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UNIVERSAL TIME COULD REMEDY SOCIAL JETLAG

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The Johns Hopkins Institute for Applied Economics,
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Universal Time Could Remedy Social Jetlag

By Taylor Chan

About the Series

The *Studies in Applied Economics* series is under the general direction of Professor Steve H. Hanke, Founder and Co-Director of the Johns Hopkins Institute for Applied Economics, Global Health, and the Study of Business Enterprise (hanke@jhu.edu).

About the Author

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Abstract

In this paper, the author examines why socially constructed time systems, including time zones and daylight savings time, are problematic. These systems exacerbate the misalignment between the social clock and the human circadian rhythm – an effect known as "social jetlag," which leads to a multitude of adverse health effects and significant economic costs. A universal time standard, under which the entire world would operate on a single time zone, could potentially remedy the social jetlag problem by encouraging individuals and society as a whole to adhere more closely to their biological schedules.

Acknowledgements

I thank Professors Steve H. Hanke and Richard Conn Henry for their guidance in writing this paper. Their ideas on universal time, which can be accessed via their website (hankehenryontime.com), have directly motivated me to delve into such a unique topic. I also thank Spencer Ryan for his edits and comments.

Introduction

A Chinese proverb states, "An inch of time is an inch of gold, but an inch of time cannot be purchased for an inch of gold." The value of time in today's highly advanced societies cannot be overstated; as the social construct according to which markets are operated, meetings are planned, and transactions are executed, time is what sustains a well-functioning economy. Moreover, it is impossible to fathom a world devoid of clocks, our measurer of time. Given that time and clocks are so integral to how economies and civilization as a whole function, it is ironic that so few economists have ventured into studying these subjects. Limited discourse exists on the question of whether the current normalized time systems, namely, time zones and daylight savings time, are indeed the most efficient and promote the greatest levels of economic well-being.

The few economists and health experts who have conducted research studies on this question saw unexpected and unnerving results. It turns out that time zones and daylight savings time cost society far more than "an inch of gold;" not only do they exacerbate health problems, but they also incur significant economic costs. One revealing study by Osea Giuntella and Fabrizio Mazzonna entitled "Sunset time and the economic effects of social jetlag: evidence from US time zone borders" examines how as a result of time zones, there is a disjunction between people's social schedules and their biological (circadian) rhythms, which makes individuals on one side of the time zone more susceptible to health problems. They prove that this disjunction, classified as "social jetlag," is the root of many health and economic issues (2019).

Even fewer economists have identified this problem and proposed a solution. In addition to surveying time zone history and bringing the social jetlag issue into academic discourse, this paper argues for a universal time standard as a potential remedy to the issue. Mass adoption of universal time, especially in relation to its role as a solution, is an idea that has only been publicly advanced by few, most notably Professors Steve. H. Hanke and Richard Conn Henry at the Johns Hopkins University (Hanke & Henry, 2018, 2011; Hanke, 2019; Henry 2007).

Time Zone and Daylight Savings Time History in the U.S.

In order to understand the inherent flaws within a multiple time zone system, it is essential to be aware of how time zones came to be implemented in the first place. Prior to the

invention of the first clock in the 17th century, people utilized various instruments, like sundials, which directly functioned according to the sun's movements. After the invention of the chronometer in 1764, cities and towns began setting their clocks according to **local solar time**, in effect creating over 300 time zones in the United States (Buckle, 2009).

After the introduction of railroads, coordination presented itself as a chaotic challenge. The confusion of traveling through many different time zones led to fatal accidents; on one occasion in 1853, mismatched timetables caused a train collision that killed 14 people and injured 23. Mounting safety concerns and the need for a solution inspired New York schoolmaster Charles F. Dowd to develop and pitch the now familiar four-zone system to the railroads in 1869. In 1872, the General Time Convention was organized by the railroads to evaluate new potential time zone systems. Eleven years later, the U.S. Naval Observatory implemented Dowd's four-zone idea and designated times accordingly. Even then, locals adhered to their solar time zones, until Congress finally mandated national time zones in 1918 under the Standard Time Act.

Interestingly, the four-zone system was not Dowd's "first-draft." The final system was actually modified from Dowd's original idea for a single national time zone, which would have entailed a single time recognized from Boston to San Francisco. As universal time implied that solar noon would have differed by four hours across the country, Dowd adjusted his initial solution, making it easier to gain acceptance (Pusey, 2019).

Daylight savings time (DST) was invented by a New Zealand naturalist George Vernon Hudson in the late 19th century, and by 1918 the system had been accepted by Germany, the U.S., Europe, and Russia to "reduce energy costs" during wartime. 1966 marked the U.S.'s official peacetime adoption of DST with Congress passing the Uniform Time Act. Additionally, the government intended to use DST to hedge the U.S. economy against oil price shocks in the 70s (Pavlus, 2010).

Arguments For and Against Time Zones and Daylight Savings Time

The origin story of time zones sheds light on why the system is widely supported and unquestioned. The four-time-zone system trumped the 300-time-zone system in that it made coordination and conversion significantly easier, preventing railroad accidents. Having *fewer* time zones facilitated business operations across the country. People like time zones because

they are comfortable seeing the sun at its zenith when their clocks hit noon. People also like to adhere to a uniform schedule across the country, in which people rise and go to bed around the same times. With a fixed relationship between the clock and solar time, people of different regions can put time differences into perspective. As for the daylight savings time debate, those who support the annual clock change argue that adding an hour of daylight to the afternoon reduces crime, saves energy, and encourages people to go outside. The tourism industry also profits from the lengthened afternoons (Buckle, n.d.).

As the world has become accustomed to distinct time zones and daylight savings time, people have ignored these systems' faults and have succumbed to their inconveniences. The same issues of miscoordination endemic in the local solar time system are not entirely eliminated from the U.S.'s four-zone system. In a highly globalized, technologically connected world, it can be impractical and unnecessarily irksome to arrange meetings across different time zones – for instance, conversion errors and miscommunications are likely. However, the negatives extend beyond such petty inconveniences into far graver effects; *the most critical argument against these conventional time systems revolves around their deleterious, large-scale consequences on people's health and the economy.*

The "Social Jetlag" Issue

"Social jetlag" is what results from the misalignment of rigid social schedules and natural biological schedules, or circadian rhythms. *Biological schedules,* or *circadian rhythms* refer to humans' internal clocks, their natural sleep-wake cycle. *Environmental light* is the primary signal for the body's circadian rhythm. *Social schedules* are artificially imposed synchronizations of people's time. For instance, the 9am-5pm workday is a socially constructed schedule that everyone follows. Time zones enforced by the government also structure social schedules – people adhere to the clock schedule the government forces their region to follow.

What happens when circadian rhythms and regular sleep are hampered with? A study conducted by Francesco P. Cappuccio, MD, FRCP, Lanfranco D'Elia, MD, Pasquale Strazzullo, MD, and Michelle A. Miller, PhD on short and long duration of habitual sleep and adverse health outcomes demonstrates that the "forced synchronization" of schedules can disrupt human circadian rhythms and have detrimental effects on health and productivity:

> "Lack of sleep exerts deleterious effects on a variety of systems with detectable changes in metabolic, endocrine, and immune pathways. Over the last few decades there has been growing evidence to suggest that too little sleep and too much sleep are associated with adverse health outcomes, including total mortality, cardiovascular disease, type 2 diabetes, hypertension, respiratory disorders, and obesity, and poor self-rated health" (Cappuccio et al., 2010).

How Time Zones Exacerbate Social Jetlag

Osea Giuntella and Fabrizio Mazzonna's research study reveals that *the misalignment of biological and social schedules is most intensified and problematic at time zone borders* (2019). Their study is integral to understanding the exact health and economic consequences that arise from having multiple time zones. For individuals living on the "late-sunset" side of a time zone border – the eastern side that experiences sunsets in the later hours of the day – the effects are the most detrimental. *These individuals tend to go to bed later but do not compensate for this by waking up later*, instead waking up for work at 9am and prioritizing their social schedules. In other words, because individuals occupying opposite sides of a time zone border must follow *different* social schedules yet experience the *same* sunset (and should follow the *same* biological schedule), it is inevitable that the circadian rhythms of those on one side will be affected.

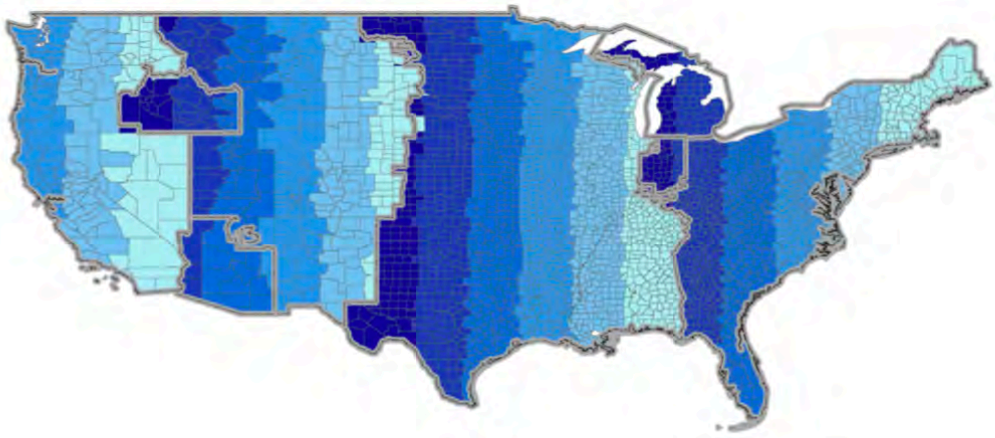

Fig 1. Time Zones and Average Sunset Time. *Notes - Average sunset time over a year was computed using the NOAA Sunrise/ Sunset and Solar Position Calculators and information on the latitude and longitude of US counties' centroids. Counties were divided into 5 quintiles based on the average sunset time in a given year. The darker the circles, the later the average sunset time.* **Source**: "Sunset Time and Economic Effects of Social Jetlag: Evidence from the US Time Zone Borders."

The main issue tied to social jetlag is sleep deprivation. When people who have more daylight in the later hours of the day sleep later but do not wake up later, they are disrupting their

circadian rhythms. The research showed that on average, those inhabiting the "late-sunset" side of the border get 19 less minutes of sleep than their counterparts on the other side and are more likely to be sleep deprived (getting less than 6 hours of sleep) (p. 218). Individuals who start work before 7am or have children who they drop off at school before 8am sleep "substantially less." Specifically, "among those entering work later than 8:30 in the morning, a one-hour increase in average sunset time decreases sleep duration by 27 minutes for those who brought children to school before 8am." Sleep quality is also affected. For instance, those on the late-sunset side woke up multiple times in the middle of the night – 1% more times than those on the other side of the border – and were restless 90 seconds more than those on the other side (p. 220). *Sleep deprivation and ignoring one's circadian rhythm drive a multitude of health and economic problems.*

Giuntella and Mazzonna ran multiple regressions to identify discontinuities in sunset time at the time zone borders related to outcomes in sleep and other health conditions. The data they sampled was pulled from two sources: (1) the American Time Use Survey from the years 2003-2013, in which participants strictly detail their time spent sleeping and eating. The group they were specifically surveying included individuals in the labor force (both employed and unemployed) living within 250 miles of each time zone boundary (Pacific–Mountain, Mountain–Central, Central–Eastern), 18-55 years old; (2) county-level data from the Centers for Disease Prevention and Control (CDC), which reports the presence of obesity, diabetes, cardiovascular disease, and breast cancer (p. 211).

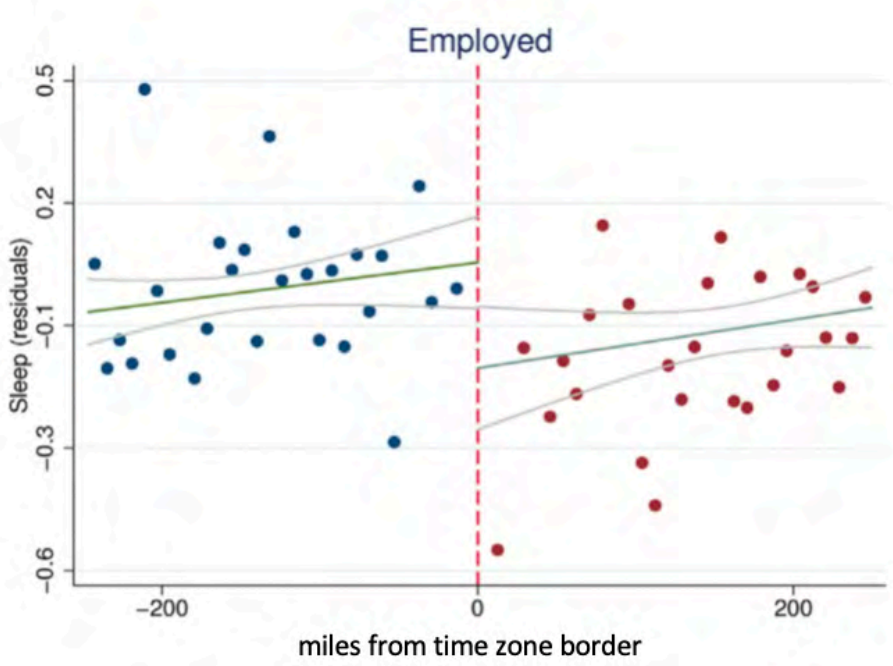

Fig 2. Sleep Residuals for Employed Individuals.
Source: "Sunset Time and Economic Effects of Social Jetlag: Evidence from the US Time Zone Borders."

Sleep Residuals for Employed Individuals: Regression was performed to analyze the *relationship between location relative to the time zone border and sleep among employed residents*. Employed residents are the most ideal population to examine as they are strongly constricted by artificial social schedules and having to rise early for work. The dotted red line represents the time zone border. Each point represents the average *residual* (sleep) for a group of counties. Here, higher residuals on the graph represent more sleep on average while the more negative values indicate less sleep. Higher positive values on the x-axis indicate distances farther east of the border while negative values represent distances west of the border. We can see the difference in average amount of sleep is the largest in counties closest to the border; the late-sunset side of the border had an average of 20 minutes less sleep (p. 218).

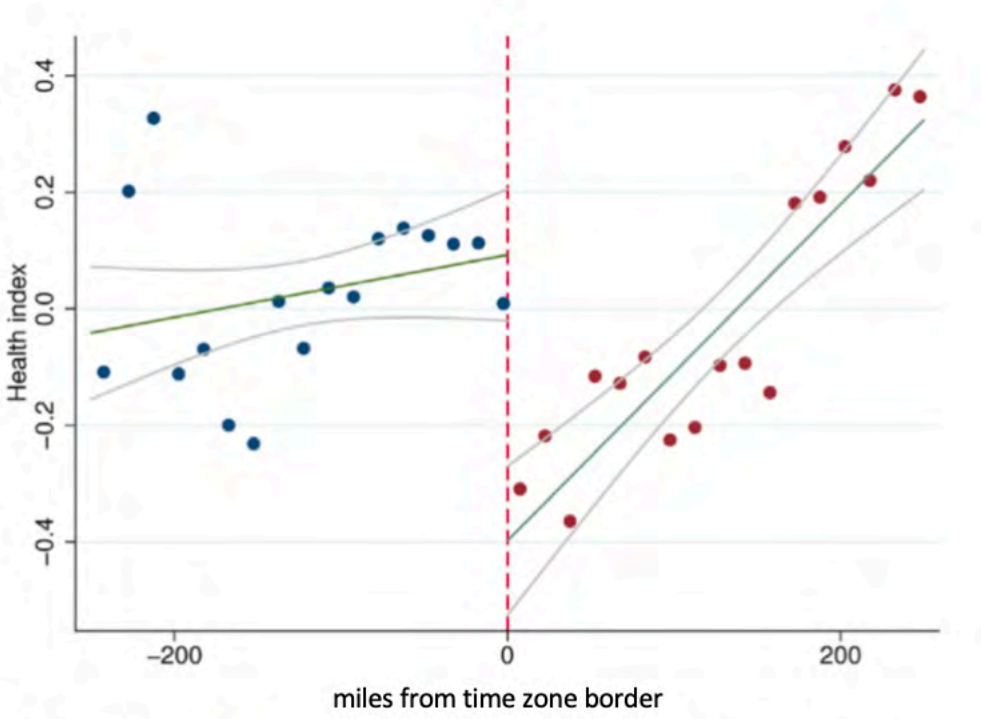

Fig 3. Discontinuity in Health (County Level Data). *Notes - Data are drawn from the CDC 2004-2013.*
Source: "Sunset Time and Economic Effects of Social Jetlag: Evidence from the US Time Zone Borders."

Health Index Residuals: The residuals were obtained from a regression of the *composite health index and location relative to the time zone border.* The dotted red line represents the time zone border. Each point represents the mean (health) residuals for counties within a 15-mile average distance. The health index is a composite of different health indicators, including obesity, diabetes, acute myocardial infection, coronary and angina disease, stroke, and breast, colorectal and prostate cancer at the county level. Here, higher residuals on the graph represent better health and fewer instances of the aforementioned diseases while the more negative values indicate poorer health. Higher positive values on the x-axis indicate distances farther east of the border while negative values represent distances west of the border. We can see the difference in health and occurrences of diseases is the largest in counties *closest to the border*. Note that if the two extreme datapoints beyond -200 miles (200 miles west) of the border with health residuals greater than or equal to 0.2 were excluded, the data would exhibit a parallel pattern and fall closer in line with the trends we expect – like the trends observed for the sleep residuals (p. 221).

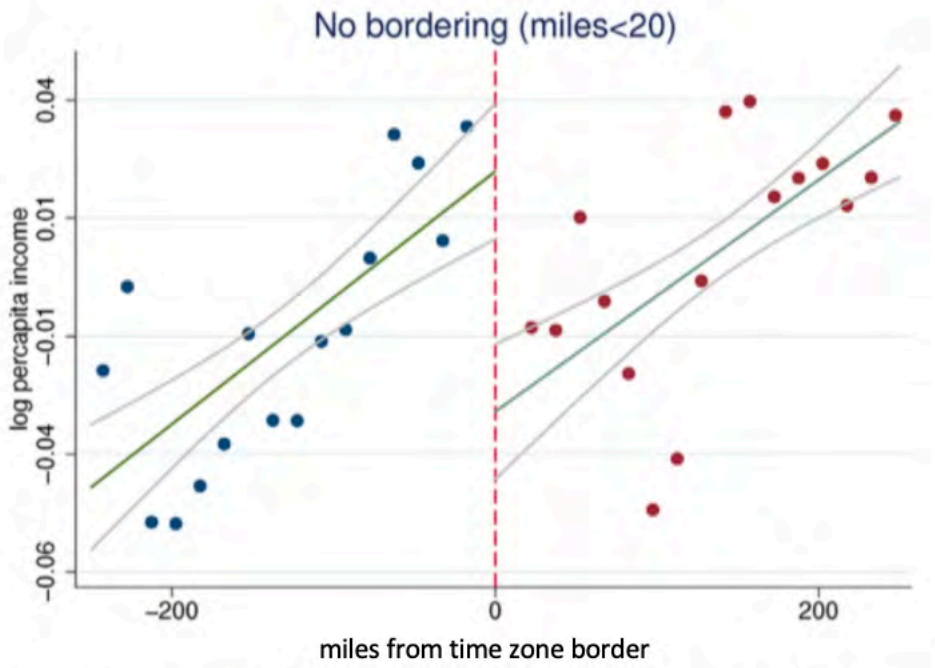

Fig 4. Income per Capita 2014 (Zip Code Level). *Notes - Data are drawn from ACS 2010-2014.*
Source: "Sunset Time and Economic Effects of Social Jetlag: Evidence from the US Time Zone Borders."

Income Residuals: The residuals were obtained from a regression of the *zipcode level income per capita from 2010-2014 and location relative to the time zone border***.** This graph excludes the zipcodes within 20 miles of the time zone border since individuals in those areas may be participating in the same labor market and have similar incomes. The dotted red line represents the time zone border. Each point represents the mean residuals (per capita income) for counties within a 15-mile average distance. Here, higher residuals on the graph represent higher incomes while the more negative values indicate lower incomes. Higher positive values on the x-axis indicate distances farther east of the border while negative values represent distances west of the border. It is clear to see that incomes are lower for individuals on the late-sunset side of a time zone border; once again, a discontinuity exists (p. 224).

Sleep Data for the Late-Sunset Side	Sleep hours - 250mi bandwidth	Sleep hours - 100mi bandwidth	Sleep ≥ 8hrs	Employed sleep hours
Percentage point difference in outcome	-30.8	-40.3	-8.1	-31.5
Number of observations	16,557	3,918	16,557	16,557
Socio-demographics controlled?	YES	YES	YES	N/A
State fixed-effects controlled?	YES	YES	NO	NO
Bandwidth (distance from time zone border in miles)	250	100	250	250

Fig 5. Summarized Sleep Data for Late-Sunset Side.
Source: "Sunset Time and Economic Effects of Social Jetlag: Evidence from the US Time Zone Borders."
Prepared by Prof. Steve H. Hanke, The Johns Hopkins University.

The table above summarizes *sleep data for the late-sunset side* of a time zone border. The *results* of the study can be seen in the row "Percentage point difference in outcome." Each entry in this row signifies the percentage point differences in likelihood or occurrence of a given outcome for the late-sunset side compared to the other side of the border. Negative percentage points signify lower likelihood of a certain outcome compared to the non-late-sunset group, and positive percentage points signify a higher likelihood than the other group. Also indicated within the table is whether socio-demographic variables (age, race, sex, education, marital status, etc.) and/or state fixed effects were controlled in the experiment; the more controls, the lower the chance of confounding variables and biased results. Bandwidth, the distance from the time zone border in miles, indicates whether the study conducted only included counties near the border, within 100 miles, or farther out, within 250 miles. For sleep data, the discontinuity effect is stronger closer to the border. *Late-sunset counties within 250 miles of the border got 30.8 percentage points less sleep than the non-late-sunset counties. Those within 100 miles got even less, sleeping 40.3 percentage points less. Those on the late-sunset side were also 8.1 percentage points less likely to sleep at least 8 hours. Finally, looking solely at employed individuals, those on the late-sunset side slept 31.5 percentage points less than those on the non-late-sunset side* (p. 219). This category is highlighted in red because it is significant in that it falls in line with the story told by *Figure 2* earlier in this paper.

Health Data for the Late-Sunset Side	Overweight	Obese	Poor Health
Percentage point difference in outcome	6.9	5.6	2.0
Number of observations	4,331	4,331	9,696
Bandwidth (distance from time zone border in miles)	250	250	250

Fig 6. Summarized Health Data for Late-Sunset Side.
Source: "Sunset Time and Economic Effects of Social Jetlag: Evidence from the US Time Zone Borders."
Prepared by Prof. Steve H. Hanke, The Johns Hopkins University.

The table above summarizes *health data for the late-sunset side* of a time zone border. The *results* of the study can be seen in the row "Percentage point difference in outcome." Each entry in this row signifies the percentage point differences in likelihood or occurrence of a given outcome for the late-sunset side compared to the other side of the border. Negative percentage points signify lower likelihood of a certain outcome compared to the non-late-sunset group, and positive percentage points signify a higher likelihood than the other group. Bandwidth, the distance from the time zone border in miles, indicates the range from which data was observed; for all data within this graph, counties within 250 miles of the border were examined. *Late-sunset counties had a higher likelihood of being overweight, obese, and unhealthy – respectively, 6.9, 5.6, and 2.0 percentage points more likely than those in non-late-sunset counties* (p. 220). Just like in *Figure 3,* the table suggests a positive relationship between living on the late-sunset side and experiencing health issues.

Income Data for the Late-Sunset Side	log Per capita income - 250mi bandwidth	log Per capita income - 100 mi bandwidth	log Per capita income - excluding close zipcodes
Percentage point difference in outcome	-3.5	-3.3	-4.4
Number of observations	21,484	7,953	19,885
Socio-demographics controlled?	YES	YES	YES
State fixed-effects controlled?	YES	YES	NO
Bandwidth (distance from time zone border in miles)	250	100	250
Exclusion of zip codes within 20 miles of border?	NO	NO	YES

Fig 6. Summarized Income Data for Late-Sunset Side.
Source: "Sunset Time and Economic Effects of Social Jetlag: Evidence from the US Time Zone Borders."
Prepared by Prof. Steve H. Hanke, The Johns Hopkins University.

The table above summarizes *income data for the late-sunset side* of a time zone border. Specifically, the logs of incomes were calculated to eliminate variability and strong skewness in the raw income data. The *results* of the study can be seen in the row "Percentage point difference in outcome." Each entry in this row signifies the percentage point differences in likelihood or occurrence of a given outcome for the late-sunset side compared to the other side of the border. Negative percentage points signify a lower likelihood of a certain outcome compared to the non-late-sunset group, and positive percentage points signify a higher likelihood than the other group. Also indicated within the table is whether socio-demographic variables (age, race, sex, education, marital status, etc.) and/or state fixed effects were controlled in the experiment; the more controls, the lower the chance of confounding variables and biased results. Bandwidth, the distance from the time zone border in miles, indicates whether the study conducted only included counties near the border, within 100 miles, or farther out, within 250 miles. There is an additional row for the exclusion of zipcodes within 20 miles of the border; including the zipcodes would blur the discontinuity and effect of social jetlag, as those working at the border work within the same labor market and earn the same income. *For individuals living within 250 miles of the border, per capita incomes on the late-sunset side were lower by 3.5 percentage points than incomes on the non-late-sunset side. For those within 100 miles of the border, this difference was 3.3 percentage points. Finally, when excluding zipcodes within 20 miles of the border, the effect of social jetlag is per capita income on the late-sunset side being 4.4 percentage points lower than incomes on the other side of the border***.** This category is

highlighted in red because it is significant in that it falls in line with the story told by *Figure 4* earlier in this paper (p. 22).

How Daylight Savings Time Exacerbates Social Jetlag

Although Daylight Savings Time is a once-a-year phenomenon (unlike the constant, uninterrupted issues associated with time zones), it still has both short-term and chronic implications on health and the economy. A scholarly article by Till Roenneberg, Eva C. Winnebeck and Elizabeth B. Klerman entitled "Daylight Saving Time and Artificial Time Zones – A Battle Between Biological and Social Times*"* explains the relationships between the body's natural clock and time set by the government and social standards, presenting the myriad of problems with the DST policy (Ronneberg et al., 2019).

The switch to DST in the spring "increases the discrepancy between the sun clock and the social clock by 1h" (p. 2). Comparable to the social jetlag issue arising at time zone borders, DST causes people to go to bed an hour later; insufficient sleep in this instance is the catalyst behind chronic negative effects. One Australian study showed that despite the 1 hour shift under DST, cortisol rhythms were shown to advance only 2 minutes (Hadlow et al., 2014), demonstrating that the biological clock dependent on light operates independently of the social clock (Ronneberg et al., 2019, p. 7).

Health Consequences

When sleep and wake rhythms are misaligned with the body's physiological processes, the release of hormones tied to a healthy circadian rhythm becomes affected. The release of melatonin (which regulates sleep), cortisol (a stress hormone), ghrelin (a hunger hormone), and leptin (which inhibits hunger) are desynchronized. Consequently, a person is more susceptible to metabolic diseases, including obesity and diabetes, cardiovascular diseases and cancer progression **(**Giuntella & Mazzonna, 2019, p. 210).

Other adverse health effects associated with social jetlag include an increased likelihood of being a smoker, increased caffeine and alcohol consumption (Wittmann et al., 2006), higher risk of developing depression (Levandovski et al., 2011), decreased psychological well-being, including anxiety and other mental illnesses (Wittmann et al., 2010; Foster et al., 2013), and

hampered cognitive and academic performance (Haraszti et al., 2014; Díaz-Morales and Escribano, 2015).

The findings of the Giuntella-Mazzonna study indicate that those on the late-sunset side with disrupted circadian rhythms were more likely to report poor health status. They were 11% more likely to be overweight compared to the mean and 5.6 percentage points more likely to be obese. Those with earlier work schedules tended to show even more weight-related issues (Giuntella & Mazzonna, 2019, p. 220). In addition to **obesity**, those with misaligned biological and social clocks are more predisposed to **diabetes, cardiovascular diseases, and breast cancer**.

Ronnenberg, Winnebeck, and Klerman list studies that explore some acute effects of DST, which last a few days after the switch in time:

> Sleep is shortened (Barnes and Wagner, 2009), adolescents are sleepier during the day (Schneider and Randler, 2009), general accidents and visits to the emergency room increase (Ferrazzi et al., 2018), so do myocardial infarctions (Janszky and Ljung, 2008; Manfredini et al., 2018), ischemic stroke (Sipilä et al., 2016), the risk of in vitro fertilized mothers losing their babies (Liu et al., 2017), and suffering from negative mood changes (Monk and Folkard, 1976; Monk and Aplin, 1980) (Ronneberg et al., 2019, p. 6).

Another way to study the negative effects of DST is to examine what occurs when the clock reverts back to standard time in the fall; a Russian study discovered that there is a small decrease in winter depression symptoms under perennial Standard Time (Borisenkov et al., 2017).

Economic Costs

Economists have been ignoring the detrimental effects of forced synchronization on health and productivity. The healthcare costs associated with social jetlag and circadian rhythm disruptions influenced by the time zone border are at least $2.35 billion annually, or about $82/capita. The total is most likely larger than this calculation, which is based off a smaller age range used in the study (18-65-year olds). In addition to healthcare costs, the productivity losses from sleep deprivation are equivalent to 4.40 million days of work. Costs associated with absenteeism/presenteeism (workers missing work and being less productive because of circadian rhythm misalignment) totaled $612.9 million, or $23/capita, which is based on median hourly

wage in 2015 times the hours of work lost (Giuntella & Mazzonna, 2019, p. 222). Wages are also 3% lower on the late-sunset side (p. 225).

Another research study conducted by RAND Europe calculated the economic cost of inadequate sleep in the U.S, finding that the U.S. sustains by far the highest economic losses – up to $411 billion a year, which is 2.28 per cent of its GDP. The high number is due to the size of its economy. Japan comes in second place with costs up to $138 billion a year, or 2.92 per cent of its GDP ("The Costs of Insufficient Sleep," n.d.).

A short-term economic cost of the DST transition is an amplified stock market weekend effect, which causes large negative returns on financial market indices on the Monday after the time change. The weekend effect has specifically been found to affect foreign exchange and money markets as well as stock markets, showing its strongest impact on markets in Belgium, Brazil, Canada, New Zealand, Switzerland, the United Kingdom, and the United States (Kamstra et al., 2000, p. 1006). Coupling DST and sleep desynchronosis with the weekend effect magnifies the effect by roughly 200-500%. "In the United States alone, the daylight saving effect implies a one-day loss of $31 billion on the NYSE, AMEX, and NASDAQ exchanges" (p. 1010).

Universal Time as a Solution

Universal Time is the concept of establishing a single clock for the entire planet. Under a universal-time standard, the time displayed on your watch and the time displayed on the watch of a person in the UK as well as in Japan would be the exact same. Universal time is essentially the opposite of having distinct time zones.

Universal time was promoted by engineer-in-chief of the Canadian Pacific Railway and father of the standardized time, Sanford Fleming, as well as American, Charles F. Dowd. In 1876, Fleming published an article promoting the concept of a universal time with the prime meridian as a reference point. He saw time zones as inferior to a single world time zone, which he referred to as "Cosmic Time." While Fleming's dream of Cosmic Time never came to fruition, he is still credited with founding the UTC (Universal Time "Coordinated") *system*, an international standard upon which civil time is based (Fleming, 1886). Clocks in different time zones are offset by x number of hours with respect to "UTC+0", the principal time zone located

at the Prime Meridian. For example, Eastern Standard Time is UTC-5; we are 5 hours behind UTC+0. Note: UTC+0 is also called "Zulu Time."

The research shows that government manipulation of time and the enforcement of strict social schedules leads to social jetlag, which in turn leads to innumerable health problems and hampered economic performance. *The problem could be eliminated with the implementation of universal time, which would entail the elimination of time zones and the establishment of a worldwide clock running on UTC+0 time***.** Eliminating time zones will effectively do away with the slew of problems resulting from the stark disjuncture between biological and social schedules at the late-sunset side of the time zone border. *Instating UTC will encourage individuals and society as a whole to adhere more closely to their biological schedules*. The adjustment period that will follow UTC standardization will force society to stop relying on the social clock, and every single region, even down to the level of an individual business or institution, will have to determine their own schedule. *Society can then adjust its working hours to be more in line with the natural sunrise and sunset time within that region*. To offer an example – a business that formerly began its workday at 9am will erase that social norm after the introduction of UTC. It may decide to begin its workday at 2pm if its new sunrise under UTC occurs at 1pm. Then, employees will rise, work, and be more productive, since their social schedule has been set in accordance with their biological clocks.

Universal time aims to incorporate the benefits of the local solar time system, with over 300 time zones, and the staple four-zone system in the U.S. At the same time, it smooths over the flaws of each system. Today's four-zone system disrespects the fact that every line of longitude in the U.S. experiences a different light schedule; sunsets vary by minutes from place to place, yet the government generalizes the solar clock into one-hour chunks. And this disregard for the solar clock equates to a disregard for the biological clock, leading to social jetlag and the myriad of health and economic problems previously described. On the other hand, while the 300-zone system may have promoted better circadian rhythms, it was terminated because it was extremely impractical and led to tiresome and sometimes fatal misunderstandings. By instituting a single worldwide time zone, scheduling will in theory be the easiest as it will not necessitate conversion nor present any opportunity for error.

Critics of standardized universal time are eager to point out that coordination could become harder, as one could no longer rely on the "social clock;" for example, scheduling a

meeting could prove difficult since there are no longer different clocks and time zones to offer perspective on whether or not it is an appropriate time in a given region. To account for this challenge, solar clocks should be used in tandem with universal time. In today's age of digitalization and advanced technology, it is quite possible to develop apps or watches for widespread usage which indicate the position of the sun in the sky and their associated times for specific coordinates on the map. This could potentially look like the Day and Night World Map on Time and Date's website.

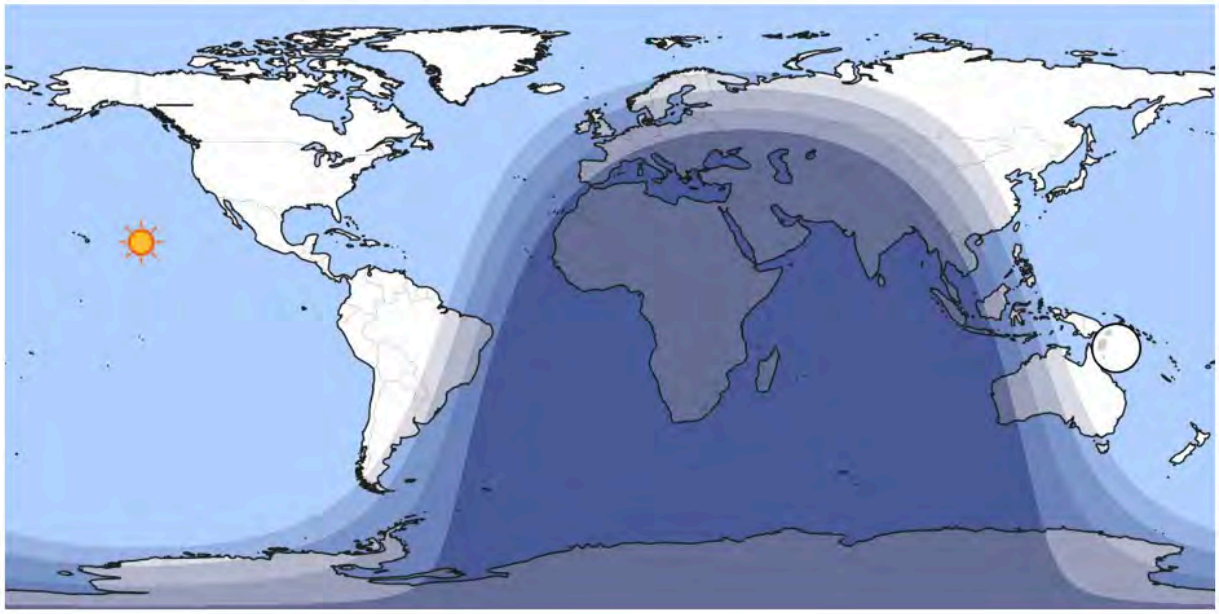

Fig 8. Day and Night World Map.
Source: timeanddate.com

Fig 9. Solar Time Calculator.
Source: timeanddate.com

In this case, to schedule a business meeting between two parties within different "time zones," the parties should refer to the position of the sun in a specified area along with the specific hours of operation for the business in said area. This way, the *scheduling norms* we rely on under the social clock system – i.e. the reliance on the fact that businesses generally open around 9am *everywhere* and the fact that people take lunch breaks at 12pm *everywhere* – will be eradicated and replaced with solar-clock based norms – i.e. the reliance on the fact that businesses operate when the sun is a quarter the distance from its zenith *everywhere* and the fact that people take lunch breaks at the sun's zenith *everywhere,* regardless of what time it is under UTC+0. While some may deem this as a somewhat tricky adjustment, it is the necessary trade-off that must be made in order to maximize people's health and economic productivity.

Applications of Universal Time Today

While most of the world still operates under time zones, several industries and official bodies have recognized the issues of acknowledging multiple time zones. These industries and entities utilize a universal time standard to ease operations. In accordance with the International Telecommunication Union Radio Regulations international mandatory treaty, all standard-frequency and time-signal emissions conform as closely as possible to UTC. Standard orders in the U.S., Chinese, Australian, Canadian, New Zealand, and UK militaries are distributed using Zulu or UTC (Greenwich Mean Time) to eliminate confusion in operations (MilitaryBenefits, n.d.). The International Space Station has a UTC time standard, used by its command center (Space_Station, 2019). Global Navigation Satellite Systems (U.S.'s GPS, Russia's GLONASS, Europe's Galileo, China's BeiDou) rely on precise time that is synchronized with UTC. They actually have their own internal time scales, but they disseminate UTC – meaning they include parameters to convert to UTC (Lewandowski, 2013). Zulu time is the world's standard for marine navigation. The National Oceanic and Atmospheric Administration transmits weather information, like storm warnings and geophysical alerts, in UTC, and marine logs and reports are typically in UTC (Willis, 2015). Aviation today is planned based on Zulu time to prevent confusion that would occur from flying through different time zones. It is standard that all flight equipment be placed in UTC to show out-of-service and return-to-service times (Brito, 2015). Amateur radio operators often schedule their radio contacts in UTC because transmissions on some frequencies can be picked up in many time zones (Horzepa, 2010). Weather forecasting

has always involved measurements with respect to a standard time. Weather is worldwide, so it is advantageous to have coordinated times in order to manage balloon launches and the like (National Hurricane Center and Central Pacific Hurricane Center, n.d.). The National Institute of Standards and Technology (NIST) operates 45 Internet time servers that are synchronized to UTC and are located at sites in the United States, including the computing facilities used by the major stock and commodity exchanges in New York and Chicago (Levine, 2013). The U.S. Geological Survey and other seismic network agencies conduct earthquake reporting according to UTC+0 instead of local time, as using a standard time reference is best for record-keeping and the exchange of data across different time zones (U.S. Geological Survey, n.d.).

Conclusion

This paper, exploring a monumental issue at the intersection of economics and public health, hopes to bring into discourse the problematic aspects of socially constructed time systems, including time zones and daylight savings time. Close analysis of the outcomes of Giuntella and Mazzonna's study on time zone borders reveals exactly how the desynchronization of circadian rhythms and the social clock are associated with adverse health effects and incur economic costs. Surveying the conclusions of the scientific community's studies on DST further bolster the argument against time systems that trigger social jetlag. A single world clock is not only practical but also remedies the social jetlag issue by encouraging local areas to adhere more closely to the nature-endowed solar clock. While universal time seems to be a radical proposition, it has actually been vehemently promoted by Professors Steve H. Hanke and Richard Conn Henry at Johns Hopkins University (Hanke & Henry, 2018, 2011; Hanke, 2019; Henry 2007) as well as Professor Stanley Brunn at the College of Arts and Sciences. To quote Brunn,

> "Time is elastic, it is fluid, it is dynamic; distance means next to nothing in cybertime and cyberspace. What is important is being connected for whatever purposes. If something stands in the way of being efficient or responsive, those barriers seek to be removed. And time zones are one of those barriers." (Clarke, 2019)

Moreover, various industries and official entities have been using universal time upon realizing the complications that come with time zones.

It is concerning that, given the considerable health effects and economic costs of social jetlag, policymakers have not been rushing to develop solutions for this problem. Luckily, a UTC+0 standard may just be the holy grail of society and the economy – both in the United States and the world at large. It is true that the introduction of universal time could cause disruption in the short run. Markets, in particular, are sensitive. But in the long run, as firms and people learn to adjust, the economic and health improvements are substantial. After all, helpful economic policies often come with an initial lag.

References

Barnes, C. M., and Wagner, D. T. (2009). Changing to daylight saving time cuts into sleep and increases workplace injuries. *J. Appl. Psychol.* 94:1305. doi: 10. 1037/a0015320

Borisenkov, M. F., Tserne, T. A., Panev, A. S., Kuznetsova, E. S., Petrova, N. B., Timonin, V. D., et al. (2017). Seven-year survey of sleep timing in Russian children and adolescents: chronic 1-h forward transition of social clock is associated with increased social jetlag and winter pattern of mood seasonality. Biol. Rhythm Res. 48, 3–12. doi: 10.1080/09291016.2016.1223778

Brito, G. B. (2015, July 13). Why does aviation use Zulu time instead of the local time? Retrieved July 9, 2019, from https://aviation.stackexchange.com/questions/16818/why-does-aviation-use-zulu-time-instead-of-the-local-time

Buckle, A. (n.d.). The Never Ending DST Debate. Retrieved May 15, 2020, from https://www.timeanddate.com/time/dst/daylight-saving-debate.html

Buckle, A. (2009, July 30). Why Do We Have Time Zones? Retrieved May 15, 2020, from https://www.timeanddate.com/time/time-zones-history.html

Clarke, L. (2019, October 31). What would happen if we abolished time zones altogether? Retrieved May 15, 2020, from https://www.wired.co.uk/article/universal-time-zones

Giuntella, O., & Mazzonna, F. (2019, April). "Sunset Time and the Economic Effects of Social Jetlag: Evidence from US Time Zone Borders." *Journal of Health Economics*, 65(13), 210–226. doi:10.1016/j.jhealeco.2019.03.007.

Cappuccio, F. P., D'Elia, L., Strazzullo, P., & Miller M. A. (2010, May). Sleep Duration and All-Cause Mortality: A Systematic Review and Meta-Analysis of Prospective Studies, *Sleep,* 33(5), 585–592. https://doi.org/10.1093/sleep/33.5.585

Day and Night World Map. (n.d.). Retrieved May 15, 2020, from https://www.timeanddate.com/worldclock/sunearth.html

Díaz-Morales, J. F., and Escribano, C. (2015). Social jetlag, academic achievement and cognitive performance: understanding gender/sex differences. Chronobiol. Int. 32, 822–831. doi: 10.3109/07420528.2015.1041599

Ferrazzi, E., Romualdi, C., Ocello, M., Frighetto, G., Turco, M., Vigolo, S., et al. (2018). Changes in accident & emergency visits and return visits in relation to the enforcement of daylight saving time and photoperiod. *J. Biol. Rhythms* 33, 555–564. doi:10.1177/0748730418791097

Fleming, Sandford (1886). "Time-reckoning for the twentieth century". *Annual Report of the Board of Regents of the Smithsonian Institution* (1): 345–366. Reprinted in 1889: Time-reckoning for the twentieth century at the Internet Archive.

Foster, R. G., Peirson, S. N., Wulff, K., Winnebeck, E., Vetter, C., and Roenneberg, T. (2013). Sleep and circadian rhythm disruption in social jetlag and mental illness. Prog. Mol. Biol. Transl. Sci. 119, 325–346. doi: 10.1016/B978-0-12-396971-2.00011-7

Hadlow, N. C., Brown, S., Wardrop, R., and Henley, D. (2014). The effects of season, daylight saving and time of sunrise on serum cortisol in a large population. Chronobiol. Int. 31, 243–251. doi: 10.3109/07420528.2013.84 4162

Hanke, S. H., & Henry, R. C. (n.d.). Hanke Henry On Time. Retrieved June 04, 2020, from http://hankehenryontime.com/index.html

Hanke, S. H., & Henry, R. C. (2018, December). Is it time to change the clocks? *Monocle*, *Edition 3*(13/12 - 19/12).

Hanke, S. H., & Henry, R. C. (2011, December 19). Changing Times. Retrieved June 05, 2020, from https://www.cato.org/publications/commentary/changing-times

Hanke, S. H. (2019, May 19). Could Donald J. Trump Become America's Caesar? Retrieved June 05, 2020, from https://www.forbes.com/sites/stevehanke/2019/05/19/could-donald-j-trump-become-americas-caesar/

Haraszti, R. Á, Ella, K., Gyöngyösi, N., Roenneberg, T., and Káldi, K. (2014). Social jetlag negatively correlates with academic performance in undergraduates. Chronobiol. Int. 31, 603–612. doi: 10.3109/07420528.2013.879164

Henry, R. C. (2007, March 10). Synchronize Your Watches. *The Washington Post*.

Horzepa, S. (2010, September 17). The National Association for Amateur Radio. Retrieved from http://www.arrl.org/news/surfin-time-for-ham-radio

Janszky, I., and Ljung, R. (2008). Shifts to and from daylight saving time and incidence of myocardial infarction. *N. Engl. J. Med.* 359, 1966–1968. doi: 10.1056/nejmc0807104

Kamstra, M. J., Kramer, L. A., and Levi, M. D. (2000). Losing sleep at the market: the daylight saving anomaly. *Am. Econ. Rev.* 90, 1005–1011. doi: 10.1257/aer.90.4.1005

Levandovski, R., Dantas, G., Fernandes, L. C., Caumo, W., Torres, I., Roenneberg, T., et al. (2011). Depression scores associate with chronotype and social jetlag in a rural population. Chronobiol. Int. 28, 771–778. doi: 10.3109/07420528.2011.60244

Levine, J. (2013, September). Impact of leap seconds on digital time services Internet time servers. Retrieved from https://itunews.itu.int/En/4276-Impact-of-leap-seconds-on-digital-time-services-BRInternet-time-servers.note.aspx

Lewandowski, W. (2013, September). Global navigation satellite systems and their system times.

Retrieved from https://itunews.itu.int/En/4272-Global-navigation-satellite-systems-and-their-system-times.note.aspx

Liu, C., Politch, J. A., Cullerton, E., Go, K., Pang, S., and Kuohung, W. (2017). Impact of daylight savings time on spontaneous pregnancy loss in in vitro fertilization patients. *Chronobiol. Int.* 34, 571–577. doi: 10.1080/07420528.2017.1279173

Manfredini, R., Fabbian, F., De Giorgi, A., Zucchi, B., Cappadona, R., Signani, F., et al. (2018). Daylight saving time and myocardial infarction: should we be worried? a review of the evidence. *Eur. Rev. Med. Pharmacol. Sci.* 22, 750–755. doi: 10.26355/eurrev_201802_14306

MilitaryBenefits. (n.d.). Military Time Conversion & Time Zones Charts: Military Benefits. Retrieved July 24, 2019, from https://militarybenefits.info/military-time/

Monk, T. H., and Aplin, L. C. (1980). Spring and autumn daylight saving time changes: studies of adjustment in sleep timings, mood, and efficiency. *Ergonomics* 23, 167–178. doi: 10.1080/00140138008924730

Monk, T. H., and Folkard, S. (1976). Adjusting to the changes to and from daylight saving time. *Nature* 261:688. doi: 10.1038/261688a0

National Hurricane Center and Central Pacific Hurricane Center. (n.d.). What is UTC or GMT Time? Retrieved July 24, 2019, from https://www.nhc.noaa.gov/aboututc.shtml

Pavlus, J. (2010). Daylight Savings Time. Scientific American, 303(3), 69.

Pusey, A. (2019). Nov. 18, 1883: US railroads enact standard time zones. *ABA Journal*, *105*(8), N.PAG.

Roenneberg, T., Winnebeck, E. C., & Klerman, E. B. (2019). Daylight saving time and artificial

time zones - A battle between biological and social times. *Frontiers in Physiology, 10*, 944. doi:10.3389/fphys.2019.00944

Schneider, A.-M., and Randler, C. (2009). Daytime sleepiness during transition into daylight saving time in adolescents: are owls higher at risk? *Sleep Med.* 10, 1047–1050. doi: 10.1016/j.sleep.2008.08.009

Sipilä, J. O. T., Ruuskanen, J. O., Rautava, P., and Kytö, V. (2016). Changes in ischemic stroke occurrence following daylight saving time transitions. *Sleep Med.* 2, 20–24. doi: 10.1016/j.sleep.2016.10.009

Space_Station. (2019, February 20). The astronauts set their clocks to Greenwich Mean Time, or GMT. [Tweet]. Retrieved from https://twitter.com/Space_Station/status/1098315678493433856

The Costs of Insufficient Sleep. (n.d.). Retrieved October 12, 2019, from https://www.rand.org/randeurope/research/projects/the-value-of-the-sleep-economy.html.

U.S. Geological Survey. (n.d.). What is UTC, and why don't you report earthquakes in the local time where the earthquake occurred? Retrieved July 24, 2019, from https://www.usgs.gov/faqs/what-utc-and-why-don-t-you-report-earthquakes-local-time-where-earthquake-occurred?qt-news_science_products=0#qt-news_science_products

Willis, T.J. (2015, June 29). *T.J. Willis' Answer to What time zone is followed by ships (naval, cargo and commercial) sailing across international waters and crossing multiple time zones?* Retrieved from https://www.quora.com/What-time-zone-is-followed-by-ships-naval-cargo-and-commercial-sailing-across-international-waters-and-crossing-multiple-time-zones

Wittmann, M., Paulus, M., and Roenneberg, T. (2010). Decreased psychological well-being in

late ‘chronotypes’ is mediated by smoking and alcohol consumption. Subst. Use Misuse 45, 15–30. doi: 10.3109/10826080903498952