The complexity of seasonal time arrangements in the European Union: the role of the Commission*

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The impact of seasonal time arrangements and the call for its cancellation made by the Juncker Commission in 2018 is analyzed.

From the results of the public consultation on time arrangements launched by the European Commission and the Harmonized European Time Use Survey we show that an earlier the onset of human activity predicts less appetite for practicing seasonal regulations of time. The result is in line with the primordial goal of the regulation.

The complexity of deciding which clock should survive is reviewed in relation with the span in longitude of Member States. This issue may have helped the decision to stall. We conclude that, in face of the myriad of societal and geographical issues that impact this regulation and the large variability across Member States the European Commission should have not taken a political action on this issue. Instead it should have allowed opt-outs and play the technocratic role of regulating transition dates for those Member State that preferred to continue the practice.

Keywords: DST; summer time; latitude; Europe; evidence-based policy; Daylight Saving Time; ex-post assessment

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1. INTRODUCTION

There is an ongoing debate to elucidate the nature of the European Commission. With the passing of the years some perceive it shifted from a technocratic institution to a political actor (van Voorst and Zwaan, 2019). We bring here the case of the directives on summer time arrangements —the biannual changing of clocks, one hour backwards in autumn and one hour forward in spring—. Originally, the inefficiencies in the internal market caused by non-synchronous transitions across Member States prompted the Commission to play the technocratic role of harmonizing transitions.¹ This role only came after Member States had decided to practice the regulations on a solo basis, some of them with the purpose of coordinating with neighbours. After the 7th directive² (94/21/EC) summer time arrangements were synchronized (harmonized) in the Union. The current 9th directive³ (2000/84/EC) was meant to extend the provisions indefinitely in line with the long-standing stability of European time zones: since the end of World War Two (1945) only one European country has successfully altered winter time (Iceland, after canceling the seasonal⁴ regulations in 1969), whereas many others successfully started seasonal time arrangements, thus altering summer time, in a process that was completed in 1983. In sharp contrast, the Juncker Commission shook these calmed waters in 2018 calling for cancelling the seasonal arrangements. The Commission turned its technocratic role —harmonizing transition dates— into a political action —the European Union (EU) will harmonize best by cancelling the regulations—.

The European Commission is committed to take evidence-based policy decisions. In this case the main guidelines for the Commission were the ex-post assessment report on the 2000/84/EC (European Parliament *et al.*, 2017) and the ICF-International report “The application of summertime in Europe” demanded by the Directorate-General for Mobility and Transport —the caretaker of European seasonal regulations of time— and focused on harmonization issues (Kearney *et al.*, 2014). Nonetheless, the apparent decider was an on-line public consultation⁵ with a low participation rate: 0.9% of EU population, yet the largest in this kind of surveys (European Commission and Directorate-General for Mobility and Transport, 2019). The consultation showed a clear 5 respondents wishing to cancel the regulations per respondent willing to continue them and a divisive 3 respondents pushing for permanent summer time per 2 respondents pulling for permanent winter time. In line with these results, the Juncker Commission called the cancellation of the regulations and demanded Member States to handle the devious dilemma of which clock

¹ <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31980L0737&from=EN>

² <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31994L0021:EN:HTML>

³ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32000L0084>

⁴ See Appendix B for the nomenclature in this work

⁵ https://ec.europa.eu/commission/presscorner/detail/en/IP_18_5302

should survive. Underneath these grand numbers every metric of the consultation showed huge difference across Member States. We will address here the origin of these differences to understand the complexities of this issue.

The seasonal regulations of clocks have always faced a complex, unpopular, annoying fact: the biannual transitions they bring in. On the first hand, population is bothered twice a year with the changing of clocks and ask themselves why one time does not fit all. On the other hand, the regulator must take care twice a year of the few sectors that are running operations when the changes come. Indeed, experts at the public hearing “Time to revisit summertime?” held on 24 March 2015 agreed that “the issue that caused inconvenience was the changing of the clocks rather than the application of summer time per se” (European Parliament *et al.*, 2017). Likewise the Commission press release⁶ following its announcement reads: after discontinuing the regulations citizens “will no longer have to worry about adjusting their clocks” and that businesses will “benefit from not having to adjust to clock changes”. Yet the seasonal regulations have a long standing record of sustainability: a great portion of the European population has only lived under seasonal regulations —Queen Elizabeth II of England is one of such persons—. In line with this, the ICF-International report and the on-line public consultation met a common fact: low participation rate, either by Member States (report) or by the general public (on-line consultation) when asked about the regulations. This lack of interest is interpreted in favor of the current arrangements.

A standalone point of view on seasonal time regulations is provided by the following analogy: all else equal, seasonal regulations of clocks are like a seasonal regulation of time schedules. As an example, in 1810 Cádiz Cortes —the first National Assembly in Spain— regulated seasonally their sitting times, reproducing item by item modern seasonal clock changing: a “summer timing” (from May to September), a “winter timing” (October to April), with the former one hour earlier than the latter. The stroke of one hour was mandated by the social preference for whole hours. In retrospect, modern clock changing made the same time schedule stand year round and, at the same time, brought seasonal variability into human activity (Martín-Olalla, 2019b). Understandably businesses and stakeholders did not complain about the practice.

The analogy also serves to catch many misunderstandings that populate this seasonal regulation of clocks like: (1) thinking of winter time as natural and standard, while thinking of summer time as an artificial regulation; and, (2), in a more broad context, thinking that seasonal regulations pose relevant risks for the average person.

In connection with the last item, many research studies have provided insight on the impact of the regulations and have claimed statistically significant increased risks associated with the spring transition in some societal issues and some health issues (Meira e Cruz *et al.*, 2019; Roenneberg *et al.*, 2019). This has fueled the current wave challenging the practice. Yet we point out that these research studies have only identified a bias associated with the spring transition —there is an increase of the risks associated with the sleep deprivation that the advancement of clocks and earlier human activity bring— but the size of the increase is not larger than the noise of the signal. Therefore it is not worse than a regular “bad” day or week in the record. Its overall significance is then slight. In addition to this, the net balance of the practice —the balance of the risks at the spring transition and the autumn transition— is seldom presented and, finally, the risks of not practicing seasonal regulations of time are not assessed either (Martín-Olalla, 2022).

Energy savings were the key issue for governments to take political action and still are considered in the assessment of the practice. Yet, energy saving can not explain why regulations succeeded and sustained in time. We identify two facts: first, the seasonal arrangements were physiologically well-designed, in-line with Nature, and, second, the population easily met the expected outcome: daylight leisure time in summer. Furthermore, we note that during the 20th century the annual worked hours have plummeted in Europe and America (Ausubel and Gröbler, 1995), increasing the leisure hours and allowing the seasonal regulations of time to better meet their outcomes.

Here we analyze the societal issues related with the practice of seasonal time arrangements in Europe. We show that the modern dislike for the practice can be associated with the preference for an earlier onset of human activity, developed after World War Two, and with the past history of time arrangements. We also analyze the impact of latitude and longitude in this issue. Taking into account the large variability of results we conclude that the European Commission should allow opt-outs on this issue and play only the technocratic role it originally played.

2. THE SEASONALITY OF THE LIGHT AND DARK CYCLE

The tilt of the Earth’s rotation axis (23.5°) gives rise to the seasonal variations: depending on calendar date, one hemisphere leans towards the beam of incoming solar rays —the bright side— and the remaining hemisphere leans

⁶ https://ec.europa.eu/commission/presscorner/detail/en/MEMO_18_5641

FIG. 1 The effect of the axial tilt in the illumination conditions. Left panel, the Earth on December at 6am UT: the beam of solar rays illuminates a higher fraction of the Southern hemisphere, where summer begins. Right panel, the same in the June solstice, when the summer begins in the Northern hemisphere. The wobbling of the planet is only apparent: the rotation axis is always pointing towards Polaris, the effect comes as a result of Earth's positioning around its orbit. As a consequence, solar elevation changes by 47° ($2 \times 23.5^\circ$) every six months. The efficiency of the insolation at noon and the solar elevation angle (in parentheses) are annotated in rays impacting on the major parallels. The dashed thick black line in either picture translates the line of shadow in the alternating picture and helps to visualize the span of sunrise times from December to June. Bright dots on the dark side of the planet visualize populated areas listed in <https://www.geonames.org>.

towards the opposite side —the dark side—. Figure 1 sketches the scenario in the extreme conditions (solstices): December (left), when summer begins in the Southern hemisphere, and June (right), when summer begins in the Northern hemisphere. Both pictures show the same hour of day: 6am Universal Time (UT). That is 7am Central European Time (left) and 8am Central European Summer Time (right).

The beam of incoming solar rays is arranged to impact the Earth at the marked circles of latitude. Every ray is annotated with the efficiency of the impact at noon as a percentage of the highest efficiency —which occurs when the Sun is overhead and no shadow is cast—, and the solar elevation. The apparent wobbling of the planet makes clear the changes in the solar elevation, and the changes in solar insolation at noon —which eventually give rise to the feelings of warm and chill associate with either season in the extratropical range—. Table 1 lists geographical features of selected European countries related to seasonal variations.

The changes in insolation can be summarized in the following ideas: in summer, below the 47th circle of latitude —that transverses France, Switzerland and Hungary in Europe— the insolation is greater than the insolation at the Equator and characteristically Tropical; in winter above the 47th circle of latitude the insolation is smaller than the insolation at the corresponding summer polar circle. To put it in a simple example: during three months around the summer solstice, the insolation on Madrid or Rome is more intense than at the center of Kenya, and during three months around the winter solstice, the insolation is less intense in those two cities than on a large fraction of the coast of Antarctica.

Aside from that, mechanical clocks reckon time following Earth's rotation through meridians. In so doing, they track time relative to noon or to midnight, but the apparent wobbling makes them useless to track sunrise and sunset times: see the line of shadow in Figure 1 crossing the array of hour meridians differently in either panel. This causes a delay in sunrise time with increasing latitude in winter, and an earlier sunrise time with increasing latitude in summer. The span of sunrise times from winter to summer is noted by the thick dashed line over either summer hemisphere, which indicates the winter sunrise. At the 47th circle of latitude the span of sunrise times is slightly smaller than four hours.

To understand the interplay between seasons, latitude, human activity and, to some extent, the minor role played by mechanical clocks, we bring the case of four countries located on the physical UT+00 time zone along different circles of latitude: Cote d'Ivoire (latitude 5.4° , in the Tropical range), Portugal and Spain (latitude 40° , in the mid Extratropical range, below the 47th circle of latitude) and United Kingdom (latitude 51° , in the far Extratropical

FIG. 2 The progress of sunrise across Europe and North Africa. All times are noted in UT+01 (Central European Time). Solid thin circles of latitude show whole hours for the span of sunrise times from winter to summer (values annotated on the lines), and broken circles of latitude show major circles. Whole hour meridians are noted by dash-dotted lines, and half-hour meridians (boundaries of physical time zones) are noted by solid lines. Cote d'Ivoire (Africa) and Portugal, Spain, and United Kingdom (Europe) are highlighted in darker ink. They all are located on the physical UT+00 time zone but winter sunrise delays up to two hours from South to North.

range, above the 47th circle of latitude), see Figure 2. Mean solar time is quite similar in them all—the difference is no more than twenty minutes—. Yet yearly-averaged patterns in human home-work commuting from mobile phone data in Cote d'Ivoire and Portugal found morning results advanced by “one hour” in the African country (Kung *et al.*, 2014, see Figure 3 therein). In a similar way, morning daily rhythm of labor in Spain is advanced one hour and a quarter relative to British daily rhythm, as deduced from the pre-prepared tables of the Harmonized European Time Use Survey⁷ (HETUS) (Martín-Olalla, 2018, see Table 2 therein). These results show a delay in the human activity with increasing distance to the Equator that matches with the delay in winter sunrise times: see the lines of sunrise shown in Figure 2.

The role of the insolation can be assessed by comparing Cote d'Ivoire and Portugal. In the African country the insolation at noon is at least 88 % year round; this pushes, year round, for an early human activity so as to prevent the exposure to the central hours of the day. In the European country the insolation goes from 44 % (winter) to 94 % (summer). In winter the gentle insolation at noon is very much welcome whereas in summer it is hazardous and invites to an early start of human activity to prevent exposure.

Compensating the winter delay in summer is then a rational, practical solution in many circumstances. We provide now a list of ways of accomplishing this goal: (1) by a smooth seasonal regulation of human activity as must have occurred before mechanical clocks came into play; (2) by a seasonal regulation of time schedules like the one observed at Cadiz Cortes in 1810 (see Section 1); here the stroke of one hour already seemed unavoidable as population started preferring whole hours for their convenience; (3) by seasonal time arrangements, only after the standardization of time was completed and governments learned to set time zones. In Section 3 we will discuss the case in which the winter delay is compensated in the same winter season.

To end this argument we note that Portugal practices seasonal time arrangements and Cote d'Ivoire does not. Yearly averaged data in Kung *et al.* (2014) can be seasonally described in the following way: (1) Portuguese and Ivorian morning home-work commuting differ by one hour during the autumn-winter season; and (2) they are largely coincidental in time during the spring-summer season. Similar results were obtained after comparing the sleep-wake

⁷ <https://www.h6.scb.se/tus/tus/>

cycle in pre-industrial, Tropical societies with those of industrial, Extratropical societies under seasonal regulations of clocks (Martín-Olalla, 2019a).

2.1. Seasonal time arrangement snapshot

The regulation of clocks introduces a seasonal variability into the otherwise non-seasonal local time. The wavy sinusoidal behaviour of solar latitude is accommodated into two settings: one if observer's hemisphere leans toward the Sun (summer; for Europe, June), another one if observer's hemisphere leans towards the opposite side (winter; for Europe, December).

The arrangements are directional and take care of sunrise times: clocks are delayed in autumn and advanced in spring so that, all else equal, human activity is moved later in autumn-winter and earlier in spring-summer. With this choice the population observes the apparent shrink of one hour in the span of sunrise times and the equivalent expansion in the span of sunset times. A physiological goal is accomplished: the start of human activity is tied to sunrise. This goal is more efficiently achieved at midlatitudes. A societal goal is also accomplished: if societies stick to the rule "first duties, then pleasure" then an extra-hour of daylight pleasure arises as a result of the earlier start of duties. Simple as that, this is the most evident outcome of the seasonal time arrangements and the reason they succeeded. We very much stress that this last outcome is independent of latitude and, because of that, the role of this magnitude is often ignored in this issue.

However, latitude plays a role in the remaining outcomes of the practice: the seasonal regulations make little sense in the Tropic because the seasonal span of sunrise times becomes exceedingly small. In contrast, above some circle of latitude, the seasonal span of sunrise times is exceedingly larger than one hour, so that the regulations are unable to bind human activity to sunrise. To be more specific: at the Polar Circles, midnight sun is followed by the Polar Night and the stroke of one hour is unable to make any difference.

Seasonal time arrangements started in early 20th century only after the increasing industrialization, urbanization and standardization of human social life had brought the desire for stable, year-round time schedules. By that time, the impact of artificial light was modest and the starting point of activity must have been largely determined by the winter sunrise. The time arrangements helped to seasonally regulate human activity in a simplistic way.

3. PATTERNS IN THE CURRENT WAVE OF DISLIKE FOR SEASONAL TIME ARRANGEMENTS

The dislike for the regulations of clocks can be attributed to two issues. First and foremost, the transitions are a complexity that disturbs the otherwise smooth routine of human societies. Population is reluctant to alter their habits and love having their duties under a regular, year-round time schedule. The biannual transitions are nowadays the one and only time disturbance many face in one full year. From another point of view, the fact that, first, some people called for the regulations and, second, some governments took action at the beginning of the 20th century shows that, by then, human activity conducted with little seasonality, loving also regular, year-round time schedules. One way or the other, the annoying biannual transitions have always played against the regulations. Nowadays this feeling has been further exacerbated in relation with the impact in human health.

Notwithstanding this, we find another issue in relation with the current dislike for seasonal time arrangements: during the 20th century human activity has colonized the hours of the winter dawn as cheap, efficient artificial light came into play. In line with that, and also helped by increasing uses of artificial light at night, most of the working population set alarm-clocks to wake up; they do not feel any variation in their wake-up times from winter to spring; instead they feel the stroke of one hour promoted by the spring transition. In connection with Section 2, the transfer of human activity to the early hours of the winter is a new, modern way of compensating the winter delay.

We now present the interplay between the preferences for seasonal regulations of clock and this shift. First, we will use the results from the 2018 public consultation on summer time regulations launched by the Juncker Commission. We understand that this consultation may provide value knowledge since it was taken simultaneously in every Member State—a broad scope that is seldom accomplished in polls—although we acknowledge that the sample extraction of the consultation was of poor quality, unrepresentative and unscientific by all means. We will hypothesize that the quality of the extraction was equally poor here and there, so that for every Member State the shares of population willing to cancel the regulations, as per the consultation, scales with the real shares through an unknown factor which is roughly similar for every Member State. Therefore, we will not take care of the values reported by the consultation, instead we will take care of the trends that these results may unveil. In our analysis we will exclude the edges of the distribution: Austria, Germany, and Luxembourg, which hit relatively large participation rates ($> 1.5\%$)

FIG. 3 Scatter plot of the shares of population willing to abolish seasonal regulations of clocks as per the 2018 European Commission public consultation vs the solar elevation at work start in winter as per HETUS. Color depths punctuate the year of continued practice of regulation. The null hypothesis “time distance to winter sunrise at work start does not explain shares of population willing to abolish regulations” does not sustain at the standard level of significance $N = 13$, $R^2 = 0.558$, $p = 0.003$. United Kingdom and Italy were excluded from the analysis due to low participation rate. Their observed values match with the prediction. If they were included in the regression the significance improves: $N = 15$, $R^2 = 0.666$, $p = 0.0002$. Germany was excluded due to high participation rate. For graphical purposes its participation rate is topped at 2%. Table 2 lists the data values that generated this plot.

compared to the remaining Member States; and United Kingdom, Italy and Roumania, which hitted relatively low participation rates ($< 0.1\%$).

On the other hand we will take the pre-prepared table from the Harmonized European Time Use Survey⁸ (HETUS). They help assessing the average starting point of labor activity in fifteen European countries (Martín-Olalla, 2018, see Table 2 therein). We retrieve the time distance from the work start point to the winter sunrise. This metric is alien to clocks and highlights the worst ambient-light conditions population face in one year: negative values imply early activity in the winter dawn; positive values early activity in daytime year round.

Figure 3 shows a scatter plot of the time distance from work start to winter sunrise (horizontal axis, predictor) and the shares of population willing to cancel regulations of time as per the 2018 public consultation (vertical axis, outcome). The shares of population were computed by scaling the shares of respondents willing to cancel the regulations in each Member State with its participation rate. Color depth punctuates the number of years of continued practice of seasonal regulation of clocks in four bins annotated in the plot.

The null hypothesis “preferences for abolishing the regulations do not depend on the time distance from work start to winter sunrise” does not sustain ($p = 0.003$) under the standard level of significance (0.05). Therefore the alternate sustains. The correlation ($R^2 = 0.558$) brings larger shares of population willing to cancel the seasonal regulations of time with earlier starting point of work relative to winter sunrise time, as expected from Section 2.1. Notice that we do not take care of which choice —keep summer time year round or keep winter time year round— respondents might prefer.

To understand the significance of this result we tested the shares of respondents willing to cancel the regulations against the latitude for this set of Member States. The regression resulted weaker ($R^2 = 0.202$) and the null hypothesis was not broken ($p = 0.12$) at the standard level of significance. Furthermore, if the full set of Member States ($N = 22$, excluding Austria, Germany, Italy, Luxembourg, Romania and United Kingdom) is tested, then the statistics showed a weak correlation ($R = 0.189$) which was barely significant ($p = 0.043$).⁹ Therefore the preference for discontinuing

⁸ <https://www.h6.scb.se/tus/tus/>

⁹ To provide some understanding, if the observed shares of preferences were randomly assigned to the observed starting points then 3 in 1000 simulations would result in a larger correlation. In contrast, if they were assigned randomly to the observed latitudes then 43 in 1000 would result in larger correlations.

FIG. 4 The interplay between winter sunrise and summer sunset, the early activity in winter and seasonal time arrangements. Irrespective of latitude winter sunrise differs by 12 h from summer sunset. Every row locates a human winter starting point (SP) and a summer human SP moved one hour earlier as per the seasonal regulations of time. From bottom to top the winter SP moves one hour earlier simulating the span of starting points in Figure 3. Notice that in the top row human summer SP comes only 9 h after summer sunset, which jeopardizes bedtimes in summer.

the seasonal regulations of time is efficiently predicted by human activity earlier than winter sunrise time and this magnitude should be taken into account to understand the ex-post assessment of the practice.

Before describing some implications of this trend we want to emphasize that in no manner we are meaning that a majority of population would have a preference for discontinuing the regulations here or there, or that regulations should be cancelled here or there. To be more specific, and playing with the extreme cases of the distribution, we are not deducing that seasonal regulations of time must be canceled in Finland because their starting point of activity is well advanced relative to winter sunrise; we are not deducing either that the regulations must continue in Italy because their starting point is bound to winter sunrise. We simply highlight a metric for characterizing the seasonal preferences and point out that the myriad societal things that punctuate the regulations of time.

Figure 4 shows a rationale behind the trend observed in Figure 3 which is independent of latitude. The thing to note is that winter sunrise and summer sunset differ by some twelve hours everywhere. If the starting point of human activity comes earlier than the hour of winter sunrise, then it also comes closer to the hour of summer sunset. If the seasonal clock regulations further move the starting point one hour earlier after the spring transition, then the starting point comes further closer to the summer sunset. Therefore increasing shares of working population would find bedtimes before night in summer and would feel dislike for the scenario.

Opposite to this feeling there is another rationale in which latitude does play a role. Some people find convenient an earlier start of human activity because end points will come earlier and will increasingly avoid ending points at night in winter. This is so much the case the higher the latitude, because the winter sunrise delays more, the winter sunset happens earlier, and as a result the winter daylight shrinks the more: at latitude 50° winter daytime is eight hours, at latitude 54° it is seven hours, in line with the standard for daily hours worked. In this scenario, some individuals challenge the autumn transition delay and would like to extend the summer time further in autumn-winter.

History also helps to understand the issue of latitude and early human activity. We first note in Figure 3 that those countries where human activity best bound to winter sunrise, happen to hold the longest record of sustained seasonal regulations of clocks (chiefly Italy, Ireland and United Kingdom, noted by light colours). In other words: seasonal time arrangements—which trades early human activity in spring-summer for late human activity in autumn-winter—brought the extra-hour of daylight leisure time in summer and, also, slowed down the transfer of human activity to the hours of the previous to the winter sunrise (Martín-Olalla, 2022).

On the contrary for the States that restarted seasonal time arrangements in the aftermath of the Oil Crises we find that the higher the latitude the more distance from the starting point of work to winter sunrise ($N = 14$; $R^2 = 0.717$; $p = 0.00013$). The lack of seasonal time arrangements since the end of World War Two to the Oil Crises promoted an early onset of human activity. As a result we also find that the higher the latitude the later the seasonal time arrangements were restarted in the aftermath of the 20th century Oil Crises ($N = 25$; $R^2 = 0.25$; $p = 0.01$).

This technicality was omitted by the Juncker Commission and by the ICF-International report (Kearney *et al.*, 2014), which analyzed different scenarios in which the regulations of time in one or few Member States were not harmonized. None of the scenarios considered that these movements could stratify with latitude. All this may jeopardize the primary commitment of the European Commission: the one-size-fits-all solution for the sake of the internal market efficiency.

4. THE ROLE OF LONGITUDE: A FURTHER COMPLEXITY

The cancelling of the seasonal time regulations faces a divisive dilemma: which clock (summer or winter) should survive. This opens a new challenge for large sized countries: the impact of the final decision for Easterners and Westerners, a question which may not have been considered yet. The Commission eluded this question when it pushed for discontinuing the regulation as the public consultation on summer time arrangements showed unclear preferences for either.

After time was standardized and referred to hour meridians —superseding local mean solar times, in use until then—, the longitude impacted the preferences for time schedules. With sunrises occurring earlier at the East, later at the West, and with a common clock regulating social life for a given country or a given time zone in a country, Easterners push for earlier time schedules as they tend to feel delayed, and Westerners pull for later time schedules, as they tend to feel advanced. In line with this, Easterners would tend to prefer permanent summer time while Westerners would tend to prefer permanent winter time. If the preference for either clock stratifies with longitude then governments face a devious decision, which becomes more complicated with increasing size (longitude span) of the country.

To understand the magnitude of this effect in Europe, Figure 5 shows the earliest (summer, orange) and the latest (winter, blue) sunrise lines in Poland, Germany, United Kingdom, France, Italy and Spain. These are the six largest Member States by area below the Arctic Circle. In the figure we annotate the current winter sunrise local time and summer sunrise local time. In black we also annotate the resulting sunrise time should the current regulation be canceled so that either (1) permanent summer time delays winter sunrise local time or (2) permanent winter time advances summer sunrise local time.

In figure 5 (right column) we see that in Spain and Italy the span of sunrise times is limited to three hours under the current regulations. Remarkably, if the regulations were canceled, then the Spanish and Italian governments must take a decision over a span of five hours in sunrise times. In France, the decision span increases from four to six hours due to latitude. In these three countries the summer insolation efficiency at noon is larger than 90 % and the winter daytime length is larger than 8 h, therefore sunrise time is an efficient lodestar for the onset of human activity. This primordial role is jeopardized by such dilemma and eventually may have stalled government decisions. In Germany, Poland and United Kingdom (left column) latitude magnifies the span of sunrise times and the impact of the regulations is less significant.

As matter of fact, we must add that governments had already taken decisions on these issues. United Kingdom —as well as Ireland— agreed during the past one hundred years that reducing the span by one hour was convenient; that they agreed that permanent summer time was inconvenient —this setting failed to sustain in 1969—; and had not even considered the choice for permanent winter time since 1916. Italy decided in 1966 that permanent winter time and permanent summer time were also inconvenient.¹⁰ Little new knowledge or new evidences have been provided since.

5. CONCLUDING REMARKS

The seasonal time arrangements are a natural, efficient, simplistic and coordinated way of regulating human activity in modern, Extratropical societies with time schedules tightly determined by clock time. Without the arrangements, some would find a hard time trying to seasonally regulate time schedules demanding early human activity in summer and later human activity in winter, a process that can not be any more synchronous than the current arrangements. These arrangements also find a compromise between those who push for early human activity year round and those who pull for late human activity year round. The compromise prevents the former from finding late time schedules in the summer mornings and prevents the later from finding early time schedules in the winter mornings. The downside of this compromise is the annoying biannual transitions. Also, under the arrangements, those who do not like a seasonal regulation of human activity find a hard time trying to compensate the arrangements by demanding later human activity in summer, or early human activity in winter. If those who benefit from the seasonal regulation of time outnumber those who do not, then the onset of the regulation by governments is a rational policy action.

The understanding of the balance of these preferences finds contradictory evidences: polls show larger number of respondents willing to abolish the practice, yet time use surveys show that people seldom try to compensate the effects of either transition and accepted the seasonal regulation. Most importantly, the balance of preferences is

¹⁰ See *Avremo l'ora legale* (Clock change decided) *La Stampa* 15 March 1964 http://www.archiviolaStampa.it/component/option,com_lastampa/task,search/mod,libera/action,viewer/Itemid,3/page,3/articleid,0096_01_1964_0064_0003_9342395/

FIG. 5 Entry point of sunrise in summer (oranges, Northeastern most) and exit point of sunrise in winter (blueish, Northwestern most) for United Kingdom, Poland, Germany, France (excluding overseas territories), Italy and Spain (excluding overseas territories). Hours of the day are given in the present local times CET=UT+01 for winter and CEST=UT+02 for summer. In discontinuing seasonal regulations of time either the summer value would advance by one hour or the winter value would delay for one hour (annotated in black). The population centroid is noted (circle) for every country and its latitude is annotated left to the name. Centroids, entry points and exit points were computed for populated areas listed in <https://geonames.org>

a local issue impacted by the geographical location, societal issues, physiological issues and the way in which past decisions modulated human activity through past decades. As far as the European Union is concerned, “local” points to the level of Member States, which exhibit vividly different geographical conditions of which latitude is probably the most determinant magnitude; and exhibit different approaches to the interplay between human activity and the cycle of light and dark. All these issues give birth to the correlation between the onset of human activity, the number of years with continued seasonal time arrangements and the shares of population willing to discontinue the arrangements observed in Figure 3. Also, the range of longitude may be relevant to understand the difficulties of large sized Member States —like France, Spain or Italy— in determining which clock should survive if regulations were canceled.

Based on these evidences, we suggest that the European Commission should abandon its commitment to synchronous time arrangements in the benefit of the internal market. Instead, the Commission should allow member States to opt-out. In other words, the efficiency of the internal market should not legally bind a Member State to practice regulations unwillingly —for instance if most of their population do not benefit from a seasonal regulation of the activity—. Likewise, it must not legally bind a Member State to discontinue seasonal time regulations unwillingly —for instance if their population benefit from the regulations—. Elsewhere there are examples of efficient internal markets where regional arrangements of time apply —Australia, Brazil, Chile, USA—. In most of them latitude plays the leading role in understanding the seasonal preferences.

The European Commission should then stick to its primordial, technocratic role of regulating the legally binding transition dates for those Member States willing to practice the seasonal regulations of time. The Commission should also get assurances that the choices for practicing or for not practicing seasonal time arrangements sustain in time for periods of five years —or any other convenient window of time— so that the choice will be publicly available with

due anticipation.

In a more descriptive format, we recall that the seasonal time arrangements were adopted last in Northern European countries, likely with the idea of harmonizing time with neighbours. Adding to this the recent experience of Chile—where seasonal time arrangements do not apply in the Southernmost tip of the country since 2015—and Russia—where the arrangements were canceled in 2011—we find plausible that canceling the regulations might sustain in the Northernmost Member States of the Union. However we must alert that population preferences will only be fully understood in the event that the regulations were cancelled. In the end only this natural experiment could provide an answer to a problem that would remain occurring regardless of the regulations: the adaptation of human activity to the seasonal cycle of light and dark. In line with this we stress that the choice for seasonal regulations of time has successfully sustained in the last four decades in every Member State of the European Union.

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United Kingdom ceased to be a Member State of the European Union on 1 February 2020. Throughout the manuscript United Kingdom is considered a Member State as it was the case when the events analyzed occurred.

Colormap in Figure 3 is Fabio Crameri’s `bilbao` sequential colour scheme, available at <https://www.fabiocrameri.ch/colourmaps.php>.

Preferences for winter permanent time and summer permanent time were obtained from Figure 22 in European Commission and Directorate-General for Mobility and Transport (2019) helped by Ankit Rohatgi’s `WebPlotDigitizer` <https://apps.automeris.io/wpd/>.

Supplementary Material A: Tabular material

Country	Latitude	Longitude	Noon span (minutes)	Winter daylength (hours)	Seasonal sunrise time span (hours)	Solar elevation (insolation efficiency) at noon	
						summer	winter
CY Cyprus	+35°	+33°	6	9.8	2.4	78°(98 %)	32°(52 %)
MT Malta	+36°	+14°	1	9.7	2.4	78°(98 %)	31°(51 %)
GR Greece	+38°	+24°	34	9.5	2.6	75°(97 %)	29°(48 %)
PT Portugal	+39°	−9°	13	9.4	2.8	74°(96 %)	27°(46 %)
ES Spain	+40°	−4°	54	9.3	2.9	73°(96 %)	26°(44 %)
BG Bulgaria	+43°	+25°	24	9.0	3.1	71°(94 %)	24°(41 %)
IT Italy	+44°	+12°	47	8.9	3.2	70°(94 %)	23°(39 %)
HR Croatia	+45°	+16°	23	8.7	3.5	68°(93 %)	21°(36 %)
RO Romania	+46°	+26°	37	8.7	3.5	68°(93 %)	21°(36 %)
SI Slovenia	+46°	+15°	12	8.6	3.6	67°(92 %)	21°(35 %)
CH Switzerland	+47°	+8°	17	8.5	3.7	66°(92 %)	19°(33 %)
HU Hungary	+47°	+19°	26	8.4	3.8	66°(91 %)	19°(33 %)
FR France	+48°	+2°	57	8.4	3.8	65°(91 %)	19°(32 %)
AT Austria	+48°	+16°	30	8.4	3.8	65°(91 %)	19°(32 %)
SK Slovakia	+49°	+19°	21	8.3	3.9	65°(90 %)	18°(31 %)
LU Luxembourg	+50°	+6°	3	8.1	4.1	64°(90 %)	17°(29 %)
CZ Czech Republic	+50°	+15°	26	8.1	4.1	63°(89 %)	17°(29 %)
BE Belgium	+51°	+4°	15	7.9	4.3	63°(89 %)	16°(27 %)
DE Germany	+51°	+9°	36	7.9	4.3	62°(89 %)	16°(27 %)
PL Poland	+52°	+19°	39	7.8	4.4	62°(88 %)	15°(26 %)
GB United Kingdom	+52°	−1°	38	7.7	4.5	61°(88 %)	15°(25 %)
NL Netherlands	+52°	+5°	15	7.7	4.5	61°(88 %)	15°(25 %)
IE Ireland	+53°	−6°	16	7.5	4.7	60°(87 %)	13°(23 %)
LT Lithuania	+55°	+24°	22	7.2	5.1	58°(85 %)	12°(20 %)
DK Denmark	+56°	+12°	28	7.0	5.2	58°(85 %)	11°(19 %)
LV Latvia	+57°	+24°	27	6.7	5.6	56°(83 %)	10°(17 %)
SE Sweden	+59°	+16°	52	6.1	6.2	54°(81 %)	7°(13 %)
EE Estonia	+59°	+25°	23	6.1	6.3	54°(81 %)	7°(13 %)
NO Norway	+60°	+10°	104	5.9	6.5	53°(80 %)	7°(12 %)
FI Finland	+61°	+25°	39	5.5	6.9	52°(79 %)	5°(9 %)
IS Iceland	+64°	−22°	35	4.2	8.5	49°(76 %)	2°(4 %)

TABLE 1 Geographical parameters for selected European countries in Western, Central and Eastern European Time. The table lists those parameters associated with seasons (see Figure 1). The first data column lists the latitude of the centroid; followed by the winter daylength—the shortest daytime year round—; the seasonal span of sunrise times—as measured by local time—and the solar elevation and insolation efficiency at noon in winter and summer. ISO-3166 `alpha-2` codes are listed for every country.

Supplementary Material B: Nomenclature

Because seasons are the only thing underlying the regulations, throughout this study we will speak of *seasonal* regulation of clocks, we will label *winter time* as the time zone to which clocks are set in autumn-winter on a given location; and we will label *summer time* as the time zone to which clocks are set in spring-summer, which is one hour ahead of winter time. From a standalone, unbiased, evidence-based point of view the choices *seasonal time arrangements/winter time/summer time* catch every of the issues at stake in the problem, providing a direct link to the natural phenomenon which the practice is associated with.

In American usage *winter time* is called *standard time*; *summer time* is known as *daylight saving time*, *DST*. In Europe *summer time* is commonplace but *winter time* is many times omitted as in *Central European Time*. Likewise the European Commission uses *summertime arrangements*.

Both American and European choices inherit the historical way in which time regulations arose: first by advancing

Country	Continued time arrangements		Starting point of labor		Public consultation	
	since	years	Distance to winter sunrise (minutes)	Winter solar elevation	Participation rate	Wish to cancel regulations
CY Cyprus	1975	47			0.88	0.41
MT Malta	1966	56			0.25	0.14
GR Greece	1975	47			0.34	0.15
PT Portugal	1916 ^{ab}	106			0.33	0.28
ES Spain	1974	48	−26	−5.2°	0.19	0.18
BG Bulgaria	1979	43	10	0.7°	0.18	0.15
IT Italy	1966	56	17	1.8°	0.04	0.03
HR Croatia	1983	39			0.52	0.47
RO Romania	1979	43			0.04	0.03
SI Slovenia	1983	39	−43	−7.3°	0.73	0.64
CH Switzerland	1981	41				
HU Hungary	1980	42			0.21	0.19
FR France	1976	46	−38	−6.3°	0.59	0.50
AT Austria	1981	41			2.94	2.26
SK Slovakia	1979	43			0.6	0.48
LU Luxembourg	1977	45			1.78	1.41
CZ Czech Republic	1979	43			0.59	0.49
BE Belgium	1977	45	−44	−6.6°	0.55	0.46
DE Germany	1980	42	−56	−8.2°	3.79	3.18
PL Poland	1977	45	−49	−7.2°	0.34	0.32
GB United Kingdom	1916 ^b	106	5	−0.2°	0.02	0.02
NL Netherlands	1977	45			0.16	0.13
IE Ireland	1916 ^b	106	0	−1.0°	0.24	0.21
LT Lithuania	1981 ^c	41	−68	−8.9°	0.34	0.31
DK Denmark	1980	42	−40	−5.0°	0.11	0.09
LV Latvia	1981 ^c	41	−61	−7.4°	0.39	0.33
SE Sweden	1980	42	−62	−6.7°	0.48	0.42
EE Estonia	1981 ^c	41	−79	−8.4°	0.94	0.80
NO Norway	1980	42	−91	−9.5°		
FI Finland	1981	41	−115	−11.4°	0.96	0.91
IS Iceland	1969 ^d	53				

^a Permanent winter time was occasionally used in 1922, 1923, 1925, 1930 and 1933.

^b Permanent summer time was tested in late 60s, early 70s of the 20th century, but it was reverted.

^c Permanent winter time was tested at the beginning of the 21st century. Time arrangements returned short before incorporation to the European Union (2004)

^d No time arrangements since

TABLE 2 Societal metrics associated with the seasonal regulations of time for countries listed in Table 1. The first two data columns list continued seasonal time arrangements. The second two columns list the metrics of the starting point of labor, only for countries that appear in HETUS, Ireland and Denmark (Martín-Olalla, 2018). The last two columns list the results from the 2018 public consultation —only UE Member States— on summer time arrangements expressed as a percentage of country population. Figure 3 shows last column versus third data column with color depth determined by the second data column. ISO-3166 **alpha-2** codes are listed for every country. Codes are used to label Figure 3.

clocks in spring, so that winter time is either unmarked (Europe) or standard (America) and summer time is always marked.

Likewise, in some contexts *summer time* is viewed as an “artificial” setting dictated by governments. However, they are not different from a seasonal regulation of time schedules, with autumn-winter schedules delayed relative to spring-summer schedules. As an example in 1810 the Spanish Cádiz Cortes —the first National Assembly in Spain— regulated seasonally the start of their sessions: from October to April they seated from 10am to 2pm; from May to

September they started from 9am to 1pm. It is very unlikely that members of the assembly viewed the winter timing as “standard” and the summer timing as “an arrangement” or as “artificial”. Also it is hard to assess which arrangement came first and which next. They were just appropriately suited for each season, pretty much like seasonal fashion, albeit with only two seasons. The annoying clock transitions are all the same like the annoying seasonal wardrobe changes. Just one of the many features that differentiate winter from summer at Extratropical latitudes.

We also note that many chronobiologists prefer to elude the seasonal nature of the arrangements. To be more specific they prefer to elude the phrase *summer time*, labelling it as a “colloquial term” (Roenneberg *et al.*, 2019). They suggest that the spontaneous preference for *summer time* in polls is actually a biased preference for *summer*. They argue that *Daylight Saving Time* does not bring longer evenings to us; they occur irrespective of the time arrangements. While this is true, the preference for *summer time* must be not only ascribed to the season itself, but also to the time schedules that the seasonal time arrangements promote: an early onset of human activity during the spring-summer season and therefore longer leisure time in daylight.