Daylight Saving Time Policies Around the World: Diversity and Impact

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Abstract

This chapter describes the regulations on daylight saving time (DST) in Europe and the United States, with an emphasis on their historical evolution, current policies, and possible future changes, namely the abolition of the two-phase time arrangement. The chapter also documents the highly heterogeneous perception of the policy among citizens, which is often supported more by individual beliefs than by scientific evidence. The scientific evidence on the causal impact of DST on various outcomes, such as energy consumption, human health, well-being, risky behaviors, and economic performance, is examined. The variability in results reported in the literature may be attributed to differences in the population

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of interest, the outcome under consideration, and the identification strategy adopted. The chapter concludes by suggesting possible extensions to the literature.

Introduction

The idea of daylight saving time (DST) dates back to 1784 when Benjamin Franklin predicted that, thanks to shifting daylight hours, the city of Paris could have saved an "immense sum" from the candles burned in the dark evening hours (Wei-Haas 2022). However, it was only in 1916, during World War I, that Germany introduced a two-phase time arrangement to save energy. Since then, many other countries, including European countries and the United States of America (USA), followed suit. Nowadays, about 70 countries in the world employ a two-phase time arrangement based on a normal/standard/wintertime and DST/summertime. With respect to the normal time, DST shifts 1 h from the morning to the evening during spring and summer to maximize sunlight. Most of North America, Europe, New Zealand, and some regions of the Middle East change the time annually, albeit with different start and end dates, while most African and Asian countries do not change the time. South American countries and Australian states apply different policies domestically (Fig. 1).

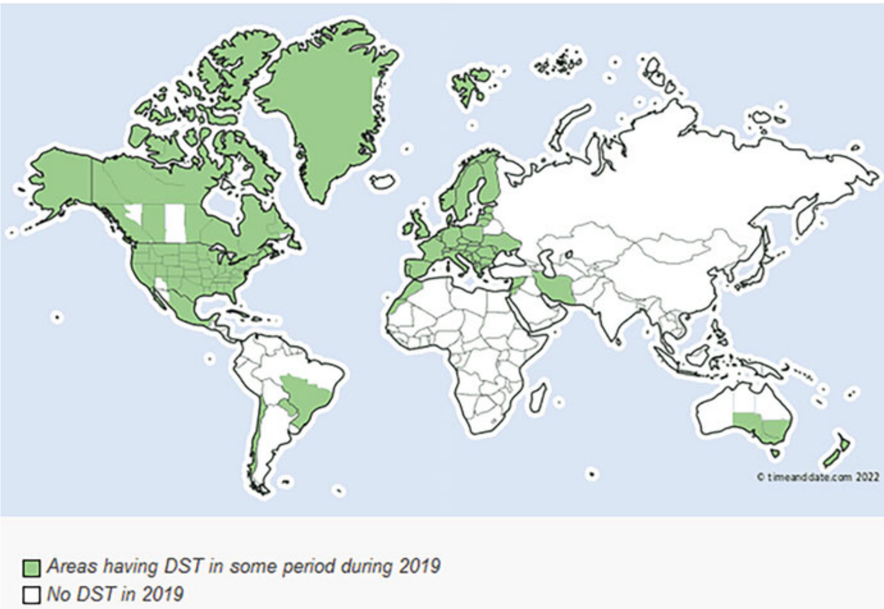


Fig. 1 Daylight saving time around the world 2019. (Source: Timeanddate (2022a))

Recently, scholars began questioning the effects of DST for at least two reasons. Firstly, DST affects not only energy consumption but also human health, mental health, and well-being – as measured by both subjective and objective indicators – as well as risky behaviors such as criminal activity, road accidents, and work-related accidents. Secondly, the effects of DST may evolve over time. For instance, the literature suggests that the impact of DST on energy consumption has decreased over the years, with some studies even indicating an *increase* in energy usage following the implementation of DST. This chapter addresses two questions related to DST.

1. How is the debate on DST evolving in countries that apply a two-phase time arrangement? This question is addressed by examining the cases of the USA and the European Union (EU). These geographical areas are probably the most interesting because they are considering abolishing the two-phase time arrangement. Which of the two phases would eventually be implemented depends on the location (e.g., it would be a choice of national competence in the EU).
2. What are the known effects of DST on human behavior and human health? This question is addressed by focusing at the most recent literature on this field.

The current debate in DST policies relies on scientific evidence only to a certain extent. Indeed, it is also characterized by strong individual opinions (Caviezel and Revermann 2016). This motivates the review presented in this chapter, which aims to systematize existing knowledge on DST by examining reports, official documentation, and scientific articles. In an attempt to provide a comprehensive overview of the ongoing discussion in the USA and Europe and to summarize the existing evidence, the chapter will not dig into the technical details of individual research papers, such as the differences in identification strategies and metrics. These details can be explored further by interested readers.

In the following, beginning with an overview of the effects on energy consumption, attention is focused on solid research that could inform the debate on the appropriateness of DST. Emphasis is given to studies aiming at assessing the causal impact of DST (see also the chapters ► Causality and ► Difference-in-Differences for Policy Evaluation in this book) and specifically to those that have examined the human resources effects of DST. Existing studies measure the direct and indirect effects that policy-imposed clock shifts might have on people's functioning. The direct effects mainly concern the process of sleep, which depends on melatonin production and the regulation of the circadian cycle, specific physical and psychological health conditions associated with sleep deprivation, and the mortality risk associated with diseases related to vitamin D insufficiency. A growing number of studies have focused attention also on the indirect impact of DST, by analyzing the induced variation in risky behaviors as measured by car accidents, workplace injuries, and crime. Other studies have analyzed effects on economic performance, by looking for example at the educational achievements of children and workers' earnings.

The chapter is organized as follows. Section "Daylight Saving Time in the USA" reviews the case of the USA and section "Switching time in the European Union" the case of the EU. Section "Evidence On the Effects of Daylight Saving Time" reviews the existing literature, with a focus on energy consumption and human health and behavior. Section "Summary" offers some concluding remarks.

Daylight Saving Time in the USA

Most of the states in the USA observe DST, except Arizona and the overseas territories. Fig. 2 shows in green the States and Federal Districts that use daylight saving time in 2022.

The current system of uniform DST was established throughout the country by the Uniform Time Act of 1966. The DST time starts on the second Sunday in March and ends on the first Sunday in November. It lasts for a total of 34 weeks every year, and it covers about 65% of the calendar year (Calandrillo and Buehler 2008).

Taking a step back, a two-phase time arrangement was adopted in the USA for the first time in 1918. The Standard Time Act of March 19, 1918, set DST to begin on March 31, 1918, and to revert on October 27. The Nation's initial response to daylight saving time was favorable, with praise for savings in energy expenses and one additional hour of trading time between the New York and the London stock exchanges. However, the experiment with daylight saving time did not outlast the war, because agricultural interests successfully lobbied Congress for repeal of the law (Calandrillo and Buehler 2008). Congress abolished the DST after the war, overriding President Wilson's veto, and the DST became a local option (66th US Congress 1919). New York City (NYC), as an example, continued to observe a metropolitan DST. Due to NYC's position as financial capital, other urban areas across the USA followed suit. By 1931, the number of cities observing the DST had grown to 483 (New York Times 1931). "As a result, daylight saving time observance

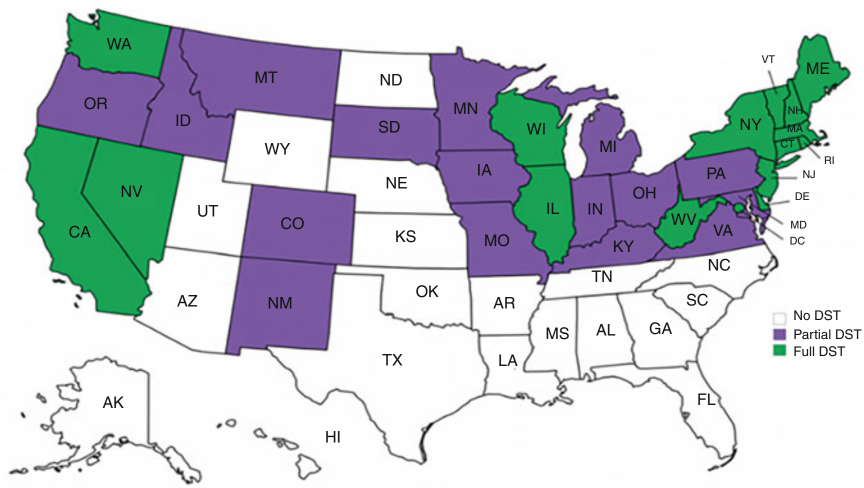
Fig. 2 States and federal districts that use daylight saving time in 2022

became an almost unsolvable puzzle" (Calandrillo and Buehler 2008). A nationwide and year-round DST, called "War Time," was established again during World War II (in 1942) by President Roosevelt. The year-round DST implied extending the time change to cover the entire year. It lasted until the end of the War, in September 1945 (Sexton and Beatty 2014).

In September 1945, the DST returned to being a local policy. There was no federal law on daylight saving time, so the drive for the two-phase time arrangement once again shifted to states and municipalities. Many states and cities adopted the DST. The DST differed not only over space but also over time, with different jurisdictions observing different beginning and ending dates. This led to the setting of a complicated patchwork of daylight saving policies that varied in length and by city, state, and municipality. Figure 3 shows the distribution of full DST (adopted in all the states), partial DST (adopted just in some areas of the state), and no DST across the US States in 1965.

During the 1960s, the transportation and broadcasting industries pushed for the setting of a federal regulation due to the confusion derived from the lack of consistency in the time schedules. As a result, despite criticisms, the Uniform Time Act was signed by President Johnson in 1966. The Act required all states to uniformly advance clocks by 1 h from the last Sunday of April until the last Sunday of October (Uniform Time Act 1966). States were allowed to exempt themselves from DST if the entire state decided to do so. Other than a few exceptions (Hawaii, Arizona, Michigan, and Indiana), the United States uniformly adopted the DST.

In 1973, when the USA experienced an oil embargo by the Organization of Arab Petroleum Exporting Countries (OAPEC), the energy crisis prompted Congress to enact a trial period of year-round DST, in an effort to conserve fuel. The trial began



SOURCE: "Congress Attacks Jumble: Nationwide Daylight Saving?" *Christian Science Monitor*, March 19, 1966, p. 1.

Fig. 3 Full DST, partial DST, and no DST in the USA in 1965 on January 6, 1974, and was supposed to end on April 27, 1975 (93rd US Congress 1973). The trial was hotly debated. Advocates claimed that increased daylight hours in the summer evening allowed more time for leisure, reduced the demand for lighting and heating, and reduced crime and car accidents. The opposition had concerns about the danger to school children caused by another hour of morning darkness and morning accidents in the construction industry. Responding to national concerns about winter daylight saving, Congress passed legislation returning the national standard time from late October to late February. Upon expiration of the Emergency Daylight Saving Time Energy Conservation Act on April 27, 1975, the Uniform Time Act of 1966 once again went into effect (Calandrillo and Buehler 2008; Chiu and Shammas 2022).

Despite the opposition of members of Congress from rural areas, since 1975 Congress extended daylight saving observation twice. In 1986, Congress passed legislation moving the start of DST from the last to the first Sunday of April. Later, in 2005 Congress enacted the Energy Policy Act, which extended daylight saving time by 4 weeks. The provisions of the Energy Policy Act went into effect in the spring of 2007.

Over the last decades, many players in the public domain have started to support the legalization of DST as the year-round clock option. More than 30 states have introduced bills to end DST or make it permanent. The advocates of year-round DST claim that the practice of shifting the clock every spring and fall is not suitable for the lifestyles and work patterns of modern-day citizens. They claim that a year-round extension would save lives, reduce crime, save energy, and stop Americans from losing sleep each time they switch their clocks (section "Evidence On the Effects of Daylight Saving Time"). For instance, exploiting data collected during the 1974 year-round DST experiment, the Department of Transportation showed evidence of beneficial effects on traffic fatalities, which decreased by about 1% during the evenings (107th US Congress 2001). The US Chamber of Commerce has appreciated the extension of daylight saving due to the Energy Policy Act since this change led to an increase in the amount of shopping and commerce during evenings, and it led to an increase in revenues in leisure industries, such as the golf industry. A US Department of Energy report, released in 2008, shows the results of a study of the impact of the 2007 DST extension 9 months after the change took effect. The report stated that for the year 2007 the nationwide electricity savings was about 0.03% (Belzer 2008).

The movement in support of the DST as the year-round clock option led the Sunshine Protection Act to be introduced in the US Senate in 2019 by Senator Rubio (State of Florida). It received bipartisan support from senators from Washington and Tennessee. Legislative houses of Oregon, Alabama, Arkansas, and Georgia also approved resolutions in favor of the Act. The US Senate unanimously passed the Sunshine Protection Act on March 15, 2022. If passed by the House of Representatives and signed by the President, the DST would have become permanent. This would have implied that clocks would not have been returned to standard time from November 5, 2023 (Shepardson 2022; Diamond 2022). However, in January 2023 the Sunshine Protection Act was not passed by the House of Representatives. In

March 2023, Senator Rubio reintroduced the bill, but, as of May 2023, no established timetable has been set to debate or vote on it. In addition, the White House has not taken a clear position on the issue.

The public opinion, which is informed by the scientific community, lobbyists, and various stakeholders, was not always in favor of the Sunshine Protection Act. For instance, the Act has been criticized by the American Academy of Sleep Medicine, the American College of Chest Physicians, and the World Sleep Society. Moreover, with worldwide energy demand expanding rapidly, along with concerns about climate change, critics of the Sunshine Protection Act have pointed out the possible negative effect of the year-round DST on energy conservation (Kotchen and Grant 2011).

The survey conducted by YouGov for the magazine "The Economist" (Frankovic 2021) documents the general opinion of American citizens. The survey used a nationally representative sample of 1500 US adult citizens interviewed online between October 30 and November 2, 2021. Americans appear to prefer a year-round time setting, which does not require changing all clocks twice a year.

As shown in Fig. 4, most US citizens (63%) stated that they would like to see the changing of the clocks eliminated. There is no substantial difference in the replies among the Democrats, Republicans, and Independents. Instead, the percentage of individuals who wishes to eliminate the changing of the clock is smaller for younger than for older adults. In particular, only 42% of Americans under the age of 30 wish to avoid changing time, while this percentage goes up to 77% for Americans 65 and older (Frankovic 2021). Thus, if there is going to be only one time for the USA,

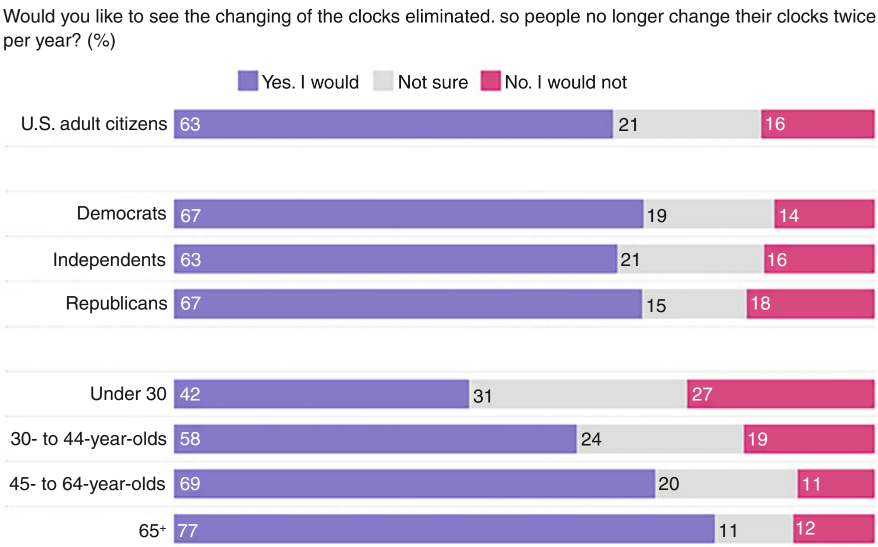


Fig. 4 Preferences of Americans toward the abolition of the DST, results of the Economist/ YouGov survey (Source: The Economist/YouGov|October 30–November 2, 2021)

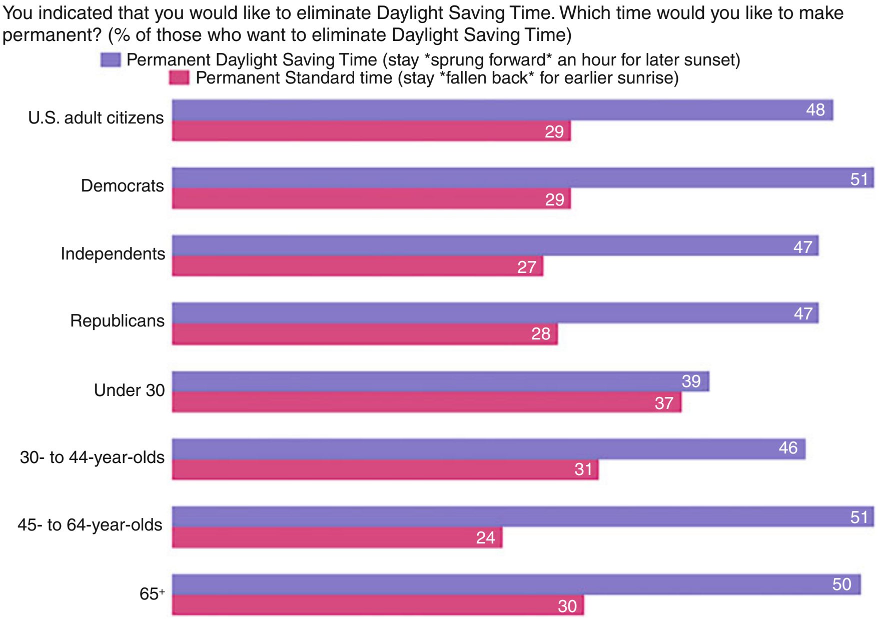


Fig. 5 Preferences of Americans toward the "spring forward" time vs the "fall back" time, results of the Economist/YouGov survey (Source: The Economist/YouGov|October 30–November 2, 2021)

which one should it be? The answers of the Economist/YouGov survey are reported in Fig. 5.

The majority of Americans who prefer not changing their clocks would prefer the daylight saving time – not the standard time – to be kept. Political beliefs do not appear to affect the preference of individuals for "spring forward" vs the "fall back" time. However, these preferences are affected by age. For instance, for adults under the age of 30, half of the interviewees wish to have sunlight later in the evening (as it happens under the DST regulation), while the other half in the morning. Differently, DST is clearly preferred by older adults (Frankovic 2021).

Finally, although the case of Canada is not considered, it is worth emphasizing that British Columbia and Ontario passed a legislation to end seasonal time changes between 2019 and 2020. The legislation would come into effect only if neighboring jurisdictions – Washington, Oregon, and California – also do the same.

Switching Time in the European Union

The time arrangement in the European Union (EU) depends on the time zone of each country and on the two-phase time arrangement. The decision on the time zone is a matter of exclusive national competence, and some Member States adhere to a

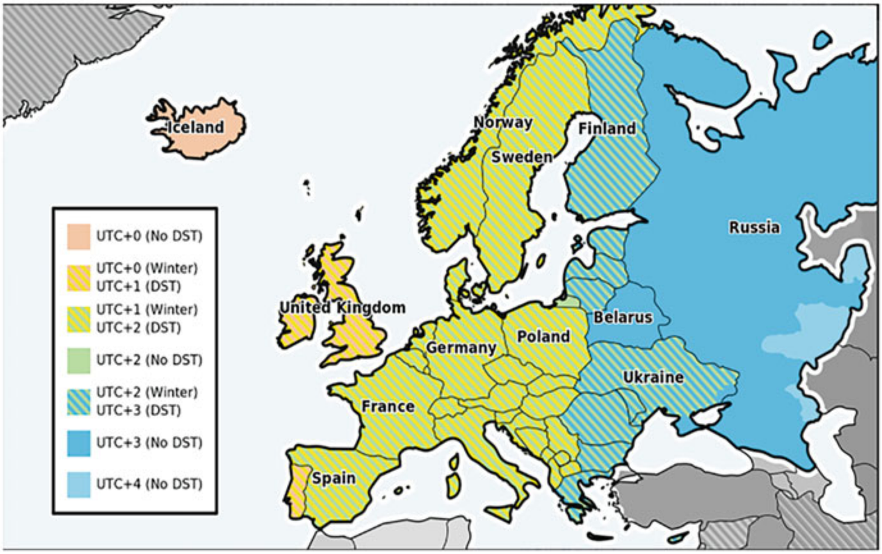


Fig. 6 Time zones in the European Union (Source: Timeanddate 2022b)

different zone with respect to what their position would indicate as "natural." For instance, Madrid is in the same time zone as Rome, although its latitude is more similar to London. Figure 6 plots the time zones of the countries in the European Union (EU).

The two-phase time arrangement has a long tradition in the EU. Apart from the world wars, when the two-phase time arrangement was applied temporarily, many countries introduced a DST on a permanent basis since the 1970s, in response to the energy crisis. While early adoptions of the summertime were independent decisions of each country, in 1980 the Council of the European Economic Community (EEC; then transformed into the European Community first and the European Union then) set a common starting date for the summer period (Directive 80/737/EEC), and in 1994, a common ending date (Directive 94/21/EC). Hence, it is only since 1996 that the European Union has a harmonized common period for the beginning and the end of the DST. Since 2001, the Directive 2000/84/EC on the time arrangement establishes that all the Member States are subject to a formal obligation to start the summertime on the last Sunday of March and to switch back to their normal time on the last Sunday of October. A compulsory and harmonized switch for all the countries of the EU serves two different goals: First, it harmonizes the calendar in a common unified market; second, it improves the functioning of sectors that requires stable, long-term planning (e.g., transportation). (The Directive explicitly mentions that "the effect of [differences in the dates of the summertime] is to complicate transport and telecommunications between these groups of member states, thereby making transport operations more complicated and costly.")

To counterbalance the mandatory nature of the two-phase time arrangements, the EU introduced formal monitoring of the implementation of the Directive. In 2007, the first monitoring of the Directive concluded that "summertime has little impact and the current arrangements are not a subject at the forefront of people's minds in the EU Member States" and that the provisions laid down by Directive 2000/84/EC on DST "continue[d] to be appropriate." A conclusion in favor of the two-phase time arrangement was reached also in 2013 when the analysis explicitly considered the potential impact of the abolishment of the two-phase time arrangements on the functioning of the internal market and on citizens and businesses. The report stressed the potential inconvenience of the repeal of the DST, especially for the transport sector and more generally for business and everyday life (ICF International 2014).

More recently, the attitude toward the time switch changed. In 2017, the Committee on Legal Affairs of the European Union (JURI) requested an ex-post evaluation of Directive 2000/84/EC on time arrangement. The ex-post evaluation aimed at taking into account the most recent research on the effects of DST with respect to economy, health, and safety in the EU. According to a public consultation from the European Commission, 84% of respondents were against the current time arrangement, and the remaining 16% were in favor. With this background, during meetings of the Council (December 2017 and June 2018), transport ministers expressed their preference for discontinuing the current summer time arrangement. Based on this decision, the European Commission proposed to discontinue the seasonal time changes in the EU, while ensuring that Member States retain the competence to decide their time set, namely the winter or the summertime.

The next section briefly describes the public consultation that led to this proposal and its timeline.

Public Consultation

The proposal of the EU Commission to discontinue the two-phase time arrangement Directive involved the citizens and the business owners. According to official reports, between 2006 and 2018 the European Parliament's Petitions Committee received about 100 requests to abandon the current time arrangement. Although these requests reflect a certain degree of dissatisfaction with DST among EU citizens and thus "must be taken seriously, their representativeness is to be assessed with caution, since summertime is a typical issue on which opponents tend to speak out, while those who are in favor of longer daylight during summer evenings and those who are indifferent tend to keep silent" (Anglmayer 2017, p. 20).

The public consultation on the time arrangement was announced with a press release and dedicated interviews and received media attention in many Member States. The public consultation ran between July 2018 and Mid-August 2018. Although more than 4.5 million valid responses were submitted online, the results of the consultation cannot be considered statistically representative of the EU population (Technopolis Group 2018), e.g., because of the self-selection of the respondents. Unfortunately, very little about the characteristics of the respondents are known; therefore, it is impossible to understand the importance of the selection or the direction of a possible bias in the responses. Germany provided the highest number of replies (more than three million), whereas Malta had the smallest one (slightly more than a thousand). The participation rate of the entire population is smaller than 5% and highly heterogeneous across countries: Germany was the most responsive country (almost 4%), and Italy, Romania, and the UK the least responsive (below 0.05%). As a consequence, also the proportionality of the responses to the questionnaire with respect to the countries' population is lost: For example, Austria with more than 250,000 responses has the third highest number of responses (after France), but it is not the third country by population. This issue further complicates the representativeness of the survey.

The questionnaire was composed of five different questions including the preference in favor or against the time switch and the reasons behind this answer. These reasons involved health, labor market, and leisure time – among others.

According to the report published by European Commission (2007), more than 75% of respondents have a negative experience with the time switch, and a larger majority (almost 85%) are in favor of abolishing it. However, with respect to the preference for the summertime or wintertime, no clear majority emerged, with the overall average being slightly more in favor of the summertime (56%).

The results published by European Commission (2007) highlight important differences across countries and stakeholders. In general, Northern countries have a higher preference for abolishing the bi-annual time switch, whereas Southern countries for keeping it. This difference is probably due to the fact that away from the equator the daylight differences between winter and summertimes are longer (see section "Evidence On the Effects of Daylight Saving Time"). While the ranking of the motivations in favor or against the current time arrangement is identical between private individuals and business owners, the shares (and therefore the importance attributed to the motivations) are remarkably different between the two groups. As expected, the former group pays much more attention to their health and leisure time and much less to the functioning of the market than business owners.

The Proposal

Based on the public consultation and the new available scientific results, on March 26, 2019, the European Parliament approved a resolution on the proposal for a Directive on discontinuing seasonal changes of time.

The Directive seeks a balance between two potentially opposite needs: on the one hand, the right of each Member State to decide on the time set in its territory; on the other hand, the need to preserve the functioning of the EU market. The decision on which time set to apply in each Member State needs to be preceded by consultations and studies, which would take into account citizens' preferences, geographical variations, regional differences, standard working arrangements, and other factors relevant to the particular Member State.

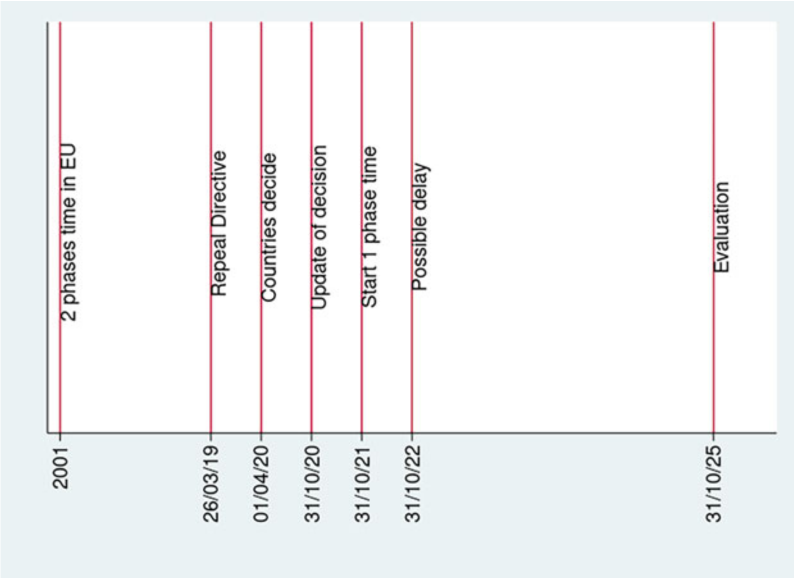


Fig. 7 Original deadlines for the repeal of the two phases time arrangement in the European Union

The Directive sets strict deadlines (Fig. 7). The original deadline was missed; however, the original timetable is useful to have an idea about the length of the process. Countries should have notified by April 1, 2020, whether they intended to change their time set on the last Sunday in October 2021. However, they could have updated their decision until October 31, 2020. The Directive should have been operative from April 1, 2021, and would have been definitive by October 2021. In practice, even this date might have been further postponed by 12 months if the time arrangement of one Member State was judged to be potentially damaging to the proper functioning of the market: During this time, the Commission would have submitted a legislative proposal.

Finally, by December 31, 2025, the Commission shall submit to the European Parliament and the Council an evaluation report on the application and implementation of this Directive, accompanied, where necessary, by a legislative proposal for its review based on a thorough impact assessment, involving all relevant stakeholders. At the moment, the Council has not finalized its position.

Evidence on the Effects of Daylight Saving Time

The recent debate in the economic literature suggests that policies regulating DST may not always effectively achieve the original goal of conserving energy. Researchers have questioned the validity of the energy consumption argument as a justification for daylight saving (see also the ► "Energy Policies, Agglomeration and

Pollution" chapter in this book). While some studies have documented a significant decrease in electricity consumption (see Mirza and Bergland 2011, for a review), more recent works have shown that increasing the use of heating and air-conditioning following DST transitions has offset the decrease in energy use for lighting (Kotchen and Grant 2011; Sexton and Beatty 2014; Guven et al. 2021), or have found negligible energy savings (Havranek et al. 2018). These findings are especially relevant in the current policy debate due to concerns about climate change, rising temperatures, and worldwide increases in cooling usage during summer. In a simulation exercise, Bellia et al. (2020) highlight the role of geographical location (latitude and longitude) and of luminous climate in understanding the differential effects that DST might have on energy consumption and human well-being. They distinguish locations according to the divergence between the nominal time that appears on the clock and the solar time determined by the position of the sun, and the level of exposure to clear and overcast sky. They find that, in most cases, DST leads to a reduction in energy consumption from electric lighting, particularly in cities located at higher latitudes.

A growing body of scientific literature has shown that the practice of changing clocks to "spring forward" or "fall back" has direct effects on individuals' health and economic performance. The extant literature covers many outcomes, often yielding conflicting evidence on the genuine causal effects of DST policy. While some studies have shown that DST directly affects the process of sleep, others have documented the existence of unintended and indirect effects on individuals' health and productivity, mediated by changes in melatonin production and the circadian rhythm. Such effects are likely amplified by the tight schedule of social and economic activities of single individuals and their communities (Hamermesh et al. 2008), which hardly adapt to changes in daylight time. Overall, the literature supports the hypothesis that the mechanisms through which regulating daylight time impacts health and economic outcomes are sleep deprivation and changes in natural light. In the following, a brief overview of the existing empirical evidence will be presented.

The medical and psychological literature documents that both the duration and the efficiency of sleep decrease just after the transition to DST (see, e.g., Lahti et al. 2006). Sleep disruptions and alterations of the circadian rhythm due to DST are also found to influence the risk of neurological and psychiatric diseases and neurophysiological functioning, which is key for human capital accumulation and work productivity (and for other activities such as driving behavior) (Johnson and Malow 2022). Typically, the effects of switching are stronger in spring when clocks are moved forward by 1 h. Adverse health effects in terms of an increase in the incidence rate of depressive episodes, however, have been documented also as a consequence of shorter light exposure induced by the transition from summer to wintertime (Hansen et al. 2017).

Additional insights about the relationship between variation in sunset time and economic performance are provided by Gibson and Shrader (2018) and Giuntella and Mazzonna (2019). The former paper identifies the short-run effect of sleeping using sunset times within a location and the long-run effect comparing two places in the same time zone but located in farther east or west positions. Gibson finds that later sunset reduces both sleep and earnings and, more specifically, that a 1-hour increase in mean weekly sleep increases average earnings by 1.1% in the short run and by 4.9% in the long run. In the latter paper, leveraging the geographical variation in sunset time at the time zone border in the USA, the authors estimate the long-term effects of the clock time-induced circadian misalignment on sleep, health and economic outcomes, and related healthcare costs and productivity losses. People who live in the late sunset time zone tend to have about 19 minutes shorter sleep (and this effect seems to be larger for those who wake up earlier in the morning due to work schedules; see also the Time Use Surveys chapter in this book), lower wages, and worse health (as documented by analyzing data on weight, diabetes, cardiovascular diseases, and specific tumors typically associated with sleep deprivation and altered circadian cycles) than people living in the other time zone. Likewise, by using a regression discontinuity design, Toro et al. (2015) find that even the small changes in sleep patterns and circadian rhythm induced by DST significantly increase the incidence of acute myocardial infarctions (AMI; 7.4%–8.5%) in Brazil and suggest that such effect is quite large compared to the evidence on the effect of other AMI risk factors, such as smoking; Manfredini et al. (2018) find similar results for Italy.

Existing studies on DST have primarily focused on the substantial effects of the spring DST transition. However, Jin and Ziebarth (2020) have taken a unique approach by mainly investigating the end of DST, referring to the fall time shift that extends individuals' sleep duration – in addition to the spring DST. Through the implementation of an event study design and examining many health outcomes, the authors estimate the sleep and daily-level health effects using US and German data. They find that the fall time shift, by increasing individuals' sleep, leads to significant and sharp reductions in hospital admissions due to cardiovascular diseases. Importantly, this effect persists for a minimum of 4 days following the transition. Furthermore, Jin and Ziebarth explore the impact of spring DST on the rate of injury admissions in Germany and find that these effects are less definitive and pronounced compared to the fall transition. Cook (2022) documents that also the spring transition has protective effects on population health, and these effects are explained by a "vitamin D" mechanism. The authors, who exploit the 2006 expansion of DST in all Indiana counties, estimate a significant reduction in overall mortality (namely, 3.93 fewer deaths per 100,000 individuals in the 77 treated counties during the DST period) and, more specifically, in mortality caused by diseases that are notably related to vitamin D deficiency (mostly cancers). These effects are heterogeneous across different demographic groups in the population, with men, white and elderly individuals benefiting the most.

If the DST policy does have an impact on health and economic outcome, it is of paramount importance to quantify the effects, especially on specific groups in the population, such as school-age, working-age, and vulnerable individuals. Goodman et al. (2014) show that longer evening daylight plays a causal role in increasing children's physical activity. Medina et al. (2015) find that (spring) DST negatively affects high school students' sleep and vigilance. The relevance of this finding can be contextualized by considering the estimated effect of sleep deprivation on both short- and long-term outcomes in children. In a recent study that exploits exogenous variation in daily sunset time, Jagnani (2021) unravels the effect of later sunset on sleep and time use of children, using data from the Indian Time Use Survey. The author shows that one-hour delay in sunset deprives children of approximately 30 min of sleep, which, in turn, decreases the time children spend studying and learning, while it increases daytime sleepiness and indoor leisure activities. Using two different data sources, Jagnani also provides evidence of the negative short-term effects on learning outcomes, as measured by test scores, and negative long-run effects on educational attainments (when sleep deficits may become chronic, sleep-deprived children would accumulate, on average, fewer years of education and lower completion rates of primary and middle school).

A few other studies on DST have focused on the potential effects on individuals' psychological well-being and mental health. Specifically, Kountouris and Remoundou (2014), Kuehnle and Wunder (2016), and Costa-Font et al. (2021) have investigated the DST's short-term impacts on measures of mood and life satisfaction, finding evidence of adverse effects when clocks are advanced by 1 h at the beginning of DST. These studies suggest that young children and full-time workers are particularly affected, with worsened sleep patterns and increased distress as the likely channels through which well-being is affected. Additionally, Osborne-Christenson (2022) has provided further evidence of a negative effect of DST on the health of vulnerable individuals. The author disentangles the impact of sleep disruptions and light exposure induced by the DST policy on "deaths of despair" (i.e., deaths from suicide and substance abuse) in the USA. The analysis reveals that, despite the increase in light exposure at the summer time switch, the suicide rate increases by 6.3% (consistent with previous results by Berk et al. 2008), and the mortality rate from suicide and substance abuse increases by 6.6%. The study suggests that changes in sleeping patterns, rather than in light exposure, are the primary channel through which DST transitions affect health outcomes.

Sleep deprivation induced by DST might also have "indirect" effects, such as an increased risk of workplace injuries, which can in turn lead to problems for organizations, particularly in terms of productivity losses. While Barnes and Wagner (2009) find that only the switch to spring DST (not fall DST) temporarily reduces employees' sleep (about 40 min), increases workplace injuries (5.7%), and results in a huge loss in working days (67.6%), Lahti et al. (2011) find that none of the transitions into and out of DST significantly increased the number of occupational accidents. However, the latter paper assumes that the two transitions produce the same effects. As a consequence, it may be the case that the positive effect of the fall transition offsets the negative effect of the spring transition.

There is also growing evidence suggesting that changes in sleeping patterns affect an individual's decision-making processes. For example, for the USA, Kamstra et al. (2000, 2002) argued that the DST change lowers stock market returns through anxiety deriving from sleep alteration (anxiety would influence the way traders choose investments). Studies on different countries, however, did not find statistically significant evidence of the DST effect on traders' decision-making and trading returns (Lamb et al. 2004; Pinegar 2002).

The recent empirical economic literature has paid attention also to the road safety consequences of the DST policy. For the UK, Carey and Sarma (2017)'s review of the existing literature reports mixed and non-conclusive evidence about the relationship between accident probability and DST in the short run and a positive DST effect in the long run. This implies the need for new and robust empirical evidence on the benefits and costs of road safety that can be used by institutions and policymakers who are debating the possibility of reforming DST policies. For the USA, Smith (2016) estimates a 6% increase in fatal accidents due to DST, providing evidence of sleep deprivation and ambient light as possible mechanisms. Robb and Barnes (2018) provide supporting evidence of an increase in car crashes on the day DST begins and the following day. In addition, Abeyrathna and Langen (2021) estimate that white-tailed deer-vehicle collision rates are approximately four times higher at the time of the fall DST transition than in spring. More recently, Bunnings and Schiele (2021) have emphasized the need to consider also the long-run effects of DST. The impact of DST on road safety is indeed much larger than that researchers typically estimate when looking at what happens just after the transitions. They show that accident risk depends not only on DST-induced sleep deprivation, which likely affects driving abilities, but also on the reduction in vision that drivers experience due to changes in natural light across the hours of the day, as in Smith (2016). Specifically, they estimate that darkness substantially increases the number of light, severe and fatal accidents, generating an annual cost of £520 million in Great Britain. They calculate that if the summertime regime were in force year-round, about £40 million per year could be saved in the long-term as a consequence of having more light in the evening time.

Another growing strand of empirical literature investigates and discusses the potential effects that the discontinuity of natural light during working hours induced by DST has on criminal activity. For the USA, Doleac and Sanders (2015) have estimated a decrease of about 7% in robbery rates due to the shift in daylight, which likely increases the probability of capture of criminals. They also simulate that, by avoiding robberies, DST would save 59.2 million dollars each year. In a more recent study, Tealde (2022) use geolocated data on crime and public lighting for the city of Montevideo (Uruguay) and focus on the heterogeneous effects of natural light on criminal activity across the city. By exploiting DST as a natural experiment that induces a sharp increase in natural light during crime-intense hours, Tealde finds evidence of a reduction in crime of about 17%, and about 33% in the darkest areas (lowest quartile of public lighting). Castriota and Tonin (2022) show that even hit-and-run road accidents, which are classified as felonies, are influenced by policies that alter the distribution of light during the 24 h. They use Italian data on car crashes and exploit the exogenous variation in daylight – both at spring and fall transitions and across seasons – as an exogenous source of variation affecting the probability of arrest by the police. They show that the conditional likelihood of hit-and-run increases by around 20% with darkness. Overall, these works suggest that the debate on eliminating or modifying DST policies should take into consideration the consequences on criminal activity.

The existing scientific literature has produced a vast range of findings, which suggest that the political debate about the usefulness of DST regulation should be informed by empirical evidence on health and economic outcomes from many different countries that have been implementing such regulation. Overall, the results depend on the outcome of interest, the population being studied, and the time horizon considered. To obtain robust estimates of the potential costs and benefits of eliminating DST, or making it permanent once for all, it is essential to consider the alternative time regimes, and the presence of both short-term (around the time of transition) and long-term consequences of time changes.

Summary

This chapter reviews the existing regulations on the two-phase time arrangements in the USA and the EU, with a reflection about the core intentions and debates about its abolition as well as the scientific studies about the effects on human being in terms of health, well-being, risky behaviors, and economic outcomes.

Public opinion on this subject is often driven by individual beliefs rather than scientific evidence, which is a potential drawback, as emphasized by Caviezel and Revermann (2016). This is partly due to the heterogeneous scientific evidence that leads to different conclusions. The mixed empirical evidence likely reflects several factors, including the populations of interest, both within a country and across countries, as well as the available data, with the main distinction being administrative versus survey data. Additionally, the identification strategies adopted (which are not discussed in order to maintain the discussion at a non-technical level) may also contribute to the mixed evidence. Therefore, it is important that any debate on the two-phase time arrangement specifies which dimension is being considered and the hypotheses under which the conclusions are valid. Given the complexity and context-specific nature of the effects, the changes in DST regulation recently proposed in Europe and the USA might have both positive and negative impacts on several aspects of individuals' everyday life. Conducting country-specific cost–benefit analyses that comprehensively consider all possible dimensions of the phenomenon and their possible interactions is crucial to measure the welfare benefits and costs associated with changing the current regulation.

In conclusion, the authors believe that further developments in the related literature are possible, as many authors have questioned the mechanisms underlying the results (e.g., Doleac and Sanders 2015; Smith 2016), without being able to test them directly using all data within the same source. Better data would lead to a more-informed discussion. For instance, the exact time and location – rarely, if ever, jointly available when an event occurs – would assist in differentiating between the relevance of sleeping and natural light as the primary channels through which DST operates.

Cross-References

► Causality
► Difference-in-Differences for Policy Evaluation
► Energy Policies, Agglomeration, and Pollution
► Time Use Surveys

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