I Z A Institute of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 11050

Broadband Internet, Digital Temptations, and Sleep

Francesco C. Billari
Osea Giuntella
Luca Stella

SEPTEMBER 2017

I Z A Institute of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 11050

Broadband Internet, Digital Temptations, and Sleep

Francesco C. Billari
Bocconi University

Osea Giuntella
University of Pittsburgh and IZA

Luca Stella
Bocconi University and IZA

SEPTEMBER 2017

Any opinions expressed in this paper are those of the author(s) and not those of IZA. Research published in this series may include views on policy, but IZA takes no institutional policy positions. The IZA research network is committed to the IZA Guiding Principles of Research Integrity.

The IZA Institute of Labor Economics is an independent economic research institute that conducts research in labor economics and offers evidence-based policy advice on labor market issues. Supported by the Deutsche Post Foundation, IZA runs the world's largest network of economists, whose research aims to provide answers to the global labor market challenges of our time. Our key objective is to build bridges between academic research, policymakers and society.

IZA Discussion Papers often represent preliminary work and are circulated to encourage discussion. Citation of such a paper should account for its provisional character. A revised version may be available directly from the author.

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Broadband Internet, Digital Temptations, and Sleep*

There is a growing concern that the widespread use of computers, mobile phones and other digital devices before bedtime disrupts our sleep with detrimental effects on our health and cognitive performance. High-speed Internet promotes the use of electronic devices, video games and Internet addiction (e.g., online games and cyberloafing). Exposure to artificial light from tablets and PCs can alterate individuals' sleep patterns. However, there is little empirical evidence on the causal relationship between technology use near bedtime and sleep. This paper studies the causal effects of access to high-speed Internet on sleep. We first show that playing video games, using PC or smartphones, watching TV or movies are correlated with shorter sleep duration. Second, we exploit historical differences in pre-existing telephone infrastructure that affected the deployment of high-speed Internet across Germany (see Falck et al., 2014) to identify a source of plausibly exogenous variation in access to Broadband. Using this instrumental variable strategy, we find that DSL access reduces sleep duration and sleep satisfaction.

JEL Classification: I1, J22
Keywords: internet, sleep duration, time use

Corresponding author:
Luca Stella
Bocconi University
Dondena Centre for Research on Social Dynamics and Public Policy
Via Guglielmo Röntgen 1
20136 Milano
Italy
E-mail: luca.stella@unibocconi.it

* This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement n. 694262), project *DisCont – Discontinuities in Household and Family Formation*. We are grateful to Nicoletta Balbo, Jan Goebel, Fabrizio Mazzonna, Valentina Rotondi and Jenny Trinitapoli for comments and suggestions.

1 Introduction

Insufficient sleep is recognized as a major public health challenge and is considered by some scholars as the most prevalent risky behavior in our society. Sleep deprivation is associated with detrimental effects on health and cognitive performance (Cappuccio et al., 2010). Statistics are alarming. In many advanced countries, the share of individuals sleeping less than the recommended 7-9 hours of sleep is increasing (Hafner et al., 2016). The costs of sleep deprivation in terms of increased health care costs and decreased productivity are large (Gibson and Shrader, 2014; Hafner et al., 2016; Heissel and Norris, 2017; Jin et al., 2015; Giuntella and Mazzonna, 2016; Giuntella et al., 2017).

Among the factors often blamed as a major cause of the sleep deprivation epidemic are Internet addiction and technology use near bedtime (Gradisar et al., 2013; Turel et al., 2016). The constant stimulation provided by electronic media devices, such as smartphones, tablets and computers disturbs our sleep process (Cain and Gradisar, 2010; Lemola et al., 2015). The ubiquity of the media devices and the "digitalization of the bedroom" before sleep can interfere with human circadian rhythms, the physiological processes that respond to the dark-light daily cycle. In particular, evening exposure to artificial light from computer or mobile screens suppresses the production of melatonin, the "sleep" hormone which regulates our sleep cycle (Cain and Gradisar, 2010; Turel et al., 2016). Furthermore, according to a recent poll on sleep behavior in the US, 20% of respondents aged 19 to 29 reported to be awakened at least a few times a week in the middle of the night by phone calls, texts, or emails (Source: Sleep Foundation).

Economists have long been interested in understanding time use allocation (Becker, 1965; Gronau, 1977; Aguiar and Hurst, 2007; Aguiar et al., 2013, 2017). However, although sleep is the most common use of time, economic research on the allocation of time to sleep has been sparse. While the first to introduce a discussion on the economics of sleeping were El Hodiri (1973), Bergstrom (1976), and Hoffman (1977), Biddle and Hamermesh (1990) were the first to formally model the sleeping decision. Motivated by the emergence of sleep deprivation as a public health epidemic, there has been a renewed interest in studying economic causes and consequences of insufficient sleep. A handful of recent studies exploit quasi-experiments and instrumental variable strategies to examine the effects of the lack of sleep on health (Jin et al., 2015; Giuntella and

Mazzonna, 2016), academic achievement (Heissel and Norris, 2017; Hafner et al., 2017), cognitive performance (Giuntella et al., 2017), fatal crashes (Smith, 2016), and economic productivity (Gibson and Shrader, 2014). Despite the growing attention of doctors and medias on the potential negative effects of Internet and digital devices on sleep, to the best of our knowledge, there are no studies that examine the causal effect of the access to high-speed Internet on sleeping behavior. The goal of this paper is to fill this gap in the literature by exploiting a plausible source of exogenous variation in access to high-speed Internet.

We focus on Germany for three main reasons. First, Germany provides an interesting case study, as a recent report by Hafner et al. (2016) documents that about 200,000 working days are lost due to insufficient sleep in Germany, corresponding to an economic loss of approximately $60 billion a year, or about 1.6 percent of its GDP. Second, this allows us to use the German Socioeconomic Panel (SOEP), one of the few panel surveys containing a rich set of information both on sleep and access to high-speed Internet. Third, it allows us to adopt an instrumental variable (IV) approach which relies on the historical peculiarities of the pre-existing telephone infrastructure across Germany (Falck et al., 2014).

We first document the relationship between digital temptations and sleep using data drawn from the German Time Use Survey (German TUS) on sleep duration, time spent playing video games, using computer and smartphones, and watching television and videos/DVDs. Among teenagers (aged 13-19) and young adults (aged up to 30), there is a significant association between the likelihood of reporting insufficient sleep and time spent on computer games or watching TV and videos/DVDs in the evening. Among adults of older ages (aged 31-59), we also find evidence of a significant correlation between shorter sleep duration and the use of computers and smartphones. Interestingly, these associations survive to the inclusion of individual fixed-effects. This descriptive evidence motivates us to further investigate the causal nexus between digital temptations and sleep outcomes. Therefore, we examine the effects of access to DSL technology on sleep duration and sleep satisfaction using data drawn from the SOEP. Since Internet access increases the marginal utility of PC and tablets use, we hypothesize that it may lead to more technology use near bedtime, which in turn may affect sleep duration and sleep quality (Lemola et al., 2015; Demirci et al., 2015; Young, 1998). The main empirical challenge is that DSL access may be correlated with unobservable socio-demographic characteristics that simultaneously influence access to high-speed Internet and sleep duration. To tackle this potential endogeneity bias, we follow the IV approach proposed by Falck et al. (2014), who study the effects of Broadband on voting behavior. Their identification relies on the fact that the location of the main distribution frames (MDFs) across Germany was determined by historical circumstances unlikely to be correlated with the demand for high-speed Internet access. The idea underlying this strategy is that while the distance of a household from the MDF is a crucial cost factor for the adoption of DSL connection, the historical distribution of MDFs across Germany can be considered exogenous to current preferences for Internet access. Using confidential information on the residential geo-coordinates of the SOEP households, we calculate the distance of each household from the MDF. Furthermore, we also exploit the fact that several regions in East Germany adopted the optical access line (OPAL) technology in the early 1990s. While this telephone infrastructure was considered a state-of-the art technology at the time, it turned out to be incompatible with DSL technology. Thus, areas that adopted the OPAL technology in the 1990s faced higher barriers to broadband Internet deployment. In this paper, we rely on the variation in Broadband access induced by these historical peculiarities of the German communication network to identify the causal impacts of high-speed Internet on sleep duration and sleep satisfaction.

Our findings reveal a large, negative impact of high-speed Internet on sleep duration. Individuals with DSL access tend to sleep 25 minutes less than their counterparts without DSL Internet. They are significantly less likely to sleep between 7 and 9 hours, the interval typically recommended by the scientific community (Hirshkowitz et al., 2015). Furthermore, they are less likely to be satisfied with their sleep. These effects are mostly concentrated among younger adults.

The remainder of this paper is organized as follows. Section 2 provides a description of the data. In Section 3, we describe our empirical specification and identification strategy. The main results of the paper are reported in Section 4, which also includes a set of robustness checks. Section 5 concludes.

2 Data

The data used in this study are drawn from two main sources. To document the relationship between media use and sleep duration, we employ the last wave of the German TUS (2012-2013). This is the third and most recent wave provided by the German Federal Statistical Office (Destatis, 2017). Each person in the household, aged 10 years and above, is requested to fill in a personal diary during two weekdays and one weekend day. This diary provides information on all performed activities recorded in ten-minute intervals. Socio-demographic and socio-economic characteristics of individuals and households are collected using individual and household questionnaires. For a detailed description of the survey, see Stuckemeier and Kühnen (2013). In our analyses, we restrict the sample to individuals between 18 and 59 years old. After this restriction, our sample consists of 10,869 diary observations resulting from 5,587 individuals. Figure A.1 in the Appendix describes the distribution of sleep hours in the sample.

While the time use data allow us to explore the relationship between digital devices and sleep, the lack of detailed information on the geographical residence of the respondents does not allow us to exploit our identification strategy which relies on spatial differences in access to broadband Internet.

Thus, our main analysis is based on the data drawn from the SOEP, a representative longitudinal dataset which surveys households and individuals in Germany since 1984, and for which we obtained access to confidential information on the geo-coordinates of the households. A unique feature of this data source lies in its wide range of information at the individual and household level, including, for instance, socio-economic characteristics, labor market outcomes, and health-related measures (see Wagner et al. (2007)).

The SOEP data contain a number of features that make them particularly attractive for our analysis. First, since 2008 they contain detailed self-reported information both on the quantitative and qualitative dimensions of sleep, which serve as outcome variables in our analyses. The following questions are asked to the respondents: "*How many hours do you sleep on average on a normal day during the working week?*"; "*How many hours on a normal weekend day?*". We construct both a linear measure of sleep duration in hours and indicators for whether individuals slept at most six or eight hours, or between 7 and 9 hours. Furthermore, we also use a qualitative metric of self-reported satisfaction with sleep, which is defined on a 11-point Likert scale ranging from 0 (very dissatisfied) to 10 (very satisfied).

Second, our data provide information on Internet access. Of particular importance for our study is the fact that the 2008 SOEP wave for the first time asks each household not only whether Internet access is available, but also whether Internet access is based on a DSL technology. The availability of such information, collected every two years from 2008 till 2012, is essential because it allows us investigating the effects of high-speed Internet. Therefore, our key explanatory variable is a dummy variable that indicates whether a household has a DSL connection. In 2008 the DSL technology was still in its initial phase of development across Germany (Falck et al., 2014). Thus, our analysis identifies the effects of the introduction of broadband Internet across Germany.

Finally, the SOEP also contains information on PC use. In the 2008 and 2013 waves, respondents are asked whether they use PC at home and how often they use it for private purposes (daily/at least once a week/at least once a month/less frequently). We exploit this information to construct an indicator variable taking value one (and zero otherwise) if the respondent reports a daily use of the computer. Since we hypothesize that the diffusion of DSL technology increases the use of PCs and digital devices with potential detrimental effects on sleep, this variable enables us to shed some light on the potential mechanisms through which broadband Internet access affects sleep behavior.

Our working sample is constructed as follows. We consider the survey years 2008, 2010 and 2012, because information on DSL access is available in these years. To avoid the problem of changes in health or sleep quality due to retirement, we restrict attention to individuals between 18 and 59 years old (Mazzonna and Peracchi, 2012; Lemola and Richter, 2012).[1] Observations with missing data for sleep outcomes, DSL access and all observables are excluded from the analysis. Finally, following Giuntella and Mazzonna (2016), we drop individuals who sleep below 2 or above 16 hours per night.[2] After these restrictions, we obtain a final longitudinal sample that contains 43,162 person-year observations resulting from 24,680 individuals.

Table A.1 in the Appendix reports descriptive statistics on the primary variables used in the

[1]In a sensitivity analysis, we show that our estimates do not change when we consider individuals aged 25-59, 18-55, 18-65 or 20-54 at the time of the interview.

[2]Results are not sensitive to this restriction.

analysis. Individuals sleep on average about 6.8 hours per night during the workweek and about 7.9 hours during the weekend. Approximately 35% of individuals in our sample sleep at most six hours, 96% sleep at most eigth hours, and 64% of them sleep between 7 and 9 hours during the weekday. Average satisfaction with sleep is 6.9. Moreover, they are 40 years old on average, about 80% of them have broadband Internet access via DSL at home, approximately 31% have received an academic secondary school track (*Abitur*) and close to 35% have obtained at most an intermediate track education (*Realschulabschluss*).[3]

For our purposes, the main limitation of the SOEP data is that sleep duration is reported in hours (see the distribution in Figure A.2 in the Appendix), and is therefore more prone to be affected by measurement error. On the other hand, diary-based estimates of time use surveys are more reliable and accurate than estimates obtained from direct questions (Bonke, 2005; Knutson and Lauderdale, 2007; Kan, 2008). This may largely explain the marked differences in average sleep duration observed in the German TUS and the SOEP data. In particular, as shown in previous research analyzing the differences between time-diary and self-reported average sleep hours, the former tends to be significantly larger (see Knutson and Lauderdale (2007)).

Figure 1 illustrates age differences in the pattern of sleeping hours between individuals with broadband Internet access at home and those without access to broadband Internet. Overall, the pattern that emerges is that individuals with high-speed Internet sleep consistently less hours over the life cycle. However, it is not clear whether this correlation is driven by selection on unobservables or whether it is capturing a causal effect. In what follows, we employ an IV strategy to investigate whether DSL availability has causally reduced sleep.

[3]The German secondary school system is traditionally structured as a tracked system. A description of the German school system can be found in Jonen and Eckardt (2006).

3 Empirical Methodology

3.1 Model Specification

To examine how the access to broadband Internet affects the sleeping behavior, we estimate the following linear regression model:

$$Y_{ist} = \alpha + \beta DSL_{ist} + \gamma X_{ist} + \mu_t + \eta_s + \lambda_s^1 t + \varepsilon_{ist} \quad (1)$$

where the index *ist* denotes an individual *i* residing in state *s* at the year of interview *t*. The outcome variable Y_{ist} is a measure of sleep duration, i.e., sleep hours, an indicator variable for whether the individual sleeps at most 6 or 8 hours, or whether she sleeps between 7 and 9 hours. We also consider satisfaction with sleep, defined on a 0 to 10 scale.

Our variable of interest is DSL_{ist}, which represents a dummy variable taking value one if the individual has a DSL subscription at home, and zero otherwise. Thus, β denotes whether sleep duration (or satisfaction) decreases for individuals with a DSL subscription. Model (1) contains survey year fixed effects (μ_t) to account for possible trends in sleep behavior. We also include a full set of federal state fixed-effects (η_s) as well as a set of linear state-specific time trends $(\lambda_s^1 t)$. The former control for unobservable, time-invariant differences across states that may influence the sleep patterns of individuals, the latter for unobserved cross-state differences in sleep over time. X_{ist} is a vector of individual controls, including gender, age and age squared, number of children, a set of secondary school track effects (basic, intermediate or academic track), indicators for marital status, occupational status, migration background, and the logarithm of net household income. Finally, ε_{ist} represents an idiosyncratic error term.

The ordinary least squares (OLS) estimation of model (1) would give rise to bias due to the potential correlation of high-speed Internet with various unobservable determinants of sleep, which may confound our relationship of interest. In fact, unobserved factors (such as unobserved socio-economic determinants of sleep, time preferences, genetics, risk aversion and the awareness of the health risks of sleepless) might simultaneously affect the willingness to pay for DSL subscription and sleep behavior. While we are able to condition our analysis on a large set of observed background characteristics to address this concern, there may still exist unobserved confounders, which would bias estimates of β. To circumvent this concern regarding endogeneity caused by omitted variables, we apply an IV identification strategy based on the geography and history of the layout of the preexisting telephone infrastructure across Germany, detailed in the next subsection.

3.2 Identification Strategy

As previously mentioned, our identification strategy follows the approach proposed by Falck et al. (2014) to study the effects of DSL availability on voting behavior. Their main idea is to exploit historical variation in pre-existing telephone infrastructure which significantly affected the cost of broadband adoption across Germany. In particular, Falck et al. (2014) rely on three unique historical and technological peculiarities of the traditional public telephone network, which influenced the deployment of DSL in German municipalities.[4] The cost of adopting DSL connection is significantly affected by the distance between a household and the main distribution frame (MDF). For technical reasons, when a customer resides more than 4,200 meters away from the MDF, DSL technology becomes substantially more costly unless households can be connected to an alternative MDF situated in the close vicinity.

We construct two household-level binary instruments: the first instrument is equal to one for households with distances to their MDF above the threshold of 4,200 meters, and zero otherwise; the second instrument is equal to one for households above the threshold which could not be connected to another MDF at a distance below 4,200 meters. Finally, a third binary instrument identifies areas in East Germany that adopted the optical access line (OPAL) technology. After reunification, many regions in East Germany lacked a proper telephone network and adopted OPAL, which at the time was the best telephone technology on the market. Yet, a decade later this technology proved to be not compatible with DSL technologies, thereby implying substantially higher costs for DSL connection in these areas. These three instruments provide us with plausibly exogenous variation in DSL availability, which we exploit to identify the causal effects

[4] See Falck et al. (2014) for a full and detailed description of the variation in the diffusion of DSL technology across municipalities throughout the country. Crucial to our purpose, high-speed Internet subscriptions in Germany are almost exclusively based on DSL technology (Falck et al., 2014).

of broadband Internet access on sleep behavior.[5]

Model (1) is estimated using two stage least squares (2SLS), and the first stage regression is given by:

$$DSL_{ist} = \eta + \delta Threshold_{ist} + \theta(No\ closer\ MDF)_{ist} + \sigma OPAL_{ist} + \rho X_{ist} + \mu_t + \eta_s + \lambda_s^1 t + \nu_{ist} \quad (2)$$

where DSL_{ist} is instrumented with $Threshold_{ist}$, an indicator for whether the respondent resides more than 4,200 meters away from their MDF. Similarly, $(No\ closer\ MDF)_{ist}$ is a binary variable identifying those respondents who were more than 4,200 meters away from their MDF, but could be connected to a closer MDF. Our third instrument is given by $OPAL_{ist}$, which indicates whether the respondent resided in an area initially supplied with OPAL technology. X_{ist}, μ_t, η_s, $\lambda_s^1 t$ are defined in the same way as in equation (1). Throughout the analysis, we cluster standard errors by household, the level of variation of our instruments.

4 Empirical Results

4.1 Media Temptations and Sleep

Before analyzing the effects of broadband Internet on sleep behavior, we use the 2012-2013 German TUS to investigate the relationship between sleep and electronic media use (i.e., playing video games, use of computers and smartphones, watching television and videos/DVDs). We report the results of this analysis in Table 1. For consistency, we include control variables identical to those included in model (1): gender, a quadratic in age, number of children, indicators of their educational attainment, marital status, occupational status, migration background and net household income. We also include indicators for the day of interview and a dummy of whether

[5] As in Falck et al. (2014), to construct these three household-level binary instruments, we used data on the geo-coordinates of the SOEP households, which for confidentiality reasons are available only on-site at the DIW in Berlin.

the respondent lives in Western Germany.[6] In general, we find evidence that media use near bedtime (between 9 pm and midnight) significantly decreases sleep duration (see columns 1 and 2 of Panel A of Table 1). In particular, there is evidence that time spent on computer games in the evening, use of PCs and smartphones as well as watching TV are negatively correlated with sleep duration (see column 1) and positively correlated with insufficient sleep (see column 2). Across age groups, time spent on computer games is significantly associated with higher probability of insufficient sleep (see columns 2, 4 and 6). A 30-minute increase in video games increases the likelihood of reporting insufficient sleep by approximately 30% relative to the mean, which corresponds to an increase of about 0.1 standard deviation. This evidence is in line with the recent findings of Aguiar et al. (2017) in the US. The impacts of computer games in terms of insufficient sleep are even more pronounced among teenagers (see Table A.2 in the Appendix). In this age group, a 30-minute increase in time spent on computer games increases the likelihood of reporting lack of sleep by 50% with respect to the average.

There is also evidence of a significant correlation between sleep duration and use of PCs and smartphones among individuals aged 31-59 (see columns 5 and 6 of Table 1). Specifically, a 30-minute increase in PC and smartphone use in the evening is associated with a 30% higher likelihood to sleep at most 6 hours. As displayed in Panel B of Table 1, results go in the same direction when analyzing the effects of digital devices near bedtime using an alternative definition of our main explanatory variable, i.e., an indicator for whether individuals were either playing video games or using PCs and smartphones, or watching TV between 11 pm and 11.10 pm.

These associations hold up to the inclusion of individual fixed effects, thereby exploiting only the within-individual variation in media use in the evening (see Tables A.3 and A.4 in the Appendix). Interestingly, these effects become smaller or non-significant when we focus on individuals without morning constraints (e.g., late work schedule, or without children in school age) or when we examine weekend diaries (see Tables A.5 and A.6 in the Appendix).[7] These results suggest that digital temptations may lead to a delay in bedtime, which ultimately decreases sleep duration for individuals who are not able to compensate by waking up later in the morning. Overall, these findings are consistent with the growing evidence on the importance

[6] This is the lowest geographical information available in the public use version of the German TUS.

[7] For space considerations, in Table A.5 we report the results only for individuals aged 18-59.

of work and school schedules (Giuntella and Mazzonna, 2016; Heissel and Norris, 2017).

The correlation between computer use at home and sleep duration is confirmed using the SOEP data (see column 1 of Table A.7 in the Appendix). Self-reported PC use increases the probability of reporting at most 6 hours sleep by 4 percentage points, which corresponds to an increase of about 13% relative to the mean. While this evidence is merely descriptive, it supports previous studies suggesting that Internet addiction and excessive media use may have large detrimental effects on sleep duration and quality (Gradisar et al., 2013; Turel et al., 2016; Lemola et al., 2015), and motivates us to verify whether these correlations may reflect a causal mechanism. Unsurprisingly, when using our IV approach, we find that DSL availability significantly increases PC use at home. Specifically, DSL access increases private use of PC by 27 percentage points, which represents an increase of approximately 64% relative to the mean (see column 2 of Table A.7). Therefore, it is natural to ask whether access to broadband Internet may have causal effects on sleep outcomes.

4.2 High-Speed Internet and Sleep

Table 2 shows the first stage and 2SLS estimates for the impact of DSL access on sleep behavior using the SOEP data. As described in the previous section, in each regression we include a set of individual controls, survey year and state fixed effects, as well as state-specific time trends. The first stage results reported in the lower part of Table 2 show that as expected, our instruments are negatively related to DSL access. With a first stage F-statistic above 30, there is no reason to fear a weak instrument problem. Moreover, the overidentification test statistics for each of the models are far from critical values at conventional significance levels, thereby providing support that the three instruments are jointly valid instruments.

We now move to the examination of the 2SLS results displayed in the upper part of Table 3. The estimate in column 1 suggests that access to DSL reduces sleep duration by 25 minutes, which corresponds to a reduction of approximately 0.37 standard deviations. Moreover, individuals with a DSL subscription are 25 percentage points more likely to sleep less than 6 hours (see column 2), 8 percentage points more likely to sleep less than 8 hours (see column 3), and are 23% percentage points less likely to sleep between 7 and 9 hours (see column 4). We also find evidence of a negative association between high-speed Internet and satisfaction with sleep (see column 5). The corresponding OLS estimates presented in Table A.8 in the Appendix indicate that the 2SLS results are consistently larger in absolute value, thereby suggesting a positive correlation between unobserved determinants of sleep duration and DSL availability. Measurement error in self-reported DSL may also explain why the OLS estimate is biased towards zero (Wooldridge, 2010). Moreover, as previously mentioned, the discrete nature of the dependent variable introduces further measurement error and may contribute to explain the relatively large difference in the magnitude between the OLS and 2SLS estimates. Finally, it is worth remarking that 2SLS results estimate a local average treatment effect for the compliers.

Access to high-speed Internet is likely to have stronger effects on younger individuals who are usually heavy consumers of Internet technology. To verify this hypothesis, in Table 3 we provide the 2SLS estimates by dividing the sample into two groups: individuals aged 18-30 (see Panel A) and those aged 31-59 (see Panel B). Consistent with our prior, we find that the effect of Internet on sleep is concentrated among younger adults. Specifically, individuals aged up to 30 with access to DSL sleep on average 70 minutes less than their counterparts without access to DSL (see column 1 of Panel A), they are significantly more likely to be sleep deprived (see columns 2 to 4), and are significantly less likely to be satisfied with their sleep (see column 5).

Interestingly, in Table A.9 in the Appendix we find no evidence of significant effects on sleep behavior during weekends. This result is in line with the reasoning that access to broadband Internet delays bedtimes affecting overall sleep duration during the workweek when individuals have constraints on wake-up times, but has no effects during weekends when individuals can compensate for a later bedtime by waking up at a later hour.

4.3 Robustness

We perform a variety of robustness checks to test how the results change when we modify the sample or use a different specification compared to our benchmark model (see Table 2). Results are reported in Table 4.

First, in Panel A we show that the main results are not affected by the inclusion of regional policy regions (Raumordnungsregionen, ROR) fixed effects and ROR-specific time trends (instead of federal state fixed effects and state-specific time trends), which are meant to control for unobservable time-invariant differences across 96 regional policy regions throughout Germany.[8] Second, we check the sensitivity of our results to the exclusion of individuals who changed the county of residence during the sample period. In this case, the major concern is that families may systematically move away across Germany in response to better DSL connections available in a given area. Reassuringly, the 2SLS estimates reported in Panel B show that the effects of DSL connection are very similar to the benchmark specification.[9]

We also demonstrate the robustness of our results to the inclusions of an indicator of self-reported poor health status, which is a potentially endogeneous variable that may be strongly related with the sleep behavior (see Panel C). In Panel D, we aggregate the analysis at the municipality-year level and study the impact of DSL access on sleeping variables. Although the coefficients of interest become larger in magnitude, the results are highly statistically significant and the overall conclusions are the same.

As a final check, we show that our results are robust to several classifications of the age groups (see Table A.10 in the Appendix).[10]

5 Conclusion

The increased use of electronic devices in the bedroom before sleep is considered one of the main factors contributing to the sleep deprivation epidemic. Access to high-speed Internet promotes excessive electronic media use, which in turn can disturb sleep habits. In this study, we document a significant association between playing video games or watching TV in the evening and sleep deprivation among teenagers (aged 13-19) and young adults (aged up to 30). Among

[8]Our results are also robust to the inclusion of county (Kreise and kreisfreie Staedte) fixed effects. For detailed information on SOEP regional data, see Knies and Spiess (2007).

[9]Results remain unaffected if we exclude from the sample individuals who changed the zip code or the residential address during the sample period.

[10]It is also worth noting that the entire analysis is not sensitive to the inclusion of the "Families in Germany" (FiD) sample for the years 2011 and 2013. For further information regarding the FiD panel survey, see Schröder et al. (2013).

adults of older ages (aged 31-59), we also find that the use of PCs and smartphones in the evening has a strong association with shorter sleep duration. Our main contribution is the analysis of the causal effects of access to high-speed Internet on sleep behavior. To circumvent the endogeneity of DSL access, we build on the identification strategy of Falck et al. (2014) and thus exploit a plausible source of exogenous variation which relies on historical differences in pre-existing technologies that affected the deployment of high-speed Internet across Germany. Using this IV strategy, we find evidence that access to DSL significantly reduces average sleep duration by 25 minutes, substantially increases the likelihood of reporting insufficient sleep and decreases self-reported satisfaction with sleep. Our results are mostly driven by younger adults.

Taken together, our findings suggest that there may be substantial detrimental effects of broadband Internet on sleep duration and quality through its effects on technology use near bedtime. High-speed Internet makes it very enticing to stay up later to play video games, surf the web and spend time online on social medias. Given the growing awareness of the importance of sleep quantity and quality for our health and productivity, providing more information on the risks associated with technology use in the evening may promote healthier sleep and have non-negligible effects on individual welfare and well-being. More research is needed to understand the behavioral mechanisms underlying Internet addiction and how to nudge individuals into healthier sleep practices.

One important limitation of this study is that we have only limited information on the sleeping behavior of teenagers. There is increased concern that social networks activity and the "digitalization of the bedroom" may have large detrimental effects on sleep and academic performance of young teenagers. Yet, causal evidence on these effects is still lacking. Exploiting the increasing availability of datasets with information on access to high-speed Internet, sleep and academic performance, future research could shed more light on the effects of the "digital revolution" on teenagers' health and human capital.

References

Aguiar, Mark and Erik Hurst, "Measuring Trends in Leisure: The Allocation of Time over Five Decades," *The Quarterly Journal of Economics*, 2007, pp. 969–1006.

_ , _ , and Loukas Karabarbounis, "Time use during the great recession," *The American Economic Review*, 2013, *103* (5), 1664–1696.

_ , Mark Bils, Kerwin Kofi Charles, and Erik Hurst, "Leisure Luxuries and the Labor Supply of Young Men," Technical Report, National Bureau of Economic Research 2017.

Becker, Gary S, "A Theory of the Allocation of Time," *The Economic Journal*, 1965, pp. 493–517.

Bergstrom, Theodore, "The deeper economics of sleeping," *The Journal of Political Economy*, 1976, pp. 411–412.

Biddle, Jeff E and Daniel S Hamermesh, "Sleep and the Allocation of Time," *Journal of Political Economy*, 1990, *98*, 922–943.

Bonke, Jens, "Paid work and unpaid work: Diary information versus questionnaire information," *Social Indicators Research*, 2005, *70* (3), 349–368.

Cain, Neralie and Michael Gradisar, "Electronic media use and sleep in school-aged children and adolescents: A review," *Sleep medicine*, 2010, *11* (8), 735–742.

Cappuccio, Francesco P, Lanfranco D'Elia, Pasquale Strazzullo, and Michelle A Miller, "Sleep duration and all-cause mortality: a systematic review and meta-analysis of prospective studies," *Sleep*, 2010, *33* (5), 585–592.

Demirci, Kadir, Mehmet Akgönül, and Abdullah Akpinar, "Relationship of smartphone use severity with sleep quality, depression, and anxiety in university students," *Journal of behavioral addictions*, 2015, *4* (2), 85–92.

Destatis, "Microdata of the time use survey," 2017. Available online at `https://www.destatis.de/EN/FactsFigures/SocietyState/IncomeConsumptionLivingConditions/SUF/SUFIntroduction_ZVE.html`, (last accessed on 6 September 2017).

Falck, Oliver, Robert Gold, and Stephan Heblich, "E-lections: Voting Behavior and the Internet," *The American Economic Review*, 2014, *104* (7), 2238–2265.

Gibson, Matthew and Jeffrey Shrader, "Time Use and Productivity: The Wage Returns to Sleep," 2014.

Giuntella, O, W Han, and F Mazzonna, "Circardian rhythms, sleep deprivation and cognitive skills. evidence from an unsleeping giant. University of Oxford," *Demography, forthcoming*, 2017.

Giuntella, Osea and Fabrizio Mazzonna, "Sunset Time and the Effects of Social Jetlag. Evidence from US Time Zone Borders," *IZA DP 9773*, 2016.

Gradisar, Michael, Amy R Wolfson, Allison G Harvey, Lauren Hale, Russell Rosenberg, and Charles A Czeisler, "The sleep and technology use of Americans: findings from the National Sleep Foundation's 2011 Sleep in America poll," *Journal of clinical sleep medicine: JCSM: official publication of the American Academy of Sleep Medicine*, 2013, *9* (12), 1291.

Gronau, Reuben, "Leisure, home production, and work–the theory of the allocation of time revisited," *Journal of Political Economy*, 1977, *85* (6), 1099–1123.

Hafner, Marco, Martin Stepanek, and Wendy M Troxel, "Later school start times in the US," 2017.

_ , _ , Jirka Taylor, Wendy M Troxel, and Christian van Stolk, "Why sleep matters–the economic costs of insufficient sleep," 2016.

Heissel, Jennifer and Samuel Norris, "Rise and shine: The effect of school start times on academic performance from childhood through puberty," *Journal of Human Resources*, 2017, pp. 0815–7346R1.

Hirshkowitz, Max, Kaitlyn Whiton, Steven M Albert, Cathy Alessi, Oliviero Bruni, Lydia DonCarlos, Nancy Hazen, John Herman, Eliot S Katz, Leila Kheirandish-Gozal et al., "National Sleep Foundations sleep time duration recommendations: methodology and results summary," *Sleep Health*, 2015, *1* (1), 40–43.

Hodiri, Mohamed El, "The economics of sleeping," *Unpublished manuscript, University of Kansas*, 1973.

Hoffman, Emily P, "The deeper economics of sleeping: important clues toward the discovery of activity X," *The Journal of Political Economy*, 1977, pp. 647–649.

Jin, Lawrence, Nicolas R Ziebarth et al., "Sleep and Human Capital: Evidence from Daylight Saving Time," 2015.

Jonen, G and T Eckardt, "The education system in the Federal Republic of Germany 2004. Secretariat of the Standing Conference of the Ministers of Education (KMK)," 2006.

Kan, Man Yee, "Measuring housework participation: the gap between stylised questionnaire estimates and diary-based estimates," *Social Indicators Research*, 2008, *86* (3), 381–400.

Knies, Gundi and C Katharina Spiess, "Regional data in the German Socio-economic Panel Study (SOEP)," Technical Report, DIW Data Documentation 2007.

Knutson, Kristen L and Diane S Lauderdale, "Sleep duration and overweight in adolescents: self-reported sleep hours versus time diaries," *Pediatrics*, 2007, *119* (5), e1056–e1062.

Lemola, Sakari and David Richter, "The course of subjective sleep quality in middle and old adulthood and its relation to physical health," *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 2012, *68* (5), 721–729.

_ , Nadine Perkinson-Gloor, Serge Brand, Julia F Dewald-Kaufmann, and Alexander Grob, "Adolescents electronic media use at night, sleep disturbance, and depressive symptoms in the smartphone age," *Journal of youth and adolescence*, 2015, *44* (2), 405–418.

Mazzonna, Fabrizio and Franco Peracchi, "Ageing, cognitive abilities and retirement," *European Economic Review*, 2012, *56* (4), 691–710.

Schröder, Mathis, Rainer Siegers, and C Katharina Spieß, "Familien in Deutschland –FiD," *Schmollers Jahrbuch*, 2013, *133* (4), 595–606.

Smith, Austin C, “Spring forward at your own risk: Daylight saving time and fatal vehicle crashes,” *American Economic Journal: Applied Economics*, 2016, *8* (2), 65–91.

Stuckemeier, Anette and Carola Kühnen, “German Time Use Survey 2012/13,” 2013.

Turel, Ofir, Anna Romashkin, and Katherine M Morrison, “Health outcomes of information system use lifestyles among adolescents: Videogame addiction, sleep curtailment and cardio-metabolic deficiencies,” *PloS one*, 2016, *11* (5), e0154764.

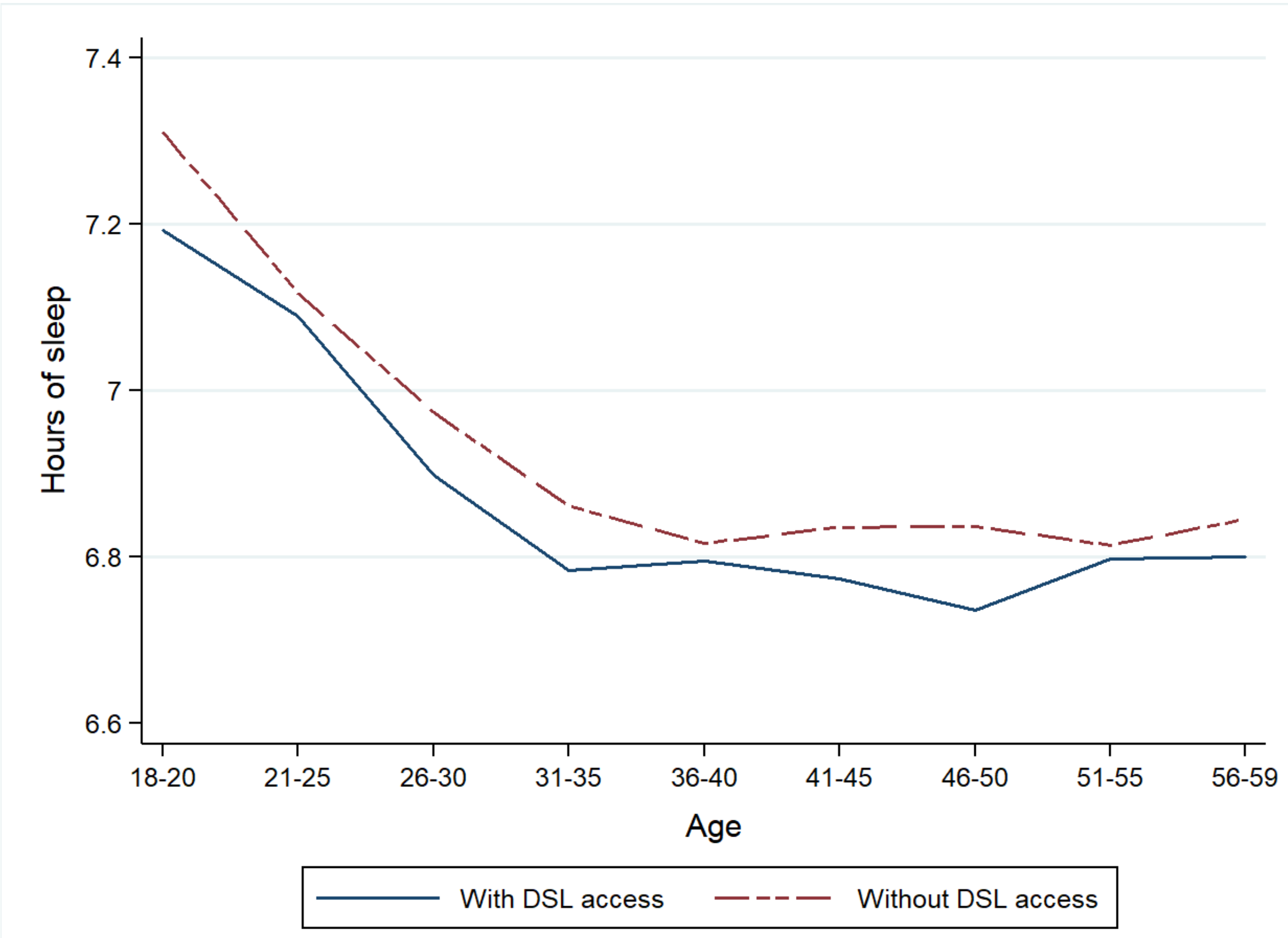
Wagner, Gert G, Joachim R Frick, and Jürgen Schupp, “The German Socio-Economic Panel study (SOEP) - Scope, Evolution, and Enhancements,” *Schmollers Jahrbuch*, 2007, *127*, 139–169.

Wooldridge, Jeffrey M, *Econometric analysis of cross section and panel data*, MIT press, 2010.

Young, Kimberly S, “Internet addiction: The emergence of a new clinical disorder,” *Cyberpsychology & behavior*, 1998, *1* (3), 237–244.

Figures and Tables

Figure 1: Average sleep hours (weekdays) by DSL access - SOEP data



Notes: Data are drawn from the SOEP (survey years: 2008, 2010, 2012).

Table 1: Effects of Media Use near Bedtime on Sleep (weekdays), OLS Estimates - German TUS

	(1)	(2)	(3)	(4)	(5)	(6)
Age group:	18-59		18-30		31-59	
Dep. var.:	Sleep hours	Sleep≤6	Sleep hours	Sleep≤6	Sleep hours	Sleep≤6
Panel A: Media use in 10-minute intervals between 9 pm and midnight						
Computer games (10-minute intervals)	-0.042***	0.010***	-0.033	0.011**	-0.053***	0.009**
	(0.015)	(0.003)	(0.023)	(0.004)	(0.017)	(0.005)
PC use and smartphones (10-minute intervals)	-0.029***	0.007***	0.019	-0.003	-0.057***	0.012***
	(0.010)	(0.002)	(0.018)	(0.003)	(0.012)	(0.003)
Watching TV (10-minute intervals)	-0.014***	0.001	0.036***	-0.007***	-0.027***	0.002***
	(0.004)	(0.001)	(0.009)	(0.002)	(0.004)	(0.001)
Panel B: Media use between 11 pm and 11.10 pm						
Computer games (11 pm - 11.10 pm)	-0.588**	0.172***	-0.551	0.195***	-0.634**	0.149**
	(0.231)	(0.048)	(0.373)	(0.069)	(0.268)	(0.067)
PC use and smartphones (11 pm - 11.10 pm)	-0.502***	0.145***	0.232	-0.030	-0.863***	0.232***
	(0.136)	(0.037)	(0.238)	(0.037)	(0.153)	(0.050)
Watching TV (11 pm - 11.10 pm)	-0.539***	0.110***	-0.053	0.024	-0.668***	0.132***
	(0.048)	(0.012)	(0.132)	(0.022)	(0.050)	(0.014)
Mean of dep. var.	7.843	0.103	8.231	0.102	7.742	0.103
Std. dev. of dep. var.	1.600	0.303	1.929	0.303	1.486	0.304
Observations	10,869	10,869	2,242	2,242	8,627	8,627

Notes - Data are drawn from the German TUS (2012-2013). Standard errors are reported in parentheses and are clustered at the individual level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, household income, a dummy indicating whether a person is foreign-born, an indicator for house/flat ownership, and the number of children aged less than 10. All regressions further include a dummy for West Germany and fixed effects for the day of interview. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table 2: Effects of High-Speed Internet on Sleep (weekdays), 2SLS Estimates - SOEP data

	(1)	(2)	(3)	(4)	(5)
Dep. Var.:	Sleep hours	Sleep≤6 hours	Sleep≤8 hours	7≤Sleep≤9 hours	Sleep satisfaction
DSL subscription	-0.415**	0.252***	0.086**	-0.229***	-0.702
	(0.209)	(0.087)	(0.037)	(0.087)	(0.449)
Mean of dep. var.	6.844	0.350	0.963	0.639	6.891
Std. dev. of dep. var.	1.107	0.477	0.189	0.480	2.266
First stage					
Threshold	-0.139***	-0.139***	-0.139***	-0.139***	-0.142***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
"No closer MDF"	-0.083***	-0.083***	-0.083***	-0.083***	-0.087***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
OPAL	-0.063*	-0.063*	-0.063*	-0.063*	-0.055
	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)
F-test of excluded instruments	32.25	32.25	32.25	32.25	32.30
Overidentification test	0.479	0.718	2.765	0.742	4.998
χ^2 p-value	0.787	0.699	0.251	0.690	0.082
Observations	43,162	43,162	43,162	43,162	42,699

Notes - Data are drawn from the SOEP (survey years: 2008, 2010, 2012). Standard errors are reported in parentheses and are clustered at the household level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, migration background, and log of net household income. All regressions further include state and survey years fixed effects, as well as state-specific time trends. The *F*-test for excluded instruments refers to the Kleibergen-Paap *F*-statistic. The overidentification test is based on the Huber-White robust variance-covariance matrix without clustering. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3: Effects of High-Speed Internet on Sleep (weekdays) by Age Group, 2SLS Estimates - SOEP data

Dep. Var.:	(1) Sleep hours	(2) Sleep≤6 hours	(3) Sleep≤8 hours	(4) 7≤Sleep≤9 hours	(5) Sleep satisfaction
			Panel A: Individuals aged 18-30		
DSL subscription	-1.171***	0.422**	0.303***	-0.356**	-1.905**
	(0.452)	(0.168)	(0.114)	(0.168)	(0.860)
Observations	9,264	9,264	9,264	9,264	9,157
Mean of dep. var.	7.049	0.297	0.932	0.683	7.268
Std. dev. of dep. var.	1.166	0.457	0.252	0.465	2.177
F-test of excluded instruments	10.73	10.73	10.73	10.73	10.65
			Panel B: Individuals aged 31-59		
DSL subscription	-0.215	0.198**	0.033	-0.187*	-0.409
	(0.229)	(0.099)	(0.034)	(0.099)	(0.482)
Observations	33,898	33,898	33,898	33,898	33,542
Mean of dep. var.	6.788	0.365	0.972	0.627	6.788
Std. dev. of dep. var.	1.083	0.481	0.166	0.484	2.279
F-test of excluded instruments	30.90	30.90	30.90	30.90	31.12

Notes - Data are drawn from the SOEP (survey years: 2008, 2010, 2012). Standard errors are reported in parentheses and are clustered at the household level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, migration background, and log of net household income. All regressions further include state and survey years fixed effects, as well as state-specific time trends. The *F*-test for excluded instruments refers to the Kleibergen-Paap *F*-statistic. * Significant at 10%; ** significant at 5%; *** significant at 1%.

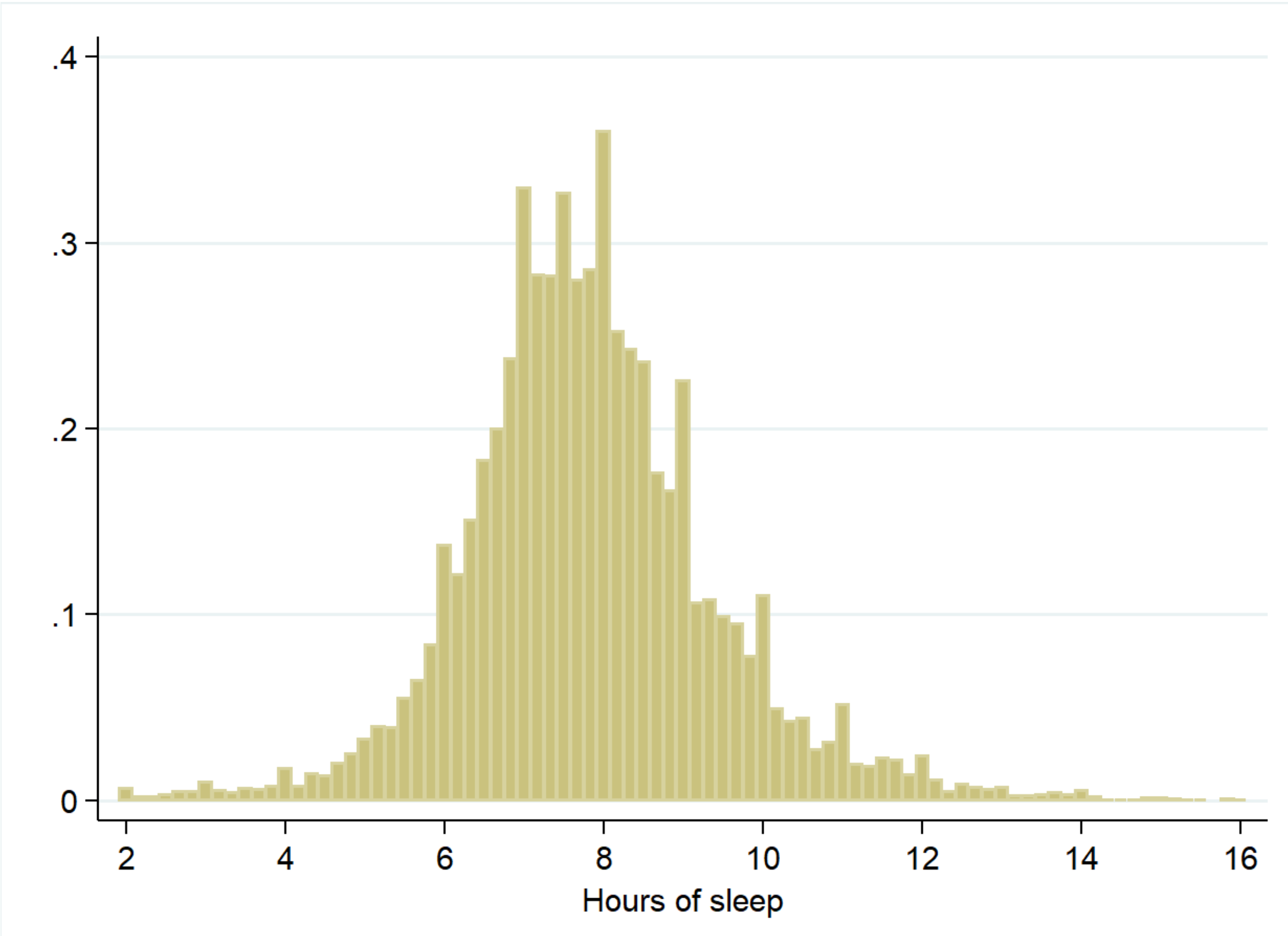
Table 4: Robustness Checks - SOEP data

Dep. var.:	(1) Sleep hours	(2) Sleep≤6 hours	(3) Sleep≤8 hours	(4) 7≤Sleep≤9 hours	(5) Sleep satisfaction
	Panel A: Including ROR F.E.				
DSL subscription	-0.369*	0.232***	0.072*	-0.206**	-0.520
	(0.211)	(0.089)	(0.037)	(0.089)	(0.442)
Observations	43,162	43,162	43,162	43,162	42,699
Mean of dep. var.	6.844	0.350	0.963	0.639	6.891
Std. dev. of dep. var.	1.107	0.477	0.189	0.480	2.266
F-test of excluded instruments	31.59	31.59	31.59	31.59	31.88
	Panel B: Exclude county movers				
DSL subscription	-0.417*	0.234**	0.118***	-0.214**	-0.713
	(0.240)	(0.098)	(0.045)	(0.098)	(0.534)
Observations	34,386	34,386	34,386	34,386	34,433
Mean of dep. var.	6.862	0.342	0.962	0.647	6.859
Std. dev. of dep. var.	1.100	0.474	0.190	0.478	2.238
F-test of excluded instruments	23.76	23.76	23.76	23.76	23.57
	Panel C: Including poor health among the controls				
DSL subscription	-0.415**	0.253***	0.086**	-0.230***	-0.738*
	(0.207)	(0.086)	(0.037)	(0.086)	(0.395)
Observations	43,152	43,152	43,152	43,152	42,668
Mean of dep. var.	6.844	0.350	0.963	0.639	6.891
Std. dev. of dep. var.	1.107	0.477	0.189	0.480	2.266
F-test of excluded instruments	32.21	32.21	32.21	32.21	32.29
	Panel D: Sleep aggregated at the municipality-year level				
DSL subscription	-0.653***	0.323***	0.155***	-0.275***	-0.120
	(0.228)	(0.096)	(0.045)	(0.095)	(0.454)
Observations	12,924	12,924	12,924	12,924	12,923
Mean of dep. var.	6.843	0.350	0.963	0.639	6.850
Std. dev. of dep. var.	0.904	0.388	0.149	0.391	1.872
F-test of excluded instruments	43.93	43.93	43.93	43.93	43.75

Notes - Data are drawn from the SOEP (survey years: 2008, 2010, 2012). Standard errors are reported in parentheses and are clustered at the household level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, migration background, and log of net household income. All regressions further include state and survey years fixed effects, as well as state-specific time trends. The *F*-test for excluded instruments refers to the Kleibergen-Paap *F*-statistic. * Significant at 10%; ** significant at 5%; *** significant at 1%.

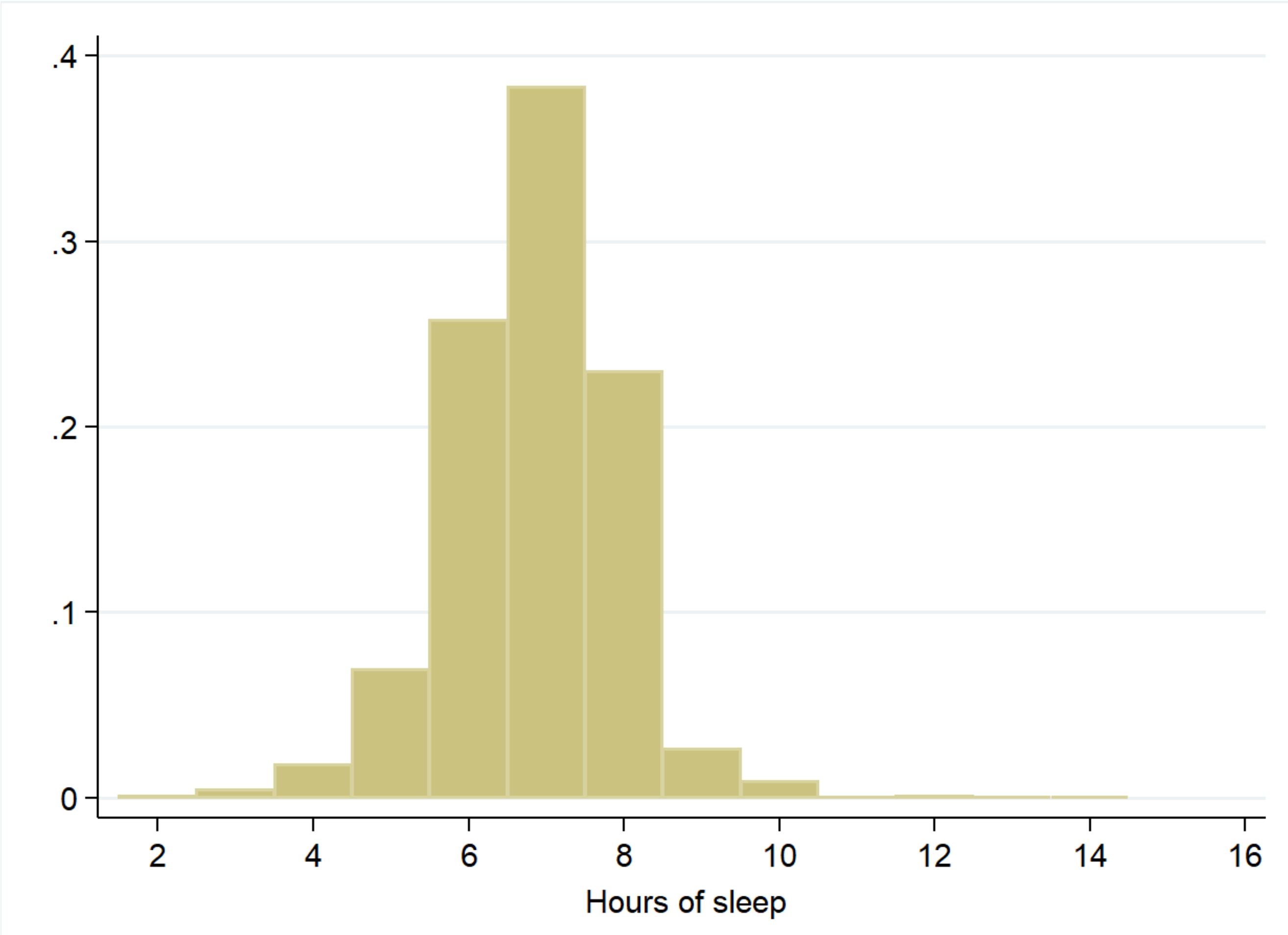
Appendix A: Supplemental Figures and Tables

Figure A.1: Distribution of sleep hours (weekdays) - German TUS



Notes: Data are drawn from the German TUS (2012-2013) for individuals aged 18-59 interviewed during the weekdays.

Figure A.2: Distribution of sleep hours (weekdays) - SOEP data



Notes: Data are drawn from the SOEP (survey years: 2008, 2010, 2012).

Table A.1: Descriptive Statistics - Observations: 43,162 - SOEP data

	Mean	Std. Dev.	Min.	Max.
Outcome Variables				
Hours of sleep (weekdays)	6.84	1.11	2	14
Hours of sleep (weekends)	7.94	1.40	2	16
Sleep at most 6 hours (weekdays)	0.35	0.48	0	1
Sleep at most 6 hours (weekends)	0.13	0.34	0	1
Sleep at most 8 hours (weekdays)	0.96	0.19	0	1
Sleep at most 8 hours (weekends)	0.71	0.46	0	1
Sleep between 7 and 9 hours (weekdays)	0.64	0.48	0	1
Sleep between 7 and 9 hours (weekends)	0.75	0.44	0	1
Sleep satisfaction	6.89	2.27	0	10
PC Use (daily)	0.43	0.49	0	1
Broadband Internet				
DSL subscription in household	0.80	0.40	0	1
Threshold dummy	0.11	0.32	0	1
”No closer MDF” dummy	0.94	0.23	0	1
OPAL dummy	0.01	0.11	0	1
Control Variables				
Female	0.55	0.50	0	1
Age	40.05	10.96	18	59
Married	0.62	0.49	0	1
Single	0.28	0.45	0	1
Divorced	0.09	0.29	0	1
Number of children	1.33	1.22	0	12
West Germany	0.81	0.39	0	1
Lower secondary education	0.23	0.42	0	1
Medium secondary education	0.35	0.48	0	1
Higher secondary education	0.31	0.46	0	1
Apprentice	0.08	0.27	0	1
Unemployed	0.07	0.26	0	1
Blue-collar worker	0.23	0.42	0	1
White-collar worker	0.43	0.49	0	1
Entrepreneur	0.07	0.26	0	1
First-generation immigrants	0.12	0.33	0	1
Second-generation immigrants	0.10	0.30	0	1
Household income (log)	7.89	0.57	0	12.21

Notes - Data are drawn from the SOEP (v32) for individuals aged 18-59 (survey years: 2008, 2010, 2012). All the samples contain individuals for whom information on all observables and the respective outcome variable are not missing. The sample sizes for hours of sleep during weekends, sleep satisfaction and daily use of PC are, respectively, as follows: 43,032; 42,699; 10,399.

Table A.2: Effects of Media Use near Bedtime on Sleep (weekdays) among Teenagers, OLS Estimates - German TUS

	(1)	(2)
Age group:	13-19	
Dep. var.:	Sleep hours	Sleep≤6
Panel A: Media use in 10-minute intervals between 9 pm and midnight		
Computer games (10-minute intervals)	-0.045*	0.012***
	(0.024)	(0.004)
PC use and smartphones (10-minute intervals)	-0.000	-0.001
	(0.022)	(0.003)
Watching TV (10-minute intervals)	-0.022**	0.000
	(0.010)	(0.001)
Panel B: Media use between 11 pm and 11.10 pm		
Computer games (11 pm - 11.10 pm)	-0.622	0.183***
	(0.399)	(0.070)
PC use and smartphones (11 pm - 11.10 pm)	0.231	0.027
	(0.359)	(0.047)
Watching TV (11 pm - 11.10 pm)	-0.553***	0.084***
	(0.153)	(0.025)
Mean of dep. var.	8.706	0.0606
Std. dev. of dep. var.	1.839	0.239
Observations	2,377	2,377

Notes - Data are drawn from the German TUS (2012-2013). Standard errors are reported in parentheses and are clustered at the individual level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, household income, a dummy indicating whether a person is foreign-born, an indicator for house/flat ownership, and the number of children aged less than 10. All regressions further include a dummy for West Germany and fixed effects for the day of interview. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table A.3: Effects of Media Use near Bedtime on Sleep (weekdays), OLS Estimates - Including Individual F.E. - German TUS

	(1)	(2)	(3)	(4)	(5)	(6)
Age group:	18-59		18-30		31-59	
Dep. var.:	Sleep hours	Sleep≤6	Sleep hours	Sleep≤6	Sleep hours	Sleep≤6
Panel A: Media use in 10-minute intervals between 9 pm and midnight						
Computer games (10-minute intervals)	-0.045**	0.009*	-0.057*	0.013*	-0.028	0.003
	(0.022)	(0.005)	(0.034)	(0.007)	(0.022)	(0.006)
PC use and smartphones (10-minute intervals)	-0.008	0.003	0.018	-0.007	-0.026*	0.009***
	(0.014)	(0.003)	(0.027)	(0.005)	(0.014)	(0.003)
Watching TV (10-minute intervals)	-0.013**	-0.000	0.023*	-0.006**	-0.027***	0.002
	(0.005)	(0.001)	(0.013)	(0.002)	(0.005)	(0.001)
Panel B: Media use between 11 pm and 11.10 pm						
Computer games (11 pm - 11.10 pm)	-0.748**	0.134**	-1.392***	0.269***	-0.062	-0.009
	(0.294)	(0.064)	(0.432)	(0.095)	(0.338)	(0.071)
PC use and smartphones (11 pm - 11.10 pm)	-0.462***	0.122***	-0.027	-0.031	-0.695***	0.204***
	(0.169)	(0.042)	(0.379)	(0.071)	(0.164)	(0.050)
Watching TV (11 pm - 11.10 pm)	-0.550***	0.093***	-0.363**	0.021	-0.622***	0.116***
	(0.065)	(0.016)	(0.183)	(0.031)	(0.064)	(0.019)
Mean of dep. var.	7.843	0.103	8.231	0.102	7.742	0.103
Std. dev. of dep. var.	1.600	0.303	1.929	0.303	1.486	0.304
Observations	10,869	10,869	2,242	2,242	8,627	8,627

Notes - Data are drawn from the German TUS (2012-2013). Standard errors are reported in parentheses and are clustered at the individual level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, household income, a dummy indicating whether a person is foreign-born, an indicator for house/flat ownership, and the number of children aged less than 10. All regressions further include a dummy for West Germany, fixed effects for the day of interview, as well as individual fixed effects. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table A.4: Effects of Media Use near Bedtime on Sleep (weekdays) among Teenagers, OLS Estimates - Including Individual F.E. - German TUS

	(1)	(2)
Age group:	13-19	
Dep. var.:	Sleep hours	Sleep≤6
Panel A: Media use in 10-minute intervals between 9 pm and midnight		
Computer games (10-minute intervals)	-0.053**	0.012**
	(0.026)	(0.006)
PC use and smartphones (10-minute intervals)	-0.035	0.005
	(0.025)	(0.004)
Watching TV (10-minute intervals)	-0.035**	-0.003*
	(0.014)	(0.002)
Panel B: Media use between 11 pm and 11.10 pm		
Computer games (11 pm - 11.10 pm)	-0.530	0.168*
	(0.519)	(0.094)
PC use and smartphones (11 pm - 11.10 pm)	-0.090	0.069
	(0.424)	(0.059)
Watching TV (11 pm - 11.10 pm)	-0.978***	0.093***
	(0.208)	(0.033)
Mean of dep. var.	8.706	0.0606
Std. dev. of dep. var.	1.839	0.239
Observations	2,377	2,377

Notes - Data are drawn from the German TUS (2012-2013). Standard errors are reported in parentheses and are clustered at the individual level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, household income, a dummy indicating whether a person is foreign-born, an indicator for house/flat ownership, and the number of children aged less than 10. All regressions further include a dummy for West Germany, fixed effects for the day of interview, as well as individual fixed effects. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table A.5: Work and Family Constraints and the Effects of Media Use near Bedtime on Sleep - Individuals aged 18-59 - German TUS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Constrained group:	Work constraints (6 am - 9 am)		No work constraints		Work or family constraints (6 am - 9 am)		No work or family constraints		With children		Without children	
Dep. var.:	Sleep hours	Sleep≤6	Sleep hours	Sleep≤6	Sleep hours	Sleep≤6	Sleep hours	Sleep≤6	Sleep hours	Sleep≤6	Sleep hours	Sleep≤6
Panel A: Media use in 10-minute intervals between 9 pm and midnight												
Computer games (10-minute intervals)	-0.069***	0.017***	-0.038*	0.006*	-0.070***	0.015***	-0.033	0.007*	-0.079***	0.012*	-0.034*	0.010***
	(0.013)	(0.005)	(0.020)	(0.003)	(0.012)	(0.005)	(0.022)	(0.004)	(0.018)	(0.007)	(0.018)	(0.003)
PC use and smartphones (10-minute intervals)	-0.038***	0.010**	-0.033**	0.005*	-0.050***	0.012***	-0.021	0.002	-0.086***	0.017***	-0.015	0.004
	(0.012)	(0.004)	(0.014)	(0.003)	(0.011)	(0.004)	(0.015)	(0.002)	(0.016)	(0.005)	(0.013)	(0.003)
Watching TV (10-minute intervals)	-0.035***	0.004***	-0.010**	-0.002*	-0.036***	0.005***	-0.004	-0.003***	-0.037***	0.003*	-0.007	-0.000
	(0.004)	(0.001)	(0.005)	(0.001)	(0.004)	(0.001)	(0.006)	(0.001)	(0.007)	(0.002)	(0.004)	(0.001)
Panel B: Media use between 11 pm and 11.10 pm												
Computer games (11 pm - 11.10 pm)	-1.325***	0.365***	-0.538**	0.098**	-1.288***	0.328***	-0.489*	0.094*	-1.013***	0.147	-0.492*	0.177***
	(0.220)	(0.089)	(0.269)	(0.047)	(0.199)	(0.083)	(0.294)	(0.049)	(0.252)	(0.107)	(0.273)	(0.053)
PC use and smartphones (11 pm - 11.10 pm)	-0.816***	0.266***	-0.614***	0.095**	-0.937***	0.268***	-0.585***	0.086**	-1.039***	0.236**	-0.388**	0.126***
	(0.151)	(0.072)	(0.179)	(0.039)	(0.148)	(0.068)	(0.184)	(0.039)	(0.225)	(0.092)	(0.156)	(0.040)
Watching TV (11 pm - 11.10 pm)	-0.888***	0.233***	-0.595***	0.052***	-0.885***	0.223***	-0.521***	0.020*	-0.812***	0.170***	-0.458***	0.092***
	(0.052)	(0.023)	(0.062)	(0.012)	(0.047)	(0.020)	(0.069)	(0.012)	(0.090)	(0.027)	(0.056)	(0.013)
Mean of dep. var.	7.241	0.138	8.427	0.0681	7.332	0.128	8.606	0.0646	7.715	0.102	7.887	0.103
Std. dev. of dep. var.	1.211	0.345	1.710	0.252	1.241	0.334	1.762	0.246	1.470	0.302	1.639	0.304
Observations	5,347	5,347	5,522	5,522	6,506	6,506	4,363	4,363	2,757	2,757	8,112	8,112

Notes - Data are drawn from the German TUS (2012-2013). Standard errors are reported in parentheses and are clustered at the individual level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, household income, a dummy indicating whether a person is foreign-born, an indicator for house/flat ownership, and the number of children aged less than 10. All regressions further include a dummy for West Germany and fixed effects for the day of interview. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table A.6: Effects of Media Use near Bedtime on Sleep (weekends), OLS Estimates - German TUS

	(1)	(2)	(3)	(4)	(5)	(6)
Age group:	18-59		18-30		31-59	
Dep. var.:	Sleep hours	Sleep≤6	Sleep hours	Sleep≤6	Sleep hours	Sleep≤6
Panel A: Media use in 10-minute intervals between 9 pm and midnight						
Computer games (10-minute intervals)	-0.020	-0.001	-0.014	-0.000	-0.039*	-0.002
	(0.018)	(0.002)	(0.025)	(0.003)	(0.023)	(0.003)
PC use and smartphones (10-minute intervals)	-0.004	-0.004***	0.042*	-0.007***	-0.028**	-0.002
	(0.012)	(0.001)	(0.024)	(0.001)	(0.012)	(0.002)
Watching TV (10-minute intervals)	-0.001	-0.005***	0.022*	-0.005***	-0.007	-0.005***
	(0.005)	(0.001)	(0.012)	(0.001)	(0.005)	(0.001)
Panel B: Media use between 11 pm and 11.10 pm						
Computer games (11 pm - 11.10 pm)	-0.647**	-0.014	-0.449	0.016	-1.050***	-0.060***
	(0.278)	(0.032)	(0.395)	(0.050)	(0.329)	(0.008)
PC use and smartphones (11 pm - 11.10 pm)	-0.247	-0.010	0.225	-0.074***	-0.593***	0.031
	(0.186)	(0.026)	(0.318)	(0.011)	(0.219)	(0.040)
Watching TV (11 pm - 11.10 pm)	-0.755***	-0.003	-0.603***	-0.022	-0.789***	0.001
	(0.055)	(0.008)	(0.147)	(0.018)	(0.058)	(0.009)
Mean of dep. var.	9.106	0.0648	9.650	0.0729	8.964	0.0627
Std. dev. of dep. var.	1.935	0.246	2.342	0.260	1.787	0.242
Observations	6,047	6,047	1,248	1,248	4,799	4,799

Notes - Data are drawn from the German TUS (2012-2013). Standard errors are reported in parentheses and are clustered at the individual level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, household income, a dummy indicating whether a person is foreign-born, an indicator for house/flat ownership, and the number of children aged less than 10. All regressions further include a dummy for West Germany and fixed effects for the day of interview. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table A.7: Effects of PC Use on Sleep (OLS) and DSL Access on PC Use (2SLS) - SOEP data

	(1)	(2)
Dep. Var.:	Sleep≤6 hours	PC Use (daily)
PC Use (daily)	0.041***	-
	(0.010)	
DSL subscription	-	0.273**
		(0.133)
Observations	10,374	10,399
Mean of dep. var.	0.309	0.427
Std. dev. of dep var.	0.462	0.495
F-test of excluded instruments	-	10.38

Notes - Data are drawn from the SOEP (survey years: 2008, 2010, 2012). Standard errors are reported in parentheses and are clustered at the household level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, migration background, and log of net household income. All regressions further include state and survey years fixed effects, as well as state-specific time trends. The *F*-test for excluded instruments refers to the Kleibergen-Paap *F*-statistic. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table A.8: Effects of High-Speed Internet on Sleep (weekdays), OLS Estimates - SOEP data

	(1)	(2)	(3)	(4)	(5)
Dep. Var.:	Sleep hours	Sleep≤6 hours	Sleep≤8 hours	7≤Sleep≤9 hours	Sleep satisfaction
DSL subscription	-0.068***	0.027***	0.005*	-0.028***	-0.102***
	(0.017)	(0.007)	(0.003)	(0.007)	(0.035)
Observations	43,162	43,162	43,162	43,162	42,699
Mean of dep. var.	6.844	0.350	0.963	0.639	6.891
Std. dev. of dep. var.	1.107	0.477	0.189	0.480	2.266

Notes - Data are drawn from the SOEP (survey years: 2008, 2010, 2012). Standard errors are reported in parentheses and are clustered at the household level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, migration background, and log of net household income. All regressions further include state and survey years fixed effects, as well as state-specific time trends. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table A.9: Effects of High-Speed Internet on Sleep (weekends), 2SLS Estimates - SOEP data

	(1)	(2)	(3)	(4)
Dep. Var.:	Sleep hours	Sleep≤6 hours	Sleep≤8 hours	7≤Sleep≤9 hours
DSL subscription	-0.053	0.072	0.005	-0.015
	(0.259)	(0.055)	(0.082)	(0.071)
Observations	43,032	43,032	43,032	43,032
Mean of dep. var.	7.936	0.130	0.705	0.747
Std. dev. of dep. var.	1.401	0.337	0.456	0.435
F-test of excluded instruments	32.67	32.67	32.67	32.67

Notes - Data are drawn from the SOEP (survey years: 2008, 2010, 2012). Standard errors are reported in parentheses and are clustered at the household level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, migration background, and log of net household income. All regressions further include state and survey years fixed effects, as well as state-specific time trends. The *F*-test for excluded instruments refers to the Kleibergen-Paap *F*-statistic. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table A.10: Robustness Checks by Age Group - SOEP data

Dep. Var.:	(1) Sleep hours	(2) Sleep≤6 hours	(3) Sleep≤8 hours	(4) 7≤Sleep≤9 hours	(5) Sleep satisfaction
Panel A: Individuals aged 25-59					
DSL subscription	-0.355	0.258***	0.045	-0.242**	-0.569
	(0.218)	(0.095)	(0.033)	(0.095)	(0.466)
Observations	38,417	38,417	38,417	38,417	38,017
Mean of dep. var.	6.805	0.360	0.969	0.631	6.818
Std. dev. of dep. var.	1.091	0.480	0.173	0.483	2.276
F-test of excluded instruments	32.64	32.64	32.64	32.64	32.87
Panel B: Individuals aged 18-55					
DSL subscription	-0.398*	0.243***	0.080**	-0.222**	-0.764*
	(0.213)	(0.088)	(0.037)	(0.088)	(0.452)
Observations	39,741	39,741	39,741	39,741	39,331
Mean of dep. var.	6.847	0.349	0.963	0.641	6.929
Std. dev. of dep. var.	1.100	0.477	0.188	0.480	2.255
F-test of excluded instruments	32.29	32.29	32.29	32.29	32.22
Panel C: Individuals aged 18-65					
DSL subscription	-0.193	0.194**	0.075**	-0.176**	-0.521
	(0.216)	(0.087)	(0.038)	(0.087)	(0.458)
Observations	47,549	47,549	47,549	47,549	46,984
Mean of dep. var.	6.865	0.344	0.960	0.645	6.865
Std. dev. of dep. var.	1.121	0.475	0.197	0.479	2.274
F-test of excluded instruments	30.66	30.66	30.66	30.66	30.63
Panel D: Individuals aged 20-54					
DSL subscription	-0.374*	0.248***	0.075**	-0.227**	-0.643
	(0.224)	(0.093)	(0.038)	(0.093)	(0.469)
Observations	37,127	37,127	37,127	37,127	36,754
Mean of dep. var.	6.830	0.354	0.966	0.637	6.908
Std. dev. of dep. var.	1.094	0.478	0.181	0.481	2.257
F-test of excluded instruments	32.44	32.44	32.44	32.44	32.29

Notes - Data are drawn from the SOEP (survey years: 2008, 2010, 2012). Standard errors are reported in parentheses and are clustered at the household level. All models include controls for education, age and its quadratic term, gender, marital status, occupational status, migration background, and log of net household income. All regressions further include state and survey years fixed effects, as well as state-specific time trends. The *F*-test for excluded instruments refers to the Kleibergen-Paap *F*-statistic. * Significant at 10%; ** significant at 5%; *** significant at 1%.