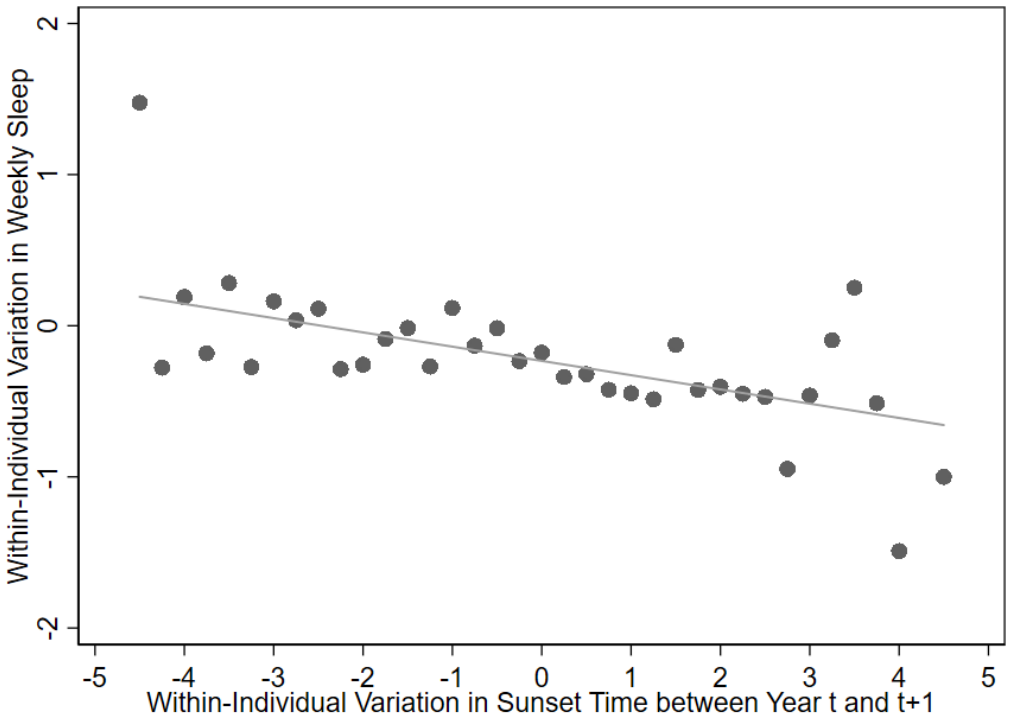



FIGURE 1: Within-Individual Variation in Sunset Time

Notes: The figure is a histogram of within-individual variation in daily local sunset time across two consecutive interview dates.




Coef = -0.094*** (0.000) R2=0.426

FIGURE 2: Changes in Sleep Hours on a Normal Week by Changes in Sunset Time

Notes: The figure is a scatter plot of within-individual variation in weekly sleep duration against within-individual variation in sunset time across two interview dates. To construct this scatter plot, we first average within-individual weekly sleep duration by within-individual variation in sunset time (in quarter of an hour). We then plot the means of the y-variable within each sunset time quarter change. The solid line shows the linear fit estimated.

TABLE 1 - Descriptive Statistics

| | | Mean (1) | SD (2) | Min (3) | Max (4) |
|---|---|---|---|---|---|
| Sleep variables | | | | | |
| | Sleep during workdays | 6.73 | 1.00 | 2 | 10 |
| | Sleep during weekends | 7.89 | 1.20 | 2 | 10 |
| | Total weekly sleep | 49.46 | 6.53 | 14 | 70 |
| Employment variables | | | | | |
| | Employed | 0.98 | 0.13 | 0 | 1 |
| | Working full-time | 0.75 | 0.43 | 0 | 1 |
| | Weekly hours worked | 43.71 | 6.65 | 25 | 80 |
| | Weekly earnings | 498.08 | 298.17 | 5.08 | 11538.46 |
| | Hourly wages | 11.35 | 6.03 | 0.13 | 174.82 |

Notes: This table provides the list, arithmetic mean and standard deviations alongside extreme values of all sleep and labour variables of interest. Figures in rows (1) to (5) are estimated on the full sample of respondents aged between 15 and 64, who are not self-employed and for whom we have sleep duration observations. Figures in rows (6) to (8) are estimated on the sample of respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and are working full-time.

TABLE 2 - IV Estimates of the Effect of Sleep on Labour Market Outcomes

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Panel A: 2SLS | | | | |
| Sleep | 0.016*** | -0.008** | 0.034*** | 0.042*** |
| | (0.005) | (0.003) | (0.010) | (0.012) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 86,044 | 63,179 | 63,811 | 63,122 |
| | Sleep | Sleep | Sleep | Sleep |
| | (1) | (2) | (3) | (4) |
| Panel B: First-Stage | | | | |
| Sunset | -0.083*** | -0.109*** | -0.112*** | -0.110*** |
| | (0.014) | (0.016) | (0.014) | (0.015) |
| Observations | 86,044 | 63,179 | 63,811 | 63,122 |
| F-statistics | 34.09 | 51.77 | 56.74 | 53.11 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

TABLE 3 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Robustness Checks

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Panel A: Socio-demo. controls | | | | |
| Sleep | 0.015*** | -0.008** | 0.029*** | 0.037*** |
| | (0.005) | (0.003) | (0.009) | (0.011) |
| Observations | 86,014 | 63,156 | 63,787 | 63,099 |
| F-statistics | 37.08 | 57.05 | 61.85 | 58.27 |
| Panel B: Job characteristics | | | | |
| Sleep | 0.012*** | -0.006** | 0.027*** | 0.033*** |
| | (0.005) | (0.003) | (0.009) | (0.010) |
| Observations | 82,181 | 60,678 | 61,252 | 60,630 |
| F-statistics | 38.34 | 49.69 | 55.53 | 50.84 |
| Panel C: House characteristics | | | | |
| Sleep | 0.019*** | -0.010** | 0.055*** | 0.066*** |
| | (0.006) | (0.004) | (0.018) | (0.021) |
| Observations | 75,585 | 54,253 | 54,826 | 54,195 |
| F-statistics | 22.14 | 23.21 | 26.30 | 23.70 |
| Panel D: All controls | | | | |
| Sleep | 0.012*** | -0.008** | 0.034*** | 0.041*** |
| | (0.004) | (0.003) | (0.013) | (0.014) |
| Observations | 69,817 | 51,796 | 52,310 | 51,746 |
| F-statistics | 27.56 | 26.93 | 30.23 | 27.33 |
| Oster(2017) | 14.88 | 23.40 | 59.26 | 43.75 |
| Panel E: Reduced-form estimates | | | | |
| Sleep | -0.001*** | 0.001*** | -0.004*** | -0.005*** |
| | (0.000) | (0.000) | (0.001) | (0.001) |
| Observations | 96,202 | 71,334 | 71,976 | 71,269 |
| Panel F: Including min. temperature | | | | |
| Sleep | 0.016*** | -0.008** | 0.031*** | 0.039*** |
| | (0.005) | (0.003) | (0.010) | (0.012) |
| Observations | 85,778 | 62,990 | 63,620 | 62,933 |
| F-statistics | 34.98 | 58.76 | 62.69 | 60.45 |
| Panel G: Including quarter FEs | | | | |
| Sleep | 0.010 | -0.007 | 0.030* | 0.037* |
| | (0.006) | (0.006) | (0.017) | (0.019) |
| Observations | 86,044 | 63,179 | 63,811 | 63,122 |
| F-statistics | 17.71 | 28.12 | 25.82 | 29.10 |
| Panel H: Including ind.*location FEs | | | | |
| Sleep | 0.015** | -0.009** | 0.035*** | 0.044*** |
| | (0.005) | (0.004) | (0.012) | (0.013) |
| Observations | 85,527 | 62,796 | 63,426 | 62,739 |
| F-statistics | 33.13 | 45.82 | 50.40 | 47.04 |

TABLE 4 - IV Estimates of the Effect of Sleep on Work Efficiency, Stress, Affective States and Health

| | A thorough worker | Effective and efficient in completing tasks | Nervous | Feel rushed by time |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Panel A: Work efficiency & Stress | | | | |
| Sleep | 0.025 | 0.043*** | -0.020 | -0.173* |
| | (0.032) | (0.016) | (0.022) | (0.093) |
| Observations | 21,593 | 21,563 | 21,560 | 13,193 |
| Outcome mean | 0.45 | 0.72 | 0.26 | 0.41 |
| Outcome SD | 0.50 | 0.45 | 0.44 | 0.49 |
| F-Statistics | 22.17 | 22.39 | 21.64 | 2.534 |
| | Angry | Worried | Sad | Happy |
| | (5) | (6) | (7) | (8) |
| Panel B: Affective states | | | | |
| Sleep | -0.102*** | -0.035 | -0.116** | -0.012 |
| | (0.021) | (0.033) | (0.051) | (0.019) |
| Observations | 56,913 | 56,847 | 56,878 | 56,878 |
| Outcome mean | 2.88 | 1.79 | 2.20 | 3.63 |
| Outcome SD | 0.96 | 0.88 | 0.96 | 0.79 |
| F-Statistics | 35.97 | 35.17 | 34.68 | 35.89 |
| | Mental health score | State of health affect tiring tasks | General health | |
| | (9) | (10) | (11) | |
| Panel C: Health | | | | |
| Sleep | 0.184* | -0.132 | 0.161* | |
| | (0.095) | (0.085) | (0.091) | |
| Observations | 13,211 | 13,191 | 13,198 | |
| Outcome mean | 3.21 | 1.44 | 3.41 | |
| Outcome SD | 0.70 | 0.59 | 0.67 | |
| F-Statistics | 2.663 | 2.638 | 2.539 | |

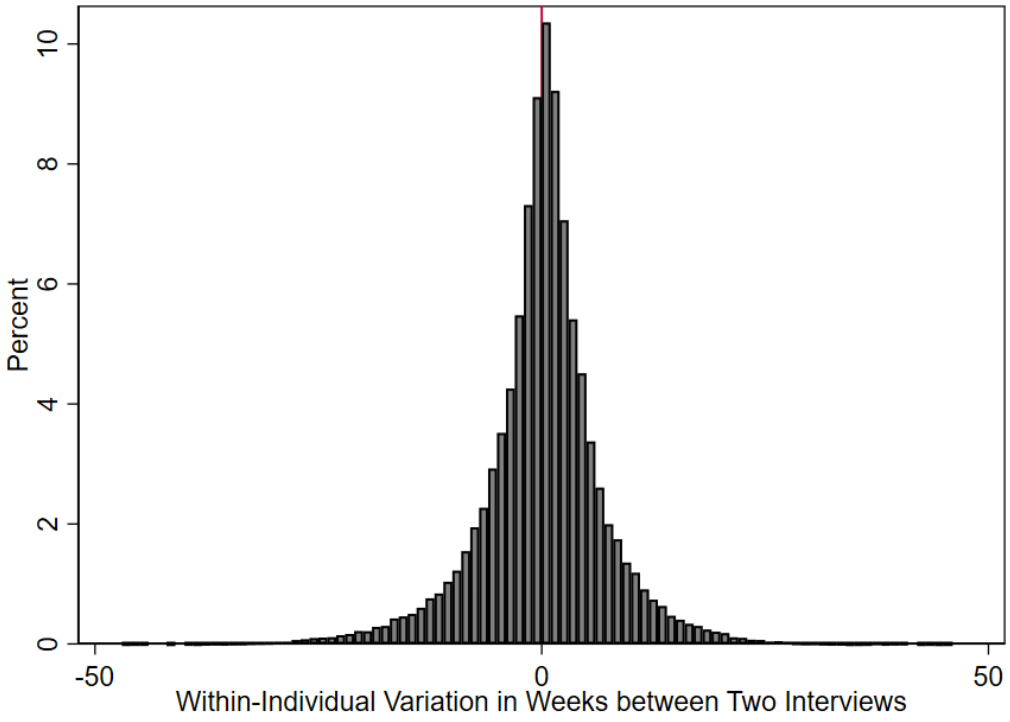
Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on work efficiency, stress, affective states, and health. Weekly sleep duration is instrumented using local variations in daily sunset times. All coefficients are estimated on respondents aged between 15 and 64, who are not self-employed, who declare positive weekly earnings and who are working full-time. We control for age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

TABLE 5 - Heterogeneity of the Effect of Sleep on Labour Market Outcomes

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Panel A: Sex | | | | |
| Male | 0.027** | -0.020** | 0.038*** | 0.042*** |
| | (0.011) | (0.008) | (0.018) | (0.018) |
| Observations | 45,122 | 35,957 | 34,157 | 31,537 |
| F-statistics | 25.66 | 13.58 | 12.25 | 9.74 |
| Female | 0.064* | 0.000 | 0.046*** | 0.036*** |
| | (0.034) | (0.005) | (0.016) | (0.011) |
| Observations | 47,404 | 16,815 | 16,063 | 15,183 |
| F-statistics | 4.25 | 14.75 | 13.64 | 16.24 |
| Panel B: Education | | | | |
| Low educated | 0.017** | -0.009* | 0.031*** | 0.040*** |
| | (0.008) | (0.005) | (0.009) | (0.011) |
| Observations | 41,260 | 30,155 | 30,494 | 30,124 |
| F-statistics | 17.91 | 20.53 | 22.31 | 21.19 |
| Hihgly educated | 0.016*** | -0.007 | 0.038** | 0.044** |
| | (0.005) | (0.007) | (0.017) | (0.019) |
| Observations | 44,500 | 32,820 | 33,105 | 32,794 |
| F-statistics | 20.53 | 19.65 | 20.37 | 20.14 |
| Panel C: Age | | | | |
| Below median | 0.031*** | -0.014** | 0.021 | 0.034 |
| | (0.011) | (0.006) | (0.023) | (0.025) |
| Observations | 38,151 | 26,890 | 27,157 | 26,854 |
| F-statistics | 13.48 | 25.39 | 27.65 | 25.63 |
| Above median | 0.007 | -0.004 | 0.042*** | 0.046*** |
| | (0.005) | (0.004) | (0.011) | (0.012) |
| Observations | 45,970 | 34,797 | 35,163 | 34,775 |
| F-statistics | 23.74 | 31.84 | 31.45 | 33.58 |
| Panel D: Children | | | | |
| No child | 0.013*** | -0.005 | 0.022 | 0.028* |
| | (0.004) | (0.004) | (0.016) | (0.014) |
| Observations | 44,699 | 34,481 | 34,875 | 34,464 |
| F-statistics | 13.40 | 39.66 | 37.12 | 40.95 |
| With children | 0.019* | -0.012 | 0.069*** | 0.081*** |
| | (0.011) | (0.008) | (0.018) | (0.022) |
| Observations | 38,812 | 26,767 | 27,003 | 26,726 |
| F-statistics | 14.43 | 22.23 | 24.67 | 22.44 |

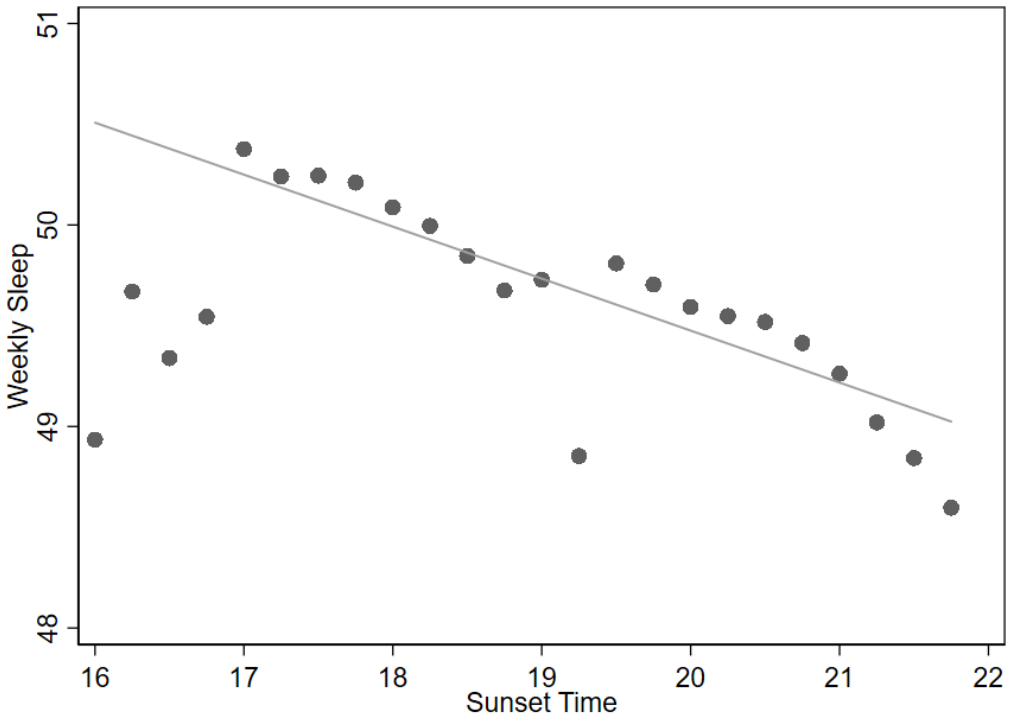
Notes: See Table 2

# 8 Online Appendix




APPENDIX FIGURE A1: Within-Individual Variation in Weeks of Interviews

Notes: The figure is a histogram of within-individual variation in weeks of interview across two consecutive interview dates.




Coef = -0.258*** (0.000) R2=0.730

APPENDIX FIGURE A2: Sleep Hours on a Normal Week by Sunset Times

Notes: The figure is a scatter plot of cross-sectional variation in weekly sleep duration against cross-sectional variation in sunset time. To construct this scatter plot, we first average weekly sleep duration by sunset time (in quarter of an hour). We then plot the means of the y-variable within each sunset time. The solid line shows the linear fit estimated.

APPENDIX TABLE A1 - Raw Correlations Between Sleep Variables

| | Weekly sleep | Sleep during workdays | Sleep during weekends | Sleep satisfaction | Sleep disorder |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Weekly sleep duration | 1 | | | | |
| Sleep during workdays | 0.949 | 1 | | | |
| Sleep during weekends | 0.757 | 0.511 | 1 | | |
| Sleep satisfaction | 0.355 | 0.339 | 0.258 | 1 | |
| Sleep disorder | -0.190 | -0.174 | -0.154 | -0.284 | 1 |

Notes: All correlations are significant at the 1% level. Weekly sleep duration, sleep during workdays and sleep during weekends are in hours. Sleep satisfaction goes from 0 to 10. And sleep disorder is a dummy equal to (1) if respondent has a sleep disorder.

APPENDIX TABLE A2 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Full Results

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.016*** | -0.008** | 0.034*** | 0.042*** |
| | (0.005) | (0.003) | (0.010) | (0.012) |
| Age dummies: | | | | |
| dage_2 | 0.029*** | 0.009** | 0.475*** | 0.469*** |
| | (0.006) | (0.003) | (0.014) | (0.016) |
| dage_3 | 0.054*** | -0.010 | 0.660*** | 0.673*** |
| | (0.010) | (0.007) | (0.019) | (0.023) |
| dage_4 | 0.064*** | -0.018** | 0.790*** | 0.811*** |
| | (0.012) | (0.008) | (0.021) | (0.025) |
| dage_5 | 0.072*** | -0.038*** | 0.881*** | 0.922*** |
| | (0.015) | (0.010) | (0.026) | (0.031) |
| Day of week dummies: | | | | |
| day_w_2 | 0.002 | -0.001 | -0.026*** | -0.027*** |
| | (0.003) | (0.002) | (0.004) | (0.004) |
| day_w_3 | 0.003 | -0.001 | -0.023*** | -0.023*** |
| | (0.003) | (0.002) | (0.004) | (0.005) |
| day_w_4 | 0.004 | -0.002 | -0.023*** | -0.022*** |
| | (0.003) | (0.002) | (0.006) | (0.007) |
| day_w_5 | 0.007*** | 0.000 | -0.022*** | -0.025*** |
| | (0.002) | (0.002) | (0.004) | (0.005) |
| day_w_6 | 0.005* | -0.000 | -0.021*** | -0.023*** |
| | (0.003) | (0.001) | (0.005) | (0.006) |
| day_w_7 | 0.004 | -0.001 | -0.016*** | -0.016*** |
| | (0.003) | (0.002) | (0.004) | (0.003) |
| Location dummies: | | | | |
| area_2 | -0.005 | 0.005 | -0.052 | -0.062 |
| | (0.011) | (0.017) | (0.037) | (0.044) |
| area_3 | 0.016 | 0.007 | 0.079 | 0.059 |
| | (0.016) | (0.022) | (0.052) | (0.060) |
| area_4 | 0.011 | 0.025 | -0.059 | -0.095 |
| | (0.016) | (0.029) | (0.057) | (0.069) |
| area_5 | 0.020 | 0.017 | 0.027 | 0.010 |
| | (0.020) | (0.024) | (0.057) | (0.067) |
| area_6 | 0.025 | -0.008 | 0.102 | 0.103 |
| | (0.022) | (0.028) | (0.079) | (0.087) |
| area_7 | 0.018 | 0.024 | 0.105 | 0.075 |
| | (0.030) | (0.030) | (0.089) | (0.088) |
| area_8 | 0.026 | 0.007 | 0.139** | 0.126* |
| | (0.020) | (0.023) | (0.058) | (0.066) |

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| area_9 | 0.037* | 0.024 | 0.173*** | 0.140** |
| | (0.021) | (0.025) | (0.058) | (0.068) |
| area_10 | 0.091 | -0.010 | -0.051 | -0.048 |
| | (0.088) | (0.045) | (0.259) | (0.276) |
| area_11 | 0.014 | 0.030 | -0.022 | -0.063 |
| | (0.022) | (0.029) | (0.053) | (0.061) |
| area_12 | -0.013 | 0.048* | 0.053 | -0.008 |
| | (0.022) | (0.026) | (0.057) | (0.062) |
| area_13 | -0.000 | 0.020 | -0.144** | -0.190*** |
| | (0.022) | (0.027) | (0.063) | (0.062) |
| area_14 | -0.011 | 0.044 | -0.001 | -0.064 |
| | (0.029) | (0.029) | (0.077) | (0.084) |
| area_15 | 0.020 | 0.059** | -0.173** | -0.227*** |
| | (0.034) | (0.024) | (0.076) | (0.078) |
| area_16 | 0.014 | 0.022 | 0.018 | -0.013 |
| | (0.023) | (0.036) | (0.091) | (0.098) |
| Occupation dummies: | | | | |
| occupa_2 | 0.002 | -0.001 | -0.005 | -0.004 |
| | (0.008) | (0.007) | (0.019) | (0.020) |
| occupa_3 | 0.010 | 0.010** | -0.002 | -0.012 |
| | (0.007) | (0.005) | (0.022) | (0.023) |
| occupa_4 | 0.009 | 0.002 | -0.024 | -0.027 |
| | (0.008) | (0.005) | (0.025) | (0.028) |
| occupa_5 | 0.011 | -0.003 | -0.014 | -0.015 |
| | (0.009) | (0.006) | (0.017) | (0.018) |
| occupa_6 | 0.017 | 0.026 | -0.013 | -0.036 |
| | (0.027) | (0.024) | (0.041) | (0.056) |
| occupa_7 | 0.005 | -0.003 | -0.011 | -0.008 |
| | (0.009) | (0.007) | (0.023) | (0.027) |
| occupa_8 | 0.013* | -0.005 | -0.040* | -0.034 |
| | (0.007) | (0.012) | (0.021) | (0.021) |
| occupa_9 | -0.016 | -0.010 | -0.042* | -0.033 |
| | (0.016) | (0.009) | (0.024) | (0.027) |
| Summer | -0.000 | 0.001 | 0.016** | 0.015** |
| | (0.002) | (0.002) | (0.007) | (0.007) |
| Observations | 86,044 | 63,179 | 63,811 | 63,122 |
| F-statistics | 34.09 | 51.77 | 56.74 | 53.11 |

Notes: See Table 2

APPENDIX TABLE A3 - IV Estimates of the Effect of Sleep Duration on Potential Covariates

| | Being married | Year of education | Permanent contract | Experience at firm | Deviations in minimum temperature |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Sleep | 0.023** | 0.011 | 0.025*** | 0.527*** | 0.728*** |
| | (0.008) | (0.008) | (0.009) | (0.201) | (0.249) |
| Individual controls | Yes | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes | Yes |
| Observations | 53,212 | 53,398 | 51,968 | 53,360 | 53,222 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on potential covariates. Weekly sleep duration is instrumented using local variations in daily sunset times. All coefficients are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A4 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Unconditional Regressions

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.023*** | -0.014** | 0.079*** | 0.095*** |
| | (0.006) | (0.004) | (0.016) | (0.019) |
| Individual controls | No | No | No | No |
| Time FE | No | No | No | No |
| Location FE | No | No | No | No |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 86,044 | 63,179 | 63,811 | 63,122 |
| F-statistics | 26.85 | 46.86 | 49.95 | 48.28 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A5 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Controlling for Maximum Temperature

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.029** | -0.008 | 0.095*** | 0.107*** |
| | (0.012) | (0.010) | (0.028) | (0.038) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 85,777 | 62,990 | 63,620 | 62,933 |
| F-statistics | 7.886 | 6.129 | 7.844 | 6.332 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for age group dummies, indicators for summer season, daily maximum temperature, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A6 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Restricting to Non-Movers

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.015*** | -0.009** | 0.034*** | 0.043*** |
| | (0.005) | (0.003) | (0.013) | (0.014) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 81,277 | 59,703 | 60,290 | 59,647 |
| F-statistics | 32.44 | 43.02 | 47.31 | 44.12 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed, and who did not move to another region of residence across the entire period. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings, who declare working full-time and who did not move to another region of residence across the entire period. We control for age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A7 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Controlling for Quarter FEs and Individual*Location FEs

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.008 | -0.008 | 0.026 | 0.035* |
| | (0.006) | (0.006) | (0.017) | (0.019) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Quarter FE | Yes | Yes | Yes | Yes |
| Individual*Location FE | Yes | Yes | Yes | Yes |
| Observations | 85,527 | 62,796 | 63,426 | 62,739 |
| F-statistics | 16.60 | 28.52 | 26.17 | 29.50 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects, quarter fixed effects and individual*location fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A8 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Controlling for Individual*Quarter FEs

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | -0.001 | -0.006 | 0.017* | 0.021* |
| | (0.004) | (0.006) | (0.009) | (0.010) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Quarter FE | Yes | Yes | Yes | Yes |
| Individual*Quarter FE | Yes | Yes | Yes | Yes |
| Observations | 71,267 | 52,296 | 52,853 | 52,258 |
| F-statistics | 41.88 | 35.29 | 32.51 | 34.55 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects, quarter fixed effects and individual*quarter fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A9 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Only Movers

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.026 | -0.005 | 0.049 | 0.047 |
| | (0.035) | (0.012) | (0.036) | (0.037) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 4,224 | 3,094 | 3,137 | 3,093 |
| F-statistics | 1.246 | 3.992 | 4.052 | 3.901 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A10 - IV Estimates of the Effect of Sleep during Workdays on Labour Market Outcomes

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.140*** | -0.062** | 0.292*** | 0.357*** |
| | (0.044) | (0.026) | (0.089) | (0.102) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 88,056 | 64,605 | 65,260 | 64,548 |
| F-statistics | 17.15 | 32.20 | 37.04 | 33.06 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in sleep during workdays the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A11 - IV Estimates of the Effect of Sleep during Week-ends on Labour Market Outcomes

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.074*** | -0.038** | 0.165*** | 0.197*** |
| | (0.026) | (0.013) | (0.056) | (0.061) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 86,094 | 63,218 | 63,850 | 63,161 |
| F-statistics | 35.12 | 46.70 | 47.94 | 46.70 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in sleep during work-ends the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A12 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Controlling for Sleep Satisfaction

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.013*** | -0.007** | 0.032*** | 0.039*** |
| | (0.005) | (0.003) | (0.011) | (0.012) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 84,642 | 62,157 | 62,779 | 62,103 |
| F-statistics | 38.32 | 42.69 | 43.98 | 42.70 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for sleep satisfaction, age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A13 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Controlling for Sleep Disorder

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.012*** | -0.007** | 0.012 | 0.019** |
| | (0.004) | (0.003) | (0.008) | (0.009) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 86,044 | 63,179 | 63,811 | 63,122 |
| F-statistics | 40.22 | 60.77 | 66.41 | 62.38 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for sleep disorder, age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A14 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Using Minimum Temperature as Additional IV

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.012** | -0.007*** | 0.013* | 0.019** |
| | (0.005) | (0.003) | (0.008) | (0.009) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 85,778 | 62,990 | 63,620 | 62,933 |
| F-statistics | 17.49 | 31.51 | 32.50 | 32.62 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times and daily minimum temperatures. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for sleep disorder, age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A15 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Using Sunrise As Alternative Instrument

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.011*** | -0.007** | 0.040*** | 0.049*** |
| | (0.003) | (0.003) | (0.013) | (0.014) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations 86,044 | 63,179 | 63,811 | 63,122 | |
| F-statistics | 23.42 | 33.92 | 36.64 | 34.97 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunrise times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for age group dummies, indicators for summer season, daily maximum temperature, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A16 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Including New Year Dummy

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.016*** | -0.008** | 0.034*** | 0.041*** |
| | (0.005) | (0.003) | (0.010) | (0.011) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 86,044 | 63,179 | 63,811 | 63,122 |
| F-statistics | 34.62 | 51.79 | 56.87 | 53.11 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. The first estimate (working) is estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. The three estimates to the right are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for age group dummies, indicators for summer season, an indicator for being in January, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A17 - IV Estimates of the Effect of Sleep on Labour Market Outcomes - Full Sample

| | Working | Log (Hours Worked) | Log (Weekly Earnings) | Log (Hourly Wages) |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.016*** | -0.007* | 0.064*** | 0.072*** |
| | (0.005) | (0.004) | (0.017) | (0.020) |
| Individual controls | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Location FE | Yes | Yes | Yes | Yes |
| Individual FE | Yes | Yes | Yes | Yes |
| Observations | 86,044 | 84,372 | 85,803 | 84,167 |
| F-statistics | 34.09 | 33.59 | 33.01 | 32.96 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on the four labour market outcomes. Weekly sleep duration is instrumented using local variations in daily sunset times. All coefficients are estimated on the full sample of respondents aged between 15 and 64, who are not self-employed. We control for age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

APPENDIX TABLE A18 - IV Estimates of the Effect of Sleep on Satisfaction by Domains

| | Satisfaction with leisure | Satisfaction with housework | Satisfaction with family | Life satisfaction |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Sleep | 0.106 | 0.198*** | -0.018 | 0.006 |
| | (0.072) | (0.048) | (0.027) | (0.030) |
| Observations | 55,144 | 48,406 | 62,336 | 62,810 |
| Outcome mean | 6.68 | 6.99 | 7.96 | 7.39 |
| Outcome SD | 2.06 | 1.85 | 1.83 | 1.53 |
| F-statistics | 29.48 | 41.30 | 41.04 | 49.33 |

Notes: This table reports the IV estimates of the effect of 1-hour increase in weekly sleep on four satisfaction measures. Weekly sleep duration is instrumented using local variations in daily sunset times. All coefficients are estimated on respondents aged between 15 and 64, who are not self-employed, who report positive weekly earnings and who declare working full-time. We control for age group dummies, indicators for summer season, day of week, location and occupation codes. We also include individual fixed effects. Standard errors are clustered at the local level.

**Additional Data Definitions**

| Variables | Questions | Answer |
|---|---|---|
| | *People can have many different qualities – some are listed below. You will probably find that some of these descriptions fit you completely and that some do not fit you at all.* | |
| A thorough worker | (i) a thorough worker | 0-1 |
| Effective and efficient in completing tasks | (ii) effective and efficient in completing tasks | 0-1 |
| Nervous | (iii) nervous | 0-1 |
| | *During the last four weeks, how often did you feel:* | |
| Feel rushed by time | (i) always or often rushed or pressed by time? | 0-1 |
| | *I will now read to you a number of feelings. Please indicate for each feeling how often or rarely you experienced this feeling in the last four weeks:* | |
| Angry | (i) angry | 1-5 |
| Worried | (ii) worried | 1-5 |
| Sad | (iii) sad | 1-5 |
| Happy | (iv) happy | 1-5 |
| | *During the last four weeks, how often did you feel:* | 1-5 |
| Mental health score | (i) rushed or pressed by time<br>(ii) down or melancholic<br>(iii) well-balanced<br>(iv) full of energy<br>That due to mental health or emotional problems:<br>(v) you achieved less than you wanted to at work or in everyday activities<br>(vi) you carried out your work or everyday tasks less thoroughly than usual | |
| State of health affect tiring tasks | *And what about other demanding everyday activities, such as when you have to lift something heavy or do something requiring physical mobility : Does you health limit you greatly, somewhat or not at all?* | 1-3 |
| | *During the last four weeks, how often did you feel:* | 1-5 |
| General health | (i) rushed or pressed by time<br>(ii) down or melancholic<br>(iii) well-balanced<br>(iv) full of energy<br>That due to mental health or emotional problems:<br>(v) you achieved less than you wanted to at work or in everyday activities<br>(vi) you carried out your work or everyday tasks less thoroughly than usual<br>That due to physical health problems:<br>(viii) you achieved less than you want wanted at work or in everyday activities<br>(ix) you were limited in some way at work or in everyday activities<br>That due to physical or mental health problems:<br>(x) you were limited socially, that is, in contact with friends, acquaintances or relatives? | |