CESifo WORKING PAPERS

9195
2021

July 2021

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CESifo

Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editor: Clemens Fuest
https://www.cesifo.org/en/wp
An electronic version of the paper may be downloaded
· from the SSRN website: www.SSRN.com
· from the RePEc website: www.RePEc.org
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CESifo *Working Paper No. 9195*

The Welfare Effects of Time Reallocation: Evidence from Daylight Saving Time

Abstract

Daylight Saving Time (DST) is currently implemented by more than seventy countries, yet we do not have a clear knowledge of how it affects individuals' welfare. Using a regression discontinuity design combined with a differences-in-differences approach, we find that the Spring DST causes a significant decline in life satisfaction. By inducing a reallocation of time, the transition into DST deteriorates sleep and increases time stress, which in turn affects physical and emotional health. After performing a simple cost-benefit analysis, we find evidence suggestive that ending DST would exert a positive effect on welfare, namely the wellbeing costs associated with DST exceed its benefits.

JEL-Codes: I180, K200, I310.

Keywords: Daylight Saving Time, wellbeing, health, sleep, time stress.

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We would link to thank Clément Bosquet, Andrew Clark, Richard Layard, Reto Odermatt, Christian Krekel, and seminar participants at the London School of Economics for their valuable comments. All remaining errors are our own.

I. Introduction

Daylight Saving Time (DST) is currently implemented by more than seventy countries around the world with the aim of reducing demand for energy. However, recent studies have shown that DST does not save energy and could actually increase the use of electricity (Kotchen and Grant, 2011). Moreover, opponents of DST argue that, a time change, even if it is only by one hour, can have lasting effects on individuals. Studies have linked DST to greater risks of car accidents (Smith, 2016; Fritz, 2020; Bunnings and Schiele, 2020), workplace injuries (Barnes and Wagner, 2009), heart attacks (Manfredini et al., 2018) and depressive symptoms (Hansen et al., 2017). In this paper, we show that DST generates high welfare costs on individuals, specifically a decrease in life satisfaction. Investigating a broad range of outcomes, we show that this decline in life satisfaction can be explained by a decrease in sleep following the transition and an increase in time pressure, which significantly affect individuals' physical and emotional health in subsequent days. Performing a cost-benefit analysis, these findings imply that the welfare costs associated with DST are larger than its potential benefits.

Over recent years, the DST policy has become increasingly controversial, with the European Parliament voting in March 2019 in favor of putting an end to the DST. Yet, so far, the process has been halted. First, because of the worldwide pandemic, but also because some countries, like the UK and Ireland, argue that ending the DST will create a patchwork of time zones, destabilizing further the European Union. At the time of writing, no negotiations have started yet, and this could take some time before we see the end of the DST in the European Union. In the United States, DST has been implemented since 1966 in most US States and has been extended as part of the Energy Policy Act of 2005. While the rationale for implementing DST has been to align more closely sunlight with day-to-day activities and reduce energy consumption, it can also have many other impacts on people's life. To shed light on this debate, it is crucial that policy makers have at their disposal estimates of the welfare costs and benefits associated with DST.

This paper focuses on a first-order effect of DST, its impact on individuals' wellbeing. So far, most of the DST literature has explored the effects of DST on specific outcomes in isolation (e.g. energy consumption, car accidents, heart attacks, workplace injuries, etc.). But in order to assess the welfare costs and benefits of DST, it is crucial that we also consider how people *experience* this transition. DST could impact population's wellbeing through two primary mechanisms. First, it induces a reallocation of time, which can largely affect individuals' sleep schedules. According to Barnes and Wagner (2009), sleep duration reduces by 40 minutes on average on Mondays following the Spring transition. Lack of sleep may result in a tendency to err from both fatigue and attention problems and impair cognitive abilities and work performance (Nuckols et al., 2009; Carell et al., 2011; Giuntella et al., 2017; Avery et al., 2019; Gibson and Shrader, 2018). Second, by moving clock forward one hour, the transition into DST reduces the total time available and strengthens the time constraint in the days following the transition. Even if this increase in time constraint is a short-term effect, this is likely to increase people's feelings of being "rushed" by time (Hamermesh and Lee, 2007) and affect their emotional health (Scholtz et al., 2004; Frankenhaeuser et al., 1989; Garling et al., 2015). Moreover, by increasing time pressure, people may devote less time to carry out restorative activities, such as eating, socializing or exercising, which are essential to their health and emotional wellbeing.

Existing evidence of the impact of DST on individuals' wellbeing are scarce. Only two studies have focused on life satisfaction and suggest that DST is associated with lower levels of life satisfaction. Kountouris and Remoundou (2014) use a fixed-effects specification and compare the life satisfaction of respondents interviewed within a week from DST transition with the rest of the year. Kuehnle and Wunder (2015) adopt a day-to-day comparison and compare life satisfaction of respondents on the days following the DST transition with similar days of the week in previous weeks. While these studies suggest a negative effect of DST on life satisfaction, these identification strategies could underestimate the true effect of DST on individuals' wellbeing. The former study only measures an average effect over the first week of transition. The latter compares life satisfaction of respondents interviewed just before and after the nighttime shift without considering potential endogenous sorting of respondents around the DST transition.

The contribution of our paper is three-fold. First, we are the first paper to implement a regression-discontinuity (RD) design combined with a differences-in-differences strategy to assess the effects of DST. We compare the average wellbeing of individuals on the days just before and after the DST transition, as it is standard in the application of RD models, but we also compare this wellbeing change with the average wellbeing of individuals on the days just before and after the last Sunday of the month in the previous and subsequent months (January, February, April and May) as a counterfactual. The use of these two identification strategies in tandem, using the discontinuity in wellbeing around the DST threshold, and using the change in wellbeing that typically occurs around the last Sunday of the month as a counterfactual, allows us not only to capture local effects of DST over subsequent days following the transition, but also to deal with the concerns that previous results on DST effects could be partially downward biased by endogenous sorting of respondents around the last Sunday of the month. To the best of our knowledge, no study so far has investigated DST effects using this empirical approach.

Second, we investigate the effects of DST on a broad range of outcomes to decompose the overall wellbeing impact into a sleep and time pressure component. This includes investigating the consequences of DST on sleep, feeling of being rushed by time, satisfaction with day-to-day activities as well as physical and emotional health of respondents. Existing work so far has only focused on life satisfaction to proxy for individuals' wellbeing or only investigates outcomes in isolation, without being able to dig into the mechanisms though which DST can affect individuals' wellbeing. Finally, we use our estimates to perform a cost-benefit analysis and discuss how putting an end to the DST could be welfare-efficient, providing guidance to policy makers on the welfare costs and benefits associated with this policy.

To identify the impact of DST on individuals' wellbeing, we use individual panel data from the German Socio-Economic Panel (SOEP) from 2008 to 2018. We first implement a regression discontinuity design, exploiting the changes between Standard Time and DST on the last Sunday of the month in March. Then using the previous and subsequent months as counterfactual, we use an RD design combined with a difference-in-differences strategy, that relies on the comparison of the average wellbeing of individuals around the Spring DST with the average wellbeing of individuals on the counterfactual day around the last Sunday of the month in other months. In both specifications, we find a decrease in life satisfaction following the DST transition. RD estimates indicate a decrease of 0.055 SD while the RD-DiD estimates report larger negative effects of around 0.069 SD. To address the possibility that some unobserved factors are driving the results, we also consider a rich set of fixed effects, including year, region, time window, day of the week, as well as individual fixed effects. The results are robust to the use of different (i) bandwidths, (ii) polynomial functions of the distance in days from the last Sunday of the month, (iii) time windows, and (iv) alternative control groups. By contrast, we find no discontinuity in life satisfaction around the last Sunday of the month in previous and subsequent months (January, February, April and May).

To investigate the persistence of these effects, we implement an event study analysis. The results indicate that the negative effects of DST on individuals' life satisfaction persist for about 6 days after the nighttime shift and then dissipate. Interestingly, on the first weekend following the transition, there is a positive effect on life satisfaction, which could suggest that at least temporarily people enjoy having one extra hour of daylight in the evening once they have adjusted to the new time schedule. It also confirms that estimating an average effect over the first week of transition, as done by Kountouris and Remoundou (2014), could provide misleading results as it would lead to average negative and positive effects altogether, hence failing to capture the dynamics of DST effects on life satisfaction. We then examine potential mechanisms.

To better understand the channels through which DST affects individuals' wellbeing, we implement our RDD-DiD strategy using a number of outcomes. First, we isolate the DST effect on sleep by examining changes in sleep satisfaction. Then, we look at the effects on a range of health variables, including overall health assessment, hospital admissions, and mental health. Second, we dig into the time pressure mechanism, by examining the effect of DST on people's feeling of being rushed by time and satisfaction with day-to-day activities including work, leisure, childcare and family life satisfaction. Of course, we cannot possibility distinguish between these two mechanisms – sleep and time pressure –, as they are likely to be intertwined and affect health outcomes and day-to-day satisfaction at the same time: sleep deprived individuals are more likely to feel being rushed by time and vice et versa. The results suggest that the DST transition significantly decreases sleep satisfaction by 0.15 SD and increases reported time pressure by 0.17 SD. Moreover, individuals tend to report lower physical and emotional health following the DST transition, as well as lower satisfaction with day-to-day activities. Once controlling for sleep variables, the impact of DST on life satisfaction falls by about 64%, which suggests that sleep reduction is one of the main drivers explaining the decrease in life satisfaction.

The results reveal an immediate decrease of 0.069 SD in life satisfaction, persisting for 6 days following the DST transition. This suggests that the nighttime shift occurring at the end of March decreases individual wellbeing by approximately 0.001 SD[1] annually. This is equivalent to an income loss of 393 euros per year.[2] Now, if we consider the potential benefits in terms of energy savings – for the sake of the exercise, we consider a decrease in energy consumption by 0.5% over the year, according to Aries and Newsham (2008) –, putting an end to the DST would then cost approximately 4.85 euros per capita.[3] As a result, any policy maker choosing to end the DST would then generate more welfare benefits than the policy would cost. And note that this estimation is a lower bound as evidence that DST allows energy saving are increasingly challenged.

The remainder of this paper is organized as follows. The next section briefly describes the literature and the mechanisms though which DST affects individuals' wellbeing. Section 3 presents the data. Section 4 discusses the empirical strategy. Section 5 contains the results. A final section concludes after a brief cost-benefit analysis in Section 6.

II. Daylight Saving Time Policy

Each year Germany as well as most European countries set clock forward one hour on the last Sunday of March (summertime). This time change always occurs at 2 AM, where the clocks are set forward to 3 A.M. Clocks are then moved back one hour at the end of DST, that is on the last Sunday of October. This process is assumed to move one extra hour of daylight from the morning to the end of the day after the end of March, hence potentially allowing to reduce electricity usage for lighting. However, by inducing a reallocation of time, the DST policy has many other impacts on people's day-to-day life.

We identify two ways in which DST affects individuals' wellbeing: disrupting sleep and increasing time constraints. Existing work has shown the influence of DST on sleep patterns (Barnes and Wagner, 2009; Lahti et al. 2006), however none of these studies have linked the decrease in sleep due to DST to decreases in individuals' wellbeing in

[1] 0.001=(0.069/365)*6

[2] Monetary equivalent is based on the common finding in the happiness literature that a 1% gain in income increases life satisfaction by around 0.002 points (see Layard et al., 2020). Comparing these 0.002 points with 0.001 times 1.65 (the standard deviation of life satisfaction) implies that the DST wellbeing effect is equivalent to an income loss of 0.93% per year. Using the German average income of 42 000 euros, it amounts to a decrease of approximately 393 euros per year.

[3] Using German average electricity cost of 0.15 euros per kWh and an energy consumption per capita of 6,453 kWh.

the first days following the transition. Using American Time Use Survey, Barnes and Wagner (2006) finds that DST reduces sleep by 40 minutes on average on the Mondays following the transition. There are individual differences in adaptation to DST with some people requiring more than 2 weeks to adjust their sleep patterns (Valdez et al., 1996), but on average it takes about one week for people to adjust (Harrison, 2013). Sleep deprivation has been shown to increase attention problems, reducing work performance and increasing workplace injuries (Barnes and Wagner, 2006; Wagner et al., 2012). It also reduces driving safety and increases traffic accidents (Smith, 2016). Sleep disruptions may lead to greater risk of heart attacks, strokes, as well as depression and mental distress (Chandola et al., 2010; Giuntella and Mazzona, 2019). From a societal point of view, sleep disruptions may induce substantial costs, particularly in societies where sleep-deprivation has become a public health issue (CDC, 2014).

The other mechanism through which DST is likely to affect individuals' wellbeing is through the reduction in the total time available following the nighttime shift. Clocks are set forward from 2 AM to 3 AM on the date of transition. This reduces the transition day by one hour, compared to the standard 24-hour day. This "missing" hour could be cut from sleep time, but it could also reduce time devoted to other day-to-day activities such as work and leisure. By strengthening the time constraint, the DST transition may ultimately increase the price of time and people's feeling of being rushed by time (Hamermesh and Lee, 2007). Increasing time pressure is likely to result in time stress, affecting people's productivity (Roskes et al., 2013), decision-making (Sutter et al., 2003; Kocher and Sutter, 2006; Kirchler et al., 2017) and significantly decreasing people's health and emotional wellbeing (Scholtz et al., 2004; Frankenhaueser et al., 1989; Garling et al., 2015).

In contrast, the Fall DST by moving clocks backward one hour increases the total amount of available time. Less studies have been investigated the effects of the Fall DST. However, while Barnes and Wagner (2009) finds no significant effect of the Fall transition on sleep, Jin and Ziebarth (2020) provides evidence that setting clocks backs by one hour significantly extends people's sleep duration. Consistent with studies examining the effect of jet lags (Klein et al., 1972; Monk et al., 2001; Flower et al., 2003) sleep patterns may adjust more quickly to the Fall transition.

It is also useful to think about more long-term effects. Indeed, the sleep effects are likely to be felt for a relatively short period following the DST transition. However, if the individuals' time constraint is tightened at the beginning, it could well be the case that once individuals have adjusted to the new time schedules, the Spring DST actually relaxes individuals' time constraint by increasing the quantity of daylight in the evening. This light effect could be felt for the entire duration of DST and causes positive effects on individuals' wellbeing. We will use event study analyses to investigate these longer term-effects.

III. Data

To investigate the effects of the Spring DST on individuals' wellbeing, we use data from the German Socio-Economic Panel. The SOEP is a large panel survey of adults aged 15 and above living in Germany. Around 11,000 households and 30,000 respondents are interviewed every year. Importantly, the SOEP contains data on the day, week, month and year of interview. This information allows us to identify the individuals who were interviewed before, during and after the day of change in clocks. We focus on the four weeks around the time shift and compare survey responses of respondents during these four weeks with those of respondents interviewed two weeks before and two weeks after the last Sunday of the Month in the previous and subsequent months (that is January, February, April and May). Most importantly, respondents have been continuously interviewed in the days before and after the last Sunday of the month in each month, which allow us to have enough observations around the cut-off dates. We have around 150,000 observations covering the years 2008-2018, with 37,000 observations around the last Sunday of March and 113,000 around the last Sunday of the month in the four other months.

Our main dependent variable is the life satisfaction of respondent, measured using the following question: "How satisfied are you with your life, all things considered?". The possible responses range from 0 (completely dissatisfied) to 10 (completely satisfied). The average life satisfaction in our sample is 7.24, with a standard deviation of 1.65. Figure 1 plots the life satisfaction reported in the four weeks surrounding the Spring DST. There is a clear drop in life satisfaction, happening right after the transition into DST. This provides graphical evidence that the Spring DST is associated with a short-term decrease in life satisfaction. Our first empirical strategies, using RD and RD-DiD designs, formally test for this discontinuity.

To dig into potential mechanisms, we also use additional variables, such as respondent's satisfaction with sleep. Respondents are asked: "How satisfied are you today with your sleep?". The possible answers again range from 0 (completely satisfied) to 10 (completely satisfied). Summary statistics of all our variables are provided in Appendix Table A1.

The SOEP questionnaire also includes a section labeled "Health and Illness", which provides detailed information on the current health status of individuals. More specifically, we are interested in the individuals' answers to the following question:

(1) "During the last four weeks, how often did you feel (i) rushed or pressed by time; (ii) down and melancholic; (iii) well-balanced; and (iv) full of energy, with possible responses: always, often, sometimes, almost never and never.

(2) "How satisfied are you today with your health?". Possible answers range from 0 (completely satisfied) to 10 (completely satisfied)

(3) "How would you describe your current health?". Possible responses are bad, poor, satisfactory, good and very good.

(4) "What about hospital stays in the last year – were you admitted to a hospital for at least one night?"

(5) "During the last four weeks, how often did you feel that due to mental health or emotional problems, (i) you achieved less than you wanted to at work or in everyday activities; (ii) you carried out your work or everyday tasks less thoroughly than usual", with possible responses: always, often, sometimes, almost never and never.[4] Combining information from (1) and (5), and following the methodology used to compute summary indices from the SF-12 questionnaire, we get an average measure of respondent's mental health (see Appendix Table A2).

[4] These variables are only available for the years 2008, 2010, 2012, 2014, 2016, 2017 and 2018.

The SOEP questionnaire also includes information on respondent's satisfaction with day-to-day activities, including work, leisure, childcare and family life. For each of these dimensions, respondents were asked: "How satisfied are you today with: your job? your leisure time? childcare? your family life?". Again, possible answers range from 0 (completely satisfied) to 10 (completely satisfied). We analyze the effects of DST on each of these dimensions.

IV. Empirical Strategy

A. Regression Discontinuity (RD) Method

We aim to estimate the effects of DST on individuals' wellbeing. To run this analysis, we first adopt a regression discontinuity (RD) design, which consists of comparing individuals' life satisfaction responses just before and after the DST transition. As the DST transition happens on the last Sunday of March, and we would not expect the effect to persist over time, the RD design then estimates the immediate effect of the DST transition.

More specifically, we first residualize the life satisfaction controlling for observed individual characteristics (age, age-squared, years of education, full-time or part-time employed, net household income, married, widowed, separated or divorced, number of children in the household and disability status), and a set of fixed effects, which includes region, year, window (1 to 12, for the four-week time window around the last Sunday of the month), day of the week (Monday to Sunday) as well as individual fixed effects.[5] To have better estimated coefficients, we perform this first step using the full SOEP sam-

[5]More specifically, we estimate the following equation:

$$WB^*_{it} = X_{it}\mu + \eta_r + \tau_{ywd} + \rho_i + u_{it}$$

where WB^*_{it} is the life satisfaction of individual i interviewed on date $t = (y, w, d)$ where y is the year of interview, w is the window of interview, d is the day of the week (Monday to Sunday). X is a vector of individual characteristics, which includes age, age-squared, education, employment status, net household income, marital status, number of children in the household and disability status. We also control for region fixed effects η_r, year, window and day of the week effects in the matrix τ_{ywd}, and individual fixed effects ρ_i. The estimated results are reported in Appendix Table A3.

ple, without restricting us to the four-week time windows around the DST transition.[6] This allows to purge the life satisfaction from differences across respondents that are due to differences in observed characteristics, unobserved time-invariant characteristics and persistent day of the week effects or more long-term time trends. Then, we implement the standard RD specification, following Calonico, Cattaneo and Titiunik (2014), with the residualized life satisfaction as our outcome variable. The estimated equation is as follows:

$$WB_{it} = \alpha + \beta POST_{t(i)} + f(D_{t(i)}) + f(D_{t(i)} * POST_{t(i)}) + \epsilon_{it} \tag{1}$$

where WB_{it} is the residualized life satisfaction of individual i interviewed on date t. $POST_{t(i)}$ is a dummy variable that takes value 1 if respondent is interviewed in the two weeks after the nighttime shift and 0 otherwise. $f(D_{t(i)})$ is a linear function of the distance in days from the transition date (that is -14, -13, ..., 0, ..., 13, 14 where 0 indicates the day of transition), interacted with treatment variable $POST_{t(i)}$, which allows for different trends on either side of the cut-off. β is our coefficient of interest and reflects the effect of DST on life satisfaction at the transition date. The standard errors are clustered over time (at the day of the week level).

In this setting, one important assumption that must be done is that conditional on the control variables included in the regression, individuals are randomly interviewed just before and after the day of change in clocks. Hence, comparing mean life satisfaction of individuals interviewed just before and after the DST transition would provide estimates of the immediate effect of DST on life satisfaction. However, individuals may have preferences over the day of the interview (Taylor, 2006), or may systematically favor being interviewed before or after the DST transition. Appendix Table A5 examines the comparability of the "before" and "after" groups for the four-week time window around the DST transition. The "before" group tend to be different from the "after group". Respondents in the "before" group are significantly older, more likely to be married, poorer, less likely to work full-time, and with more children at home.

Moreover, RD design assumes that there is no other major change on the day of

[6] Performing the same analysis, but restricting the sample to the four-week time window around the DST transition produces the same results (see Appendix Tables A3 and A4). However, note that the results are less precisely estimated as we rely on individuals who are observed several times within the four-week time window around the DST transition to estimate the effects.

change in clocks that may also affect individuals' life satisfaction. However, DST always occurs at the end of the month. If wellbeing is not continuous at the end of the month, and for instance there is a hike in life satisfaction when most people receive income from employment, then the RD design will produce biased estimates of the DST effects. The use of an RD model combined with a difference-in-differences strategy allows us to deal with these empirical issues.

B. RD approach combined with Differences-in-Differences (RD-DiD)

To implement this empirical strategy, we take advantage of respondents' answers to the life satisfaction question on counterfactual days in the previous and subsequent months to construct a plausible control group. If wellbeing varies discontinuously, or if respondents sort endogenously around the last Sunday of the month, then using counterfactual days in the previous and subsequent months could allow us to control for these effects. Appendix Table A5 examines the comparability of the "before" and "after" groups for the four-week time window around the last Sunday of the month in previous and subsequent months to DST. We find that the "before" and "after" systematically differ. They differ in terms of marital status, income, employment, education and number of children. However, these differences are qualitatively the same as the ones observed between the "before" and "after" groups for the four-week time window around the last Sunday of the month in March. It suggests that if individuals are not randomly interviewed just before and after the last Sunday of the month, it is unlikely that this endogenous sorting differs across months.

Figure 2 shows the life satisfaction in the four weeks surrounding the Spring DST as well as in the four weeks surrounding the last Sunday of the month in previous and subsequent months (January, February, April and May). It allows us to test for the "common trends" assumption that the life satisfaction behaves similarly in the days before the day of change in clock (treatment group) and in the days before the last Sunday of the month (control group). Figure 2 shows parallel trends in life satisfaction between the treatment and control groups, consistent with the common trend assumption. We also detect a decrease in life satisfaction in the treatment group, while there is no discontinuity in life satisfaction at the cut-off date in the control group as we would expect.[7]

Using respondents' life satisfaction before and after the last Sunday of the month as a plausible control group, we thus combined our RD design with a differences-in-differences strategy. We first residualize the life satisfaction using the same controls as before, that is observed individual characteristics (age, age-squared, education, employment status, net household income, marital status, number of children in the household and disability status), and a set of fixed effects, which includes region, year, window, day of the week (Monday to Sunday) as well as individual fixed effects, across the full SOEP sample. We then run the following specification using the residualized life satisfaction as our outcome variable:

$$\begin{aligned} WB_{it} = \alpha' + \beta' POST_{t(i)} * TREATED_{t(i)} + \gamma' POST_{t(i)} + \delta' TREATED_{t(i)} \\ + f(D_{t(i)} * TREATED_{t(i)}) + f(D_{t(i)} * POST_{t(i)} * TREATED_{t(i)}) \\ + f(D_{t(i)}) + f(D_{t(i)} * POST_{t(i)}) + \epsilon_{it} \quad (2) \end{aligned}$$

where WB_{it} is the residualized life satisfaction of individual i interviewed on date t. $POST_{t(i)}$ is a dummy variable that takes value 1 in the 14 days after the last Sunday of the month and is 0 in the 14 days beforehand. $TREATED_{t(i)}$ is dummy variable that takes value 1 if respondent is interviewed in the four-week window around the last Sunday of March, and 0 otherwise. The coefficient of interest, β' here, is the difference between the change in life satisfaction that we observe just before and after the day of change in clocks, and the change in life satisfaction that typically occurs just before and after the last Sunday of the month in previous and subsequent months (January, February, April and May). The standard errors are clustered over time (at the day of the week and window levels).

Our baseline specifications use optimal bandwidth selector, a first-order polynomial function of the distance in days from the last Sunday of the month, $f(D_{t(i)})$, and a triangular kernel. For robustness checks, we provide evidence that our results are robust

[7] Appendix Figure A1 shows the residualized life satisfaction in the four weeks surrounding the Spring DST as well as in the four weeks surrounding the last Sunday of the months in previous and subsequent months (January, February, April and May). Again, we see parallel trends in life satisfaction between the treatment and control groups.

using (i) alternative bandwidth selectors, (ii) higher order polynomial functions, (iii) different time windows, and (iv) alternative control groups (that is, only February and April, or only February as counterfactuals). As our dependent variable is estimated from a previous regression, we also provide evidence that our results are robust to using alternative standard errors calculations.

RD or RD-DiD designs allow us to capture the effect of DST right at the transition date. It does not allow to estimate longer-term impacts. To test whether the effects persist over time, we also conduct event-study analyses, up to two weeks after the DST transition.

V. Results

A. RD and RDD-DiD Results

Table 1 reports estimates using RD and RD-DiD models. The RD estimate in column (1) indicates that the Spring DST would be associated with a decrease in life satisfaction of 0.055 SD.[8] The results persist using a common CER-optimal bandwidth selector as shown in column (2). We then run the RD-DiD strategy and present the results in columns (3) and (4). Using counterfactual days in previous and subsequent months as a plausible control group, the point estimates for both bandwidth selectors remain negative and significant. They reveal a larger reduction in life satisfaction to the one seen in columns (1) and (2), of 0.069 SD and 0.090 SD, respectively.

To address the possibility that last Sundays of the month are systematically associated with a significant discontinuity in life satisfaction, unrelated to DST, we run the following placebo test in columns (5) and (6). We perform an RD analysis using only observations in January, February, April and May around the last Sunday of the month. The test reveals no significant effect on life satisfaction. This is consistent with Figure 2, where we could see no discontinuity in life satisfaction around the last Sunday of the month. This also confirms that the decrease in life satisfaction measured in columns (1)-(4) is not simply due to a last-Sunday-of-the-month effect, but due to the actual DST policy.

To address the concerns that our results could be driven by the width of the time

[8] We also explore several alternative standard error calculations in Appendix Table A6, including the robust bias corrected standard errors of Calonico, Cattaneo and Titiunik (2014). All coefficients remain negative and significant at conventional levels.

window we have chosen, we perform the analysis for a stricter definition, considering only the two-week time window around the DST transition/last Sunday of the month. Results are very similar to the main specifications (see Appendix Table A7). The rest of Appendix Table A7 shows that the results are robust to higher order polynomial functions and alternative control groups (i.e., restricting to February and April, or only using February only as a counterfactual). Overall, these results demonstrate that both RD models and RD-DiD strategies measure a negative effect of the Spring DST on life satisfaction.[9]

B. Potential Mechanisms

The Spring DST is likely to affect individuals' wellbeing through disrupted sleep and increasing time constraints. Hence the decrease in life satisfaction should go along with a decrease in sleep satisfaction and an increase in time stress. In order to analyze these possibilities, we investigate the effects of DST on a range of outcomes, going from sleep to health and satisfaction with day-to-day activities. We use our RD-DID strategy to estimate these effects.

Sleep and Health. Upon entering DST in the Spring, clocks are set forward from 2 AM to 3 AM. This reduces the transition day by one hour, compared to the standard 24-hour day. This "missing" hour could be cut from sleep time and reduces sleep satisfaction. To test this hypothesis, we run our RD-DiD strategy from equation (2) using sleep satisfaction as our outcome variable. The results, reported in Table 2, indicate that entering DST is associated with a significant decrease in sleep satisfaction. The effect is about 0.15 SD, which suggests that sleep plays an important role in the decline in life satisfaction observed after the nighttime shift. According to columns (2) and (3), we also detect a significant effect of DST on respondent's feeling full of energy and feeling run-down after the transition.

Sleep disruptions, even if it is only by a short amount of time, can lead to lower physical and emotional health (Chandola et al., 2010; Giuntella and Mazzona, 2019; Jin

[9] The effects are larger than prior empirical findings examining the effects of DST on life satisfaction. The average estimates of Kountouris and Remoundou (2014) indicate that DST is associated with a decrease in life satisfaction of approximately 0.015 SD, while Kuehnle and Wunder (2015) find a coefficient of 0.041 SD over the first week of transition. Our estimates reflect immediate effects in the days following the DST transition and take into account potential sorting of respondents on specific days of interview.

and Ziebarth, 2020). In columns (4) to (6), we then test whether DST significantly decreases respondent's health outcomes. Given that the health effects may not take place immediately after the transition day, we introduce a one-day lag in our equation (2). The results show significant effects of DST on respondents' satisfaction with health (β'= -0.133) and reported health (β'=-0.101) one day after the DST transition. In line with this, respondent's likelihood of hospital admission significantly increases by 0.10 SD on Mondays following the DST transition. This also confirms that the decrease in health measured in columns (4) and (5) is not simply due to a reported health effect, but due to actual decreases in health. Moreover, this provides evidence that DST, even if it affects people's sleep for a short period of time, can lead to detrimental health events consistent with previous work that has demonstrated DST's effects on heart attacks and vehicles fatalities.

Time Stress and Day-to-Day Activities. A second potential mechanism through which DST can affect individuals' life satisfaction is through the reduction in the total time available. The "missing" hour in the day(s) following the transition could be cut from sleep time, but it could also reduce time devoted to other day-to-day activities such as work and leisure. By strengthening the time constraint, the DST transition may ultimately increase the price of time and people's feeling of being rushed by time. In the SOEP, respondents are asked whether they feel that they are rushed by time. We use this variable to test for this additional channel. Table 3, column (1), shows that DST increases people's feeling of being rushed by time by 0.17 SD, one day after the DST transition. Similarly, respondents are asked whether they are able to cope with things. According to column (2), respondents are more likely to say that they barely cope with things one day after the DST transition.

If individuals have less time to carry out day-to-day activities, we might expect satisfaction with those activities to be altered. Columns (3) to (6) investigate the effect of DST on satisfaction with work, leisure, childcare and family life. The estimates suggest that satisfaction with work and leisure are significantly affected by the DST transition. DST decreases satisfaction with work by 0.15 SD on Mondays following the transition, and satisfaction with leisure by 0.16 SD. Similarly, columns (5) and (6) show that satisfaction with childcare and satisfaction with family life are significantly affected by the

DST transition. The evidence is consistent with the hypothesis that people have less time to accomplish their desired tasks after the DST transition and therefore derive less utility from these activities. This is also consistent with previous work showing that DST may induce lower productivity among workers following the nighttime shift (see Wagner et al., 2012).

Sleep versus Time Stress. To better understand the relative impacts of the sleep and time pressure mechanisms, we then introduce the sleep and time stress variables into the life satisfaction specification. More specifically, we estimate life satisfaction residuals controlling successively for (i) sleep satisfaction, feeling full of energy and run down and, (ii) feeling rushed by time and barely coping with things. We then estimate the RD-DiD model from equation (2) on these new residuals for the Spring transition. Appendix Table A8 details the results. Column (1) reproduces the baseline estimates. According to column (2), controlling for sleep in the life satisfaction specification decreases the effect of DST by 64%, with an effect on life satisfaction which decreases from -0.069 SD to -0.025 SD. This result suggests that sleep plays an important role in the decline in life satisfaction observed after the nighttime shift. Further, including time stress variables as controls in the life satisfacton increases the coefficient on DST by 15% in absolute terms: the coefficient goes from -0.07 SD to -0.08 SD. Taken together, these results could suggest that it is the sleep mechanism more than the time pressure mechanism, that causes the decline in wellbeing following the Spring transition.

A Mood Effect? As most of our variables are self-reported, one may also argue that respondents report lower satisfaction after the DST transition, not because they are less satisfied with life per se, but simply because they do not like schedule changes. To address this possibility, we turn to the Fall transition. The Fall transition is likely to increase the total time available with an additional hour on the Sunday of the transition. Therefore, we expect the sleep and time pressure mechanisms to be muted or even to have positive effects on life satisfaction after the Fall transition.[10] Alternatively, if we find any negative effect of the Fall DST on life satisfaction, this could suggest that individuals dislike

[10]Barnes and Wagner (2009) or Jin and Ziebarth (2020) do find a positive effect of DST on sleep.

time changes.[11] Appendix Table A9 reports the estimates using our RD-DiD strategy implemented on the Fall DST. The results provide evidence for a significant increase in life satisfaction after the Fall transition, which could suggest that individuals adapt easily to the Fall transition. Moreover, this casts some doubts about the idea that respondents report lower satisfaction after the DST transition, only because they dislike schedule changes. Note, however, that these Fall DST estimates have to be taken with caution as most individuals are being interviewed during the first part of the year in SOEP, and therefore the sample size for this analysis is quite reduced (around 3,500 observations).[12]

To further assess the possibility that people may just dislike time changes, we also use the initial RD-DiD strategy around the Spring transition and investigate other health outcomes which are presumably less affected by reporting bias. Appendix Table A10 provides evidence that the Spring DST decreases people's general health (β'=0.118 SD) and people's mental health (β'=0.08 SD) using the SF-12 questionnaire (see Appendix Table A2 for a brief description). We also find that the Spring DST increases the likelihood of going to see a doctor (β'=0.20 SD) and having a heart attack (β'=0.146 SD) on Mondays following the transition. These results are consistent with previous work showing detrimental effects of DST on people's health and help raise confidence in the validity of our empirical strategy. Moreover, it confirms that the decrease in satisfaction measured in Table 1 is not simply due to transitory changes in perceptions, but due to actual decreases in health with long-term consequences.[13]

[11] Or reductions in daylight exposure and disruption in circadiam rhythms outweigh the positive effects from an additional hour on life satisfaction.

[12] To provide further evidence on this, we replicate our results using the British Household Panel Survey (1996-2008) in the Appendix. Indeed, in the BHPS, most individuals are being during the second part of the year. This allows us to implement our RD-DiD strategy using a larger sample of 98,000 observations around the Fall DST. The results are reported in columns (5) and (6) of Appendix Table A9. We find again evidence of a positive effect of the Fall DST on people's life satisfaction. According to these estimates, the Fall DST increases life satisfaction by approximately 0.095 SD. This is also consistent with the idea that the Fall transition increases the total time available with an additional hour on the Sunday of the transition and therefore people may sleep longer or have more time to carry out their activities.

[13] Columns (5) and (6) of Appendix Table A10 also provide evidence that the Spring DST is associated with less positive emotions (happy) by 0.09 SD and more negative emotions (such as being sad, worried or angry) by 0.05 SD being reported in the days following the DST transition, suggesting that not only cognitive wellbeing (i.e. life satisfaction) but also emotional wellbeing is significantly affected by the DST transition.

C. Event Studies Analysis

Table 4 presents the results from the event-study analysis. While the initial columns of Table 5 examine the average effects of the Spring DST over the first and second weeks of transition, columns (3) and (4) break the DST into four components: the first three days of DST, the next three days of DST, the first week-end following the nighttime shift and the remainder of DST (the next seven days). Arguably, the sleep and time pressure mechanisms should be felt strongly over the first days of transition and dissipate once people get used to the new time schedule.

Beginning with the average effect over the first and second weeks of transition, columns (1) and (2) show that Spring DST is not associated with a significant decrease in life satisfaction over the period. Column (1) compares the first and second weeks after the last Sunday of the month in March with the two previous weeks while column (2) implements a difference-in-difference strategy, where changes in life satisfaction around the DST transition are compared with changes in life satisfaction around the last Sunday of the month in previous and subsequent months. The two strategies provide similar results. In addition to dummies for the week of interview, note that columns (1) and (2) use the same controls as in the RD and RD-DiD designs. This confirms that averaging out the effects of DST over the entire first week would lead to underestimate its effects on life satisfaction.

Turning to column (3), the results are consistent with the idea that the DST impact persists for about 6 days after the transition, but does not have negative effects over the long-term. The first three days of DST show a significant decline in life satisfaction of 0.038 SD, quite similar to the 0.055 SD and 0.069 SD decreases found in the RD and RD-DiD designs. The point estimate then decreases to 0.021 SD during the next three days, which suggests that the effect fades out over time.

Interestingly, on the first weekend following the DST transition, there is a significant and positive effect on life satisfaction. Disrupting sleep and increasing time pressure are likely to be the primary mechanisms through which DST affects individuals' life satisfaction over the first six days. But these effects are likely to be felt for a relatively short period following the DST transition.[14] If the individuals' time constraint is tightened at

[14]Event study analyses suggest no significant effects of DST on sleep satisfaction and time pressure one week after the DST transition.

the beginning, it could well be the case that once individuals have adjusted to the new time schedules, the Spring DST actually relaxes individuals' time constraint by increasing the quantity of daylight in the evening. This light effect could explain the positive effect on individuals' wellbeing estimated over the first week-end following the DST transition.

Overall, the evidence from the event-study analysis align with that found from the RD and RD-DiD models. There is a significant short-term decrease in life satisfaction following the Spring transition, consistent with a detrimental impact on sleep and the feeling of being rushed by time. However, there is also evidence for a positive effect on the first week-end after the DST transition, consistent with a light mechanism. Finally, the effect dissipates in the remainder of DST.

D. Heterogenous Effects

While all people living under DST experience the nighttime shift, the effects are likely to differ across individuals. For example, if the DST transition decreases sleep, it is possible that individuals who are sleep deprived or face more severe time constraints experience a larger drop in wellbeing. To investigate heterogenous effects of the DST transition, we estimate separate regressions by subgroups. Table 5 reports the results. For robustness checks, we also estimate regressions with interaction effects in Appendix Table A11.

Columns (1) to (8) present the estimates for respondents (i) who work full-time, (ii) who work part-time, (iii) whose working hours are in the bottom 25% of the distribution, (iv) in the top 25% of the distribution, (v) with low levels of time stress, (vi) with high level of time stress, (vii) who are blue-collar, and (viii) white-collar. The results suggest large and statistically significant effects for full-time employed people, working long hours, with high level of time stress and in blue collar jobs. These patterns may be consistent with the idea that individuals with those characteristics face less flexible time schedules, and therefore may adapt less quickly to the new schedule. This echoes the work by Hamermesh and Biddle (1990) and Hamermesh and Lee (2007) who demonstrate that sleep deprivation and time stress is more prevalent in household who spend more time on the labour market.To corroborate this idea, Appendix Table A12 provides evidence that respondents who work full-time, longer hours, and in blue collar jobs do indeed report higher time stress than people working part-time, less hours and in white collar jobs.

Columns (9) and (10) of Table 5 also show the effects for men and women separately. The effects of the DST transition on wellbeing is negative and statistically significant for men, but not for women. Again, this may be consistent with the idea that men work on average longer hours than women and may face less flexible time schedules.

Finally, columns (11) and (12) test for any significant differences between parents and non-parents. One could expect individuals with children to face tighter time schedules, and therefore to be more affected by the DST transition than individuals without children. Looking at the coefficients on columns (11) and (12),we find that individuals with children experience a higher drop in life satisfaction, compared to individuals without children. The difference is statistically significant (see Appendix Table A11).

VI. Cost-Benefit Analysis

As a way of evaluating DST as a policy, we quantify its welfare costs and benefits by measuring the effects on wellbeing. In this last section, we provide a basic framework for evaluating the effects of ending DST. Of course, such cost-benefit analysis requires many assumptions and that one has to be very cautious when interpreting these values. Nevertheless, we believe that such an exercise provides valuable insights about whether the DST policy should be maintained or abolished.

We first monetise the wellbeing benefits of ending the DST using our life satisfaction estimates. Our RD-DiD estimate implies a total loss in life satisfaction of 0.069 SD over 6 days. This suggests that ending the DST would generate an increase of 0.0011 SD in life satisfaction annually. If we multiply this effect by 1.65 (the standard deviation of life satisfaction), we get an effect of 0.0018 points per year. Next, we compare this figure with the gain in wellbeing associated with a 1% gain in income, following the extensive literature evaluating the relationship between income and life satisfaction that suggests that a 1% gain in income increases life satisfaction by around 0.002 points (see Layard et al., 2020). Hence, for an average annual income in Germany of 42,000 euros, we estimate that ending the DST would give rise to an increase in life satisfaction equivalent to an income gain of 393 euros per capita per year.

As an alternative strategy, we can consider the DST effects estimated over the first week of transition. In doing so, we estimate that the first three days of DST show a significant decline in life satisfaction of 0.038 SD, the point estimate then decreases to 0.021 SD during the next three days, to then increase to 0.131 SD on the first weekend following the DST transition. These results imply an average effect of DST of approximately 0.012 SD over the first week of transition - although not significant (see Table 4). According to these estimates, ending the DST would exert rather neutral effects on wellbeing.

Finally, we add to our analysis the additional estimates from ending the Fall DST. Our RD-DiD estimates are suggestive of an increase in life satisfaction of 0.095 SD following the Fall transition (see Appendix Table A9). According to Jin and Ziebarth (2020), these effects are expected to last for about 4 days. Assuming that we can add these gains to the negative effects experienced during the Spring transition, this would imply an overall decrease in life satisfaction of 0,0001 SD annually. Therefore, ending the entire Spring and Fall DST would be equivalent to a small income gain of 32 euros per capita per year.

These results generally show that ending the DST would produce welfare benefits. Next, we can compare these benefits of ending the DST with the costs associated to an increase in electricity consumption. According to a literature review by Aries and Newsham (2008), simple estimates suggest a reduction in national electricity use of around 0.5% on average due to DST. Hence, ending the DST in Germany could increase electricity consumption by about 0.005*6,453 kWh = 32,2 kWh per capita. Given that the average cost of 1 kWh is about 0.1505€ in Germany, the energy costs that accrue from ending the DST are estimated at roughly 4.85 euros per capita per year. Therefore, we conclude that the monetary equivalent welfare (energy) costs of ending the DST policy are estimated to be between one tenth and one hundredth the wellbeing gains.

VII. Conclusion

The Daylight Saving Time (DSL) policy affects over 1.5 billion people every year. Yet, we still do not have clear evidence of how it affects people's wellbeing. This paper exploits evidence from a regression discontinuity design combined with a differences-in-differences strategy to estimate the impact of DST on individual wellbeing. Our main finding is that the Spring transition into DST decreases life satisfaction by about 0.07 SD.

We perform several tests to assess whether this effect is due to sleep deprivation or increasing time pressure caused by the one hour reduction in the transition day. These tests indicate that people experience a large and significant drop in sleep satisfaction following the DST transition. They are also more likely to report time stress after the nighttime shift. Moreover, we find that sleep deprivation is driving most of the decrease in life satisfaction. Consistent with the literature investigating the impact of DST transitions on sleep, we show that the effect persists for the first 6 days of DST. It then dissipates once people get used to the new schedule.

These negative effects on sleep and wellbeing, even if they are only felt for a short amount of time, significantly affect people's health. They report lower health and are more likely to be hospitalised on Mondays following the DST transition. There are also large differences across individuals in how they experience DST transitions: the effects are largest among individuals with less flexible time schedules, including men, blue collar workers, and people who spend more time on the labour market in general.

Given that the DST policy has become increasingly controversial, these results are important to inform the debate. Establishing that the DST transition has negative effects on individuals' wellbeing is a crucial first step in setting a new conceptual framework to investigate how people experience the DST transition. Our results reveal that a time change, even if it is only by one hour, can induce substantial welfare costs and an inability to take these into account would fail to capture DST overall effects.

More broadly, our results call for the need to takes issues of sleep deprivation and time stress more into account in the economic discipline. Sleep deprivation may exert large negative effects not only on health but also on worker productivity (Kamstra et al., 2000; Wagner et al., 2012; Gibson and Shrader, 2018). New insights into policies may therefore be gained by including how people experience changes in time schedules in models. Although our results only consider the effects of DST, the logic may be applied to all time changes that potentially affect people's wellbeing (e.g. new work schedules, jet lag, etc.)

VIII. References

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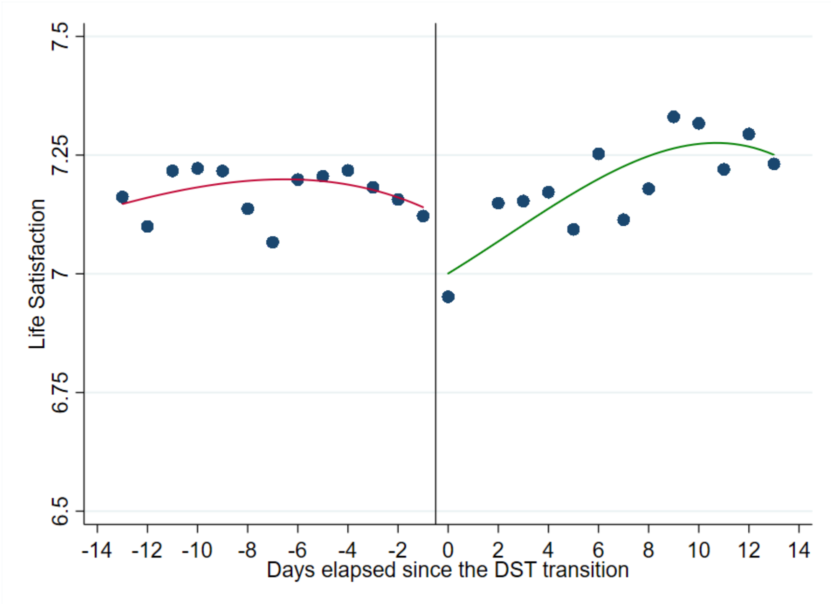
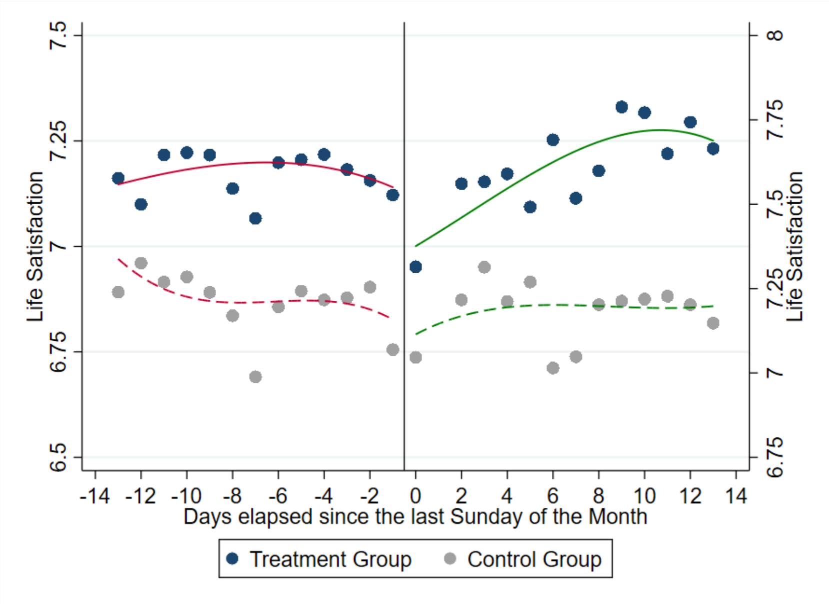
IX. Figures and Tables

FIGURE 1 - Life Satisfaction Around the Spring DST Transition



Notes: Each point represents the average life satisfaction during that day from 2008-2018. The lines are obtained using kernel-weighted local polynomial smoothing.

FIGURE 2 - Life Satisfaction Around the Last Sunday of the Month



Notes: Each point represents the average life satisfaction during that day in the treatment group (around the last Sunday of March) and in the control group (around the last Sunday of the month, in January, February, April and May).

TABLE 1 - RD and RD-DiD Estimates of the Impact of the Spring DST on Life Satisfaction (Standardized)

	RD	RD	RD-DiD	RD-DiD	Placebo	Placebo
	(1)	(2)	(3)	(4)	(5)	(6)
POST	-0.055	-0.079	-0.069	-0.090	0.007	0.006
	(0.020)	(0.000)	(0.019)	(0.003)	(0.037)	(0.040)
Bandwidth	MSE	CER	MSE	CER	MSE	CER
Observations	36,597	36,597	149,093	149,093	112,496	112,496

Notes: Dependent variable is the life satisfaction residual, net of differences in observed characteristics, and year, region, window, day of the week and individual fixed effects. All specifications use a triangular kernel. POST is the estimate of the discontinuity in life satisfaction that occurs immediately after the DST transition. In columns (1) and (2), RD models are estimated using the four weeks around the DST transition. In columns (3) and (4), RD-DiD models are estimated using the four weeks around the last Sunday of the month at the end of January, February, April and May as a reference period. Placebo investigates the discontinuity in life satisfaction that could occur immediately after the last Sunday of the month in January, February, April and May. MSE refers to one common MSE-optimal bandwidth selector; CER is one common CER-optimal bandwidth selector. Standard errors clustered at the time level are in parentheses.

TABLE 2 - RD-DiD Estimates of the Impact of the Spring DST on Sleep and Health Outcomes (Standardized)

	Satisfied with sleep in t	Full of energy in t	Feel run down in t	Satisfied with health in t+1	Current health in t+1	Hospital night in t+1
	(1)	(2)	(3)	(4)	(5)	(6)
POST	-0.155	-0.105	0.044	-0.133	-0.101	0.100
	(0.008)	(0.037)	(0.004)	(0.013)	(0.009)	(0.005)
Bandwidth	MSE	MSE	MSE	MSE	MSE	MSE
Observations	144,447	69,773	69,971	146,022	146,274	143,933

Notes: All dependent variables are net of differences in observed characteristics, year, region, window and day of the week effects, as well as individual fixed effects. All specifications use a first order polynomial and a triangular kernel. POST are RD estimates combined with DiD using the four weeks around the DST transition and the last Sunday of the month in January, February, April and May. In columns (3) to (6), a one-day lag is introduced in equation (2). Standard errors clustered at the time level are in parentheses.

TABLE 3 - RD-DiD Estimates of the Impact of the Spring DST on Time Stress and Satisfaction with Day-to-Day Activities (Standardized)

	Feel rushed by time in t+1	Barely cope with things in t+1	Satisfied with work in t+1	Satisfied with leisure in t+1	Satisfied with childcare in t+1	Satisfied with family in t+1
	(1)	(2)	(3)	(4)	(5)	(6)
POST	0.172	0.326	-0.149	-0.160	-0.709	-0.031
	(0.009)	(0.020)	(0.010)	(0.005)	(0.014)	(0.005)
Bandwidth	MSE	MSE	MSE	MSE	MSE	MSE
Observations	69,942	7,814	85,615	134,043	23,827	142,914

Notes: All dependent variables are net of differences in observed characteristics, year, region, window and day of the week effects, as well as individual fixed effects. All specifications use a first order polynomial and a triangular kernel. POST are RD estimates combined with DiD using the four weeks around the DST transition and the last Sunday of the month in January, February, April and May. In all columns, a one-day lag is introduced in equation (2). Standard errors clustered at the time level are in parentheses.

TABLE 4 - Dynamic Impacts of the Spring DST on Life Satisfaction (Standardized)

	OLS (1)	OLS (2)	OLS (3)
First seven days of DST	0.012	0.009	
	(0.022)	(0.036)	
Next seven days of DST	0.013	0.008	0.003
	(0.014)	(0.012)	(0.011)
First three days of DST			-0.038
			(0.003)
Next three days of DST			-0.021
			(0.023)
First week-end of DST			0.131
			(0.021)
Observations	36,957	149,093	149,093

Notes: Dependent variable is the standardized life satisfaction, net of differences in individual characteristics, year, region, window and day of the week fixed effects, as well as individual fixed effects. First seven days of DST is an indicator variable equal to one if the day of interview occurs in the first week of DST. Next seven days of DST is an indicator variable equal to one if the day of interview occurs in the second week of DST. First three days of DST is an indicator variable equal to one if the day of interview occurs in the first three days of DST. Next three days of DST is an indicator variable equal to one if the day of interview occurs in the next three days of DST. First week-end of DST is an indicator variable equal to one if the day of interview occurs in the first week-end of DST. In column (1), only observations from the four-week time window around the DST transition are used. In columns (2) and (3), information from both the treatment and control groups (four-week time window around the last Sunday of January, February, April and May) are used. In column (2), additional controls include indicators for first seven days after last Sunday and next seven days after last Sunday (not shown). In column (3), additional controls include indicators for first two days after last Sunday, next three days after last Sunday, first week-end after last Sunday and next seven days after last Sunday (not shown). Robust standard errors are in parentheses. Standard errors are clustered at the time level.

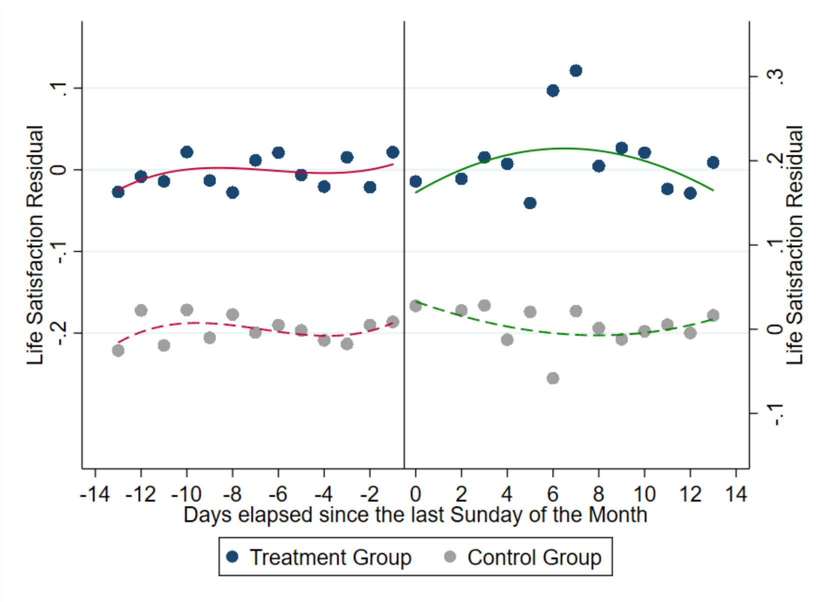
TABLE 5 - RD-DiD Estimates of the Impact of the Spring DST on Life Satisfaction (Standardized) - Heterogenous Effects

	Not full-time	Full time employed	Hours worked: bottom %25	Hours worked: top %25	Low levels of time stress	High level of time stress
	(1)	(2)	(3)	(4)	(5)	(6)
POST	-0.051	-0.064	-0.202	-0.616	-0.040	-0.306
	(0.024)	(0.019)	(0.011)	(0.008)	(0.007)	(0.127)
Bandwidth	MSE	MSE	MSE	MSE	MSE	MSE
Observations	96,074	53,019	22,348	22,846	56,689	19,866
	Blue collar	White collar	Female	Male	Without children	With children
	(7)	(8)	(9)	(10)	(11)	(12)
POST	-0.273	-0.012	0.042	-0.168	-0.046	-0.049
	(0.036)	(0.003)	(0.013)	(0.060)	(0.027)	(0.015)
Bandwidth	MSE	MSE	MSE	MSE	MSE	MSE
Observations	32,195	116, 898	80,120	68,973	100,319	48,577

Notes: Dependent variable is the life satisfaction residual, net of differences in observed characteristics, and year, region, window, day of the week and individual fixed effects. All specifications use a triangular kernel. POST is the estimate of the discontinuity in life satisfaction that occurs immediately after the DST transition. RD-DiD models are estimated using the four weeks around the last Sunday of the month at the end of January, February, April and May as a reference period. MSE refers to one common MSE-optimal bandwidth selector. Standard errors clustered at the time level are in parentheses

X. Online Appendix

APPENDIX FIGURE A1 - Life Satisfaction Around the Last Sunday of the Month (Residuals)



Notes: Each point represents the life satisfaction residual - net of differences in observed characteristics, and year, region, window, day of the week and individual fixed effects - during that day in the treatment group (around the last Sunday of March) and in the control group (around the last Sunday of the month, in January, February, April and May).

APPENDIX TABLE A1 - Summary Statistics

	Observations (1)	Mean (2)	SD (3)	Min (4)	Max (5)
Overall life satisfaction	149,093	7.24	1.65	0	10
Satisfaction with sleep	144,447	6.77	2.25	0	10
Full of energy	69,773	3.07	0.89	1	5
Feel run down	69,971	2.36	0.96	1	5
Satisfaction with health	146,022	6.64	2.18	0	10
Current health	146,274	3.36	0.95	1	5
Hospital nights	143,933	0.13	0.34	0	1
Feel rushed by time	69,942	2.77	1.05	1	5
Barely cope with things	7,814	2.38	0.63	2	4
Satisfied with work	85,615	7.08	2.07	0	10
Satisfied with leisure	134,043	7.16	2.12	0	10
Satisfied with childcare	23,827	7.29	2.37	0	10
Satisfied with family	142,914	7.94	1.87	0	10

Notes: All statistics reported are for the estimation sample.

APPENDIX TABLE A2 - Mental Health Score

During the last four weeks, how often did you feel	(1) Never	(2) Almost Never	(3) Sometimes	(4) Often	(5) Always
(i) rushed or pressed by time	5	4	3	2	1
(ii) down and melancholic	5	4	3	2	1
(iii) well-balanced	1	2	3	4	5
(iv) full of energy	1	2	3	4	5
Due to emotional problems:					
(v) achieved less than wanted	5	4	3	2	1
(vi) carried out your work less thoroughly	5	4	3	2	1
Total score : 0-30					

APPENDIX TABLE A3 - Life Satisfaction Residuals (First Step)

	Full sample	Only DST window	Only Jan., Feb., March, April and May
	(1)	(2)	(3)
Age	–	–	–
Age squared	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Married	0.136	0.216	0.126
	(0.028)	(0.082)	(0.032)
Widowed	-0.297	-0.242	-0.311
	(0.051)	(0.146)	(0.054)
Divorced	0.086	0.112	0.055
	(0.041)	(0.119)	(0.047)
Separated	-0.229	-0.268	-0.273
	(0.040)	(0.124)	(0.048)
Log HH income	0.023	0.025	0.022
	(0.004)	(0.012)	(0.004)
Full time employed	0.017	-0.030	0.018
	(0.015)	(0.047)	(0.018)
Part time employed	-0.001	-0.027	0.003
	(0.012)	(0.039)	(0.015)
Years of education	0.013	-0.011	-0.006
	(0.008)	(0.025)	(0.010)
Number of children	0.031	-0.008	0.008
	(0.008)	(0.027)	(0.010)
Disabled	-0.177	-0.228	-0.142
	(0.021)	(0.059)	(0.022)
Region FE	YES	YES	YES
Year, Window and day of the week FE	YES	YES	YES
Individual FE	YES	YES	YES
Observations	195,867	35,923	144,759

Notes: Each column represents an OLS regression of life satisfaction on various factors, controlling for region, year, window, day of the week as well as individual fixed-effects. In column (1), the full SOEP sample is used. In column (2), the sample is restriced to the four weeks around the DST transition in March. In column (3), only observations from the four weeks around the last Sunday of the month at the end of January, February, March, April and May are used.

APPENDIX TABLE A4 - RD and RD-DiD Estimates of the Impact of the Spring DST on Life Satisfaction (Standardized) - First Step using the Four Weeks Window

	RD	RD	RD-DiD	RD-DiD	Placebo	Placebo
	(1)	(2)	(3)	(4)	(5)	(6)
POST	-0.042	-0.043	-0.052	-0.059	-0.018	0.000
	(0.020)	(0.020)	(0.021)	(0.023)	(0.044)	(0.045)
Bandwidth	MSE	CER	MSE	CER	MSE	CER
Observations	35,923	35,923	144,759	144,759	108,836	108,836

Notes: Dependent variable is the life satisfaction residual, net of differences in observed characteristics, and year, region, window, day of the week and individual fixed effects. All specifications use a triangular kernel. POST is the estimate of the discontinuity in life satisfaction that occurs immediately after the DST transition. In columns (1) and (2), RD models are estimated using the four weeks around the DST transition. In columns (3) and (4), RD-DiD models are estimated using the four weeks around the last Sunday of the month at the end of January, February, April and May as a reference period. Placebo investigates the discontinuity in life satisfaction that could occur immediately after the last Sunday of the month in January, February, April and May. MSE refers to one common MSE-optimal bandwidth selector; CER is one common CER-optimal bandwidth selector. Standard errors clustered at the time level are in parentheses.

APPENDIX TABLE A5 - Summary Statistics by Weeks Around the Last Sunday of the Month

	Two weeks before (1)	One week before (2)	One week after (3)	Two weeks after (4)	T-stat (2)-(3) (5)
Treatment group:					
Male	0.46	0.46	0.47	0.45	1.21
Age	50.72	49.41	48.79	47.80	2.06
Married	0.61	0.61	0.58	0.59	2.66
Widowed	0.06	0.06	0.05	0.05	0.41
Divorced	0.08	0.09	0.09	0.10	0.23
Separated	0.02	0.02	0.03	0.02	-0.94
Log HH income	9.95	10.03	10.15	10.11	-3.78
Full time employed	0.37	0.38	0.39	0.39	-1.62
Part time employed	0.25	0.27	0.26	0.28	0.75
Years of education	12.45	12.48	12.50	12.48	-0.44
Number of children	0.60	0.70	0.61	0.78	4.69
Disabled	0.12	0.11	0.10	0.10	0.80
Control group:					
Male	0.46	0.46	0.47	0.46	-0.84
Age	49.56	50.49	50.48	51.07	0.04
Married	0.60	0.60	0.59	0.60	2.17
Widowed	0.06	0.06	0.07	0.07	-2.58
Divorced	0.08	0.09	0.09	0.09	-1.65
Separated	0.03	0.02	0.02	0.02	0.78
Log HH income	9.88	9.83	9.87	9.77	-2.17
Full time employed	0.34	0.35	0.37	0.34	-4.71
Part time employed	0.26	0.25	0.24	0.24	1.69
Years of education	12.23	12.25	12.36	12.28	-4.46
Number of children	0.67	0.61	0.56	0.59	5.57
Disabled	0.11	0.12	0.12	0.13	1.21

Notes: All statistics reported are for the estimation sample.

APPENDIX TABLE A6 - RD and RD-DiD Estimates of the Impact of the Spring DST on Life Satisfaction (Standardized) - Robustness Checks

	RD	RD	RD-DiD	RD-DiD	Placebo	Placebo
	(1)	(2)	(3)	(4)	(5)	(6)
Conventional	-0.055	-0.079	-0.069	-0.090	0.007	0.006
	(0.020)	(0.000)	(0.019)	(0.003)	(0.037)	(0.040)
Bias-corrected	-0.063	-0.084	-0.078	-0.097	-0.006	-0.004
	(0.020)	(0.000)	(0.019)	(0.003)	(0.037)	(0.040)
Robust	-0.063	-0.084	-0.078	-0.097	-0.006	-0.004
	(0.032)	(0.037)	(0.034)	(0.039)	(0.042)	(0.044)
Bandwidth	MSE	CER	MSE	CER	MSE	CER
Observations	36,597	36,597	149,093	149,093	112,496	112,496

Notes: Dependent variable is the life satisfaction residual, net of differences in observed characteristics, and year, region, window, day of the week and individual fixed effects. All specifications use a triangular kernel. POST is the estimate of the discontinuity in life satisfaction that occurs immediately after the DST transition. In columns (1) and (2), RD models are estimated using the four weeks around the DST transition. In columns (3) and (4), RD-DiD models are estimated using the four weeks around the last Sunday of the month at the end of January, February, April and May as a reference period. Placebo investigates the discontinuity in life satisfaction that could occur immediately after the last Sunday of the month in January, February, April and May. MSE refers to one common MSE-optimal bandwidth selector; CER is one common CER-optimal bandwidth selector. Standard errors clustered at the time level are in parentheses.

APPENDIX TABLE A7 - RD and RD-DiD Estimates of the Impact of the Spring DST on Life Satisfaction (Standardized) - Robustness Checks

	Only 2 weeks	Only 2 weeks	Poly. of order 2	Poly. of order 2
	(1)	(2)	(3)	(4)
POST	-0.069	-0.069	-0.122	-0.169
	(0.004)	(0.004)	(0.035)	(0.003)
Bandwidth	MSE	CER	MSE	CER
Observations	71,827	71,827	149,093	149,093
	Only Feb & April	Only Feb & April	Only Feb.	Only Feb.
	(5)	(6)	(7)	(8)
POST	-0.067	-0.089	-0.057	-0.080
	(0.020)	(0.004)	(0.020)	(0.004)
Bandwidth	MSE	CER	MSE	CER
Observations	113,503	113,503	88,515	88,515

Notes: Dependent variable is the life satisfaction residual, net of differences in observed characteristics, and year, region, window, day of the week and individual fixed effects. All specifications use a triangular kernel. POST is the estimate of the discontinuity in life satisfaction that occurs immediately after the DST transition. In columns (1) and (2), RD-DiD models are estimated using the two weeks around the last Sunday of the month at the end of January, February, April and May as a reference period. In columns (3) and (4), RD-DiD models are estimated using polynomial functions of order 2 of the distance in days from the last Sunday of the month. In columns (5) and (6), RD-DiD models are estimated using the four weeks around the last Sunday of the month at the end of February and April as a reference period. In columns (7) and (8), RD-DiD models are estimated using the four weeks around the last Sunday of the month at the end of February as a reference period. MSE refers to one common MSE-optimal bandwidth selector; CER is one common CER-optimal bandwidth selector. Standard errors clustered at the time level are in parentheses.

APPENDIX TABLE A8 - RD-DiD Estimates of the Impact of the Spring DST on Life Satisfaction (Standardized) - Controlling for Mechanisms

	Life satisfaction	Life satisfaction	Life satisfaction
	(1)	(2)	(3)
POST	-0.069	-0.025	-0.079
	(0.019)	(0.003)	(0.008)
Baseline controls	YES	YES	YES
Sleep, energy & run down	NO	YES	NO
Feel rushed & barely cope	NO	NO	YES
Bandwidth	MSE	MSE	MSE
Observations	149,093	149,093	149,093

Notes: All dependent variables are net of differences in observed characteristics, year, region, window and day of the week effects, as well as individual fixed effects. All specifications use a first order polynomial and a triangular kernel. POST are RD estimates combined with DiD using the four weeks around the DST transition and the last Sunday of the month in January, February, April and May. Standard errors clustered at the time level are in parentheses.

APPENDIX TABLE A9 - RD and RD-DiD Estimates of the Impact of the Fall DST on Life Satisfaction (Standardized)

	RD SOEP (1)	RD SOEP (2)	RD-DiD SOEP (3)	RD-DiD SOEP (4)	RD-DiD BHPS (5)	RD-DiD BHPS (6)
POST	0.025	0.122	0.128	0.226	0.095	0.149
	(0.048)	(0.000)	(0.045)	(0.014)	(0.016)	(0.000)
Bandwidth	MSE	CER	MSE	CER	MSE	CER
Observations	3,479	3,479	17,345	17,345	98,024	98,024

Notes: Dependent variable is the life satisfaction residual, net of differences in observed characteristics, and year, region, window, day of the week and individual fixed effects. All specifications use a triangular kernel. POST is the estimate of the discontinuity in life satisfaction that occurs immediately after the Fall transition. In columns (1) and (2), RD models are estimated using the four weeks around the Fall transition. In columns (3) to (6), RD-DiD models are estimated using the four weeks around the last Sunday of the month at the end of August, September, November and December as a reference period. MSE refers to one common MSE-optimal bandwidth selector; CER is one common CER-optimal bandwidth selector. Standard errors clustered at the time level are in parentheses.

APPENDIX TABLE A10 - RD-DiD Estimates of the Impact of the Spring DST on Other Outcomes (Standardized)

	Mental health in t	Overall health in t+1	Seen doctor in t+1	Heart attack in t+1	Positive emotions in t	Negative emotions in t
	(1)	(2)	(3)	(4)	(5)	(6)
POST	-0.081	-0.118	0.200	0.146	-0.096	0.050
	(0.011)	(0.006)	(0.007)	(0.073)	(0.012)	(0.019)
Bandwidth	MSE	MSE	MSE	MSE	MSE	MSE
Observations	69,960	146,280	100,633	51,543	135,758	135,560

Notes: All dependent variables are net of differences in observed characteristics, year, region, window and day of the week effects, as well as individual fixed effects. All specifications use a first order polynomial and a triangular kernel. POST are RD estimates combined with DiD using the four weeks around the DST transition and the last Sunday of the month in January, February, April and May. Standard errors clustered at the time level are in parentheses.

APPENDIX TABLE A11 - RD-DiD Estimates of the Impact of the Spring DST on Life Satisfaction (Standardized) - Heterogenous Effects

Variables X:	Full time employed	Hours worked: top %25	High level of time stress	White	Male	With children
	(1)	(2)	(3)	(4)	(5)	(6)
POST*X	-0.058	-0.383	-0.075	0.002	-0.147	-0.034
	(0.019)	(0.031)	(0.027)	(0.003)	(0.060)	(0.015)
Bandwidth	MSE	MSE	MSE	MSE	MSE	MSE
Observations	149,093	149,093	149,093	149,093	149,093	149,093

Notes: Dependent variable is the life satisfaction residual, net of differences in observed characteristics, and year, region, window, day of the week and individual fixed effects. All specifications use a triangular kernel. POST*X is the estimate of the discontinuity in life satisfaction that occurs immediately after the DST transition interacted with the characteristic X described in the column title. All models also control for POST and X separately. RD-DiD models are estimated using the four weeks around the last Sunday of the month at the end of January, February, April and May as a reference period. MSE refers to one common MSE-optimal bandwidth selector. Standard errors clustered at the time level are in parentheses.

APPENDIX TABLE A12 - Sleep Satisfaction and Time Stress by Socio-Demographic Characteristics

	Sleep Satisfaction	Time Stress
	(1)	(2)
Not full time	6.67	2.57
Full time	6.92	3.13
Hours worked: bottom 25%	6.80	2.88
Hours worked: top 25%	6.90	3.30
Blue collar	6.83	2.97
White collar	6.74	2.72
Female	6.60	2.84
Male	6.95	2.69
Without children	6.72	2.63
With children	6.85	3.14

Notes: All statistics reported are for the estimation sample.