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ABSTRACT

Market productivity is often greater, and leisure and other household activities more enjoyable, when people perform them simultaneously. Beyond pointing out the positive externalities of synchronicity, economists have not attempted to identify exogenous determinants of timing. We develop a theory illustrating conditions under which synchronicity will vary and identify three factors — the amount of daylight, the timing of television programming, and differences in time zones — that can alter timing. Using the American Time Use Survey for 2003 and 2004, we first show that an exogenous shock to time in one area due to non-adherence to daylight-saving time leads its residents to alter their work schedules to continue coordinating their activities with those of people elsewhere. With time use data from Australia, we also demonstrate the same response to a similar shock there. We then show that both television timing and the benefits of coordinating across time zones in the U.S. generally affect the timing of market work and sleep, the two most time-consuming activities people undertake. While these impacts do not differ greatly by people's demographic characteristics, workers in industries where we would expect more coordination outside of their local areas are more responsive to the effects of time zones.

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1 Introduction

Coordination is central to economic behavior. The production of goods and services typically requires the services of complementary inputs, including the services of workers of different types. Firms often cooperate with others in order to maximize their joint profits. Generating satisfaction in the household requires purchasing goods and using one's own time and rented services of others to create a commodity that yields utility (Becker, 1965). Coordination also underlies policies as policymakers must take into account the interdependence of their choices. The study of these various types of coordination of the amounts of consumer goods and producer inputs has formed the basis for much of microeconomic theory, and testing them and inferring the values of the parameters describing parts of the theories has occupied a substantial proportion of empirical economists' time for at least half a century.

That every activity implicitly must have a time subscript has entered theoretical analyses only rarely (but see the excellent exception in Winston, 1982). Using capital services alone from midnight to noon and labor services alone from noon to midnight will lead to much less (zero?) output than if both are utilized in the same twelve hours of the day; and production will probably be higher if workers of different types are on the job at the same time than if each one works at different times. Firms that cooperate do so in a time dimension, and the extent of the temporal coordination has macroeconomic impacts (Cooper, 1999). For most people the services of an automobile are more valuable if they are combined with the simultaneous inputs of drivers' and passengers' time when the auto is on hand, and the utility gained by the people involved is usually higher if enjoyed simultaneously.

When activities take place matters, as does the extent of temporal coordination in generating them. Despite the importance of when cooperating agents engage in various activities, there has been remarkably little empirical study of the temporal nature of activities and even less of temporal patterns of coordination. Cooper and Haltiwanger (1993) demonstrated how government policies can induce firms to undertake decisions about product design at the same time. Hamermesh (2002) and Hallberg (2003) showed that spouses prefer to work (and engage in household production) at the same times of the day, and that such coordination is a superior activity. Jenkins and Osberg (2005) demonstrated how an increase in the fraction of people in a region who engage in a particular leisure activity has positive ceteris paribus impacts on individuals' choices of leisure activities.

Very little other empirical study of the timing of coordination appears to have been done. Perhaps part of the reason is that while it is clear that people's synchronization of their work activities is important (Weiss, 1996), as is their coordination in timing their non-market activities, it is very difficult to identify factors that might cause the extent of synchronization to differ among different groups of workers and consumers. In this study we do exactly that: we identify several determinants of temporal coordination that are clearly external to the agents making the decisions to coordinate. We thus show that the degree of synchronization does not just happen, but that it results from the gains to coordination of activities. Temporal coordination can also can be affected by cues, both natural and artificial. The artificial cue we examine here is the timing of television programs, while the natural cue is circadian rhythm as modified by daylight (Wever, 1982). We also examine the importance of coordination that is induced by the gains to simultaneous production across geographic areas where the nominal time of day differs. We refer to these as light, television, and time zone cues, respectively.

In the next section we develop a simple model that allows us to illustrate some trade-offs involved in temporal coordination and to identify instances where we might expect cues for coordination to be more or less powerful. In Section 3 we describe the nature of the institutions that generate these cues, while in Section 4 we present the data used to analyze their importance. Section 5 offers the central results of the paper, both the results of a natural experiment that demonstrates the empirical importance of time zone cues and the estimates of models that show the independent importance of all three cues. Section 6 explores how the impacts of these cues vary across demographic and economic groups, while Section 7 replicates the natural experiment in Section 5 with an Australian data set.

2 Theoretical Model

Scheduling choices likely depend on individual preferences for the timing of activities as well as for synchronization with parties who are both internal and external to an individual's geographic area. Our model takes into account the coordination trade-offs associated with the timing of activities and then predicts which individuals will be most responsive to the coordination cues that influence the choices of others.

Consider a two-player simultaneous-response model in which there are two periods in each day and Worker i must engage in market production during one period and household production during the other. The labor-market productivity of Worker i is determined in part by coordination effects arising from the timing of his activities with both local and distant market activity. Assume that extra-regional workers choose to work during Period 1 and that Worker i's productivity increases by a factor of $\alpha_i \geq 0$ if he chooses to engage in market work during that period.[1] In addition, Worker i's productivity is increased by a factor of $\beta_i \geq 0$ if he coordinates intra-regionally by working during the same period as the other player. Finally, we allow for a desire to coordinate household production with a non-working spouse during Period 1 by letting labor productivity change by a factor of θ_i during Period 2 as a result of worker preferences for the timing of activities. Figure 1 shows a normal form representation of the payoffs for this game.

Worker i will choose to work during Period 1 if his earnings are higher during that time.

[1] Note that the sequential choice of scheduling in which external workers have selected to engage in market activity during Period 1 is a modeling convenience. Similar predictions are obtained by modeling workers in the regions as making simultaneous scheduling choices but having differences in inter-regional cues such as light.

Let be y_i^* be the difference between Period 1 and Period 2 earnings of Worker i so that

$$y_i^* = \alpha_i + \beta_i(2y_{-i} - 1) - \theta_i + \epsilon_i \tag{1}$$

$$y_i = \begin{cases} 1 & if \quad y_i^* \geq 0 \\ 0 & if \quad otherwise \end{cases} \tag{2}$$

where

$\alpha_i =$ Worker i's increased productivity due to inter-regional coordination

$\beta_i =$ Worker i's increased productivity due to intra-regional coordination

$\theta_i =$ Worker i's increased (decreased) productivity due to a preference for working during Period 2 (1)

$\epsilon_i =$ Shocks to Worker i's relative productivity that are not observed by the economist.

Depending on the preferences of the two workers, this game could result in one of five equilibria as represented in Figure 2. The middle square of this figure shows the non-unique solution (0,0) and (1,1) in which the players will coordinate with each other in either Period 1 or Period 2. The probability that this occurs is

$$H(\alpha, \beta, \theta) = \tag{3}$$
$$Pr(-\alpha_1 - \beta_1 + \theta_1 \leq \epsilon_1 \leq -\alpha_1 + \beta_1 + \theta_1; -\alpha_2 - \beta_2 + \theta_2 \leq \epsilon_2 \leq -\alpha_2 + \beta_2 + \theta_2).$$

Furthermore, let

$$\begin{aligned} H_1(\alpha, \beta, \theta) &= Pr(\epsilon_1 \leq -\alpha_1 - \beta_1 + \theta_1, \epsilon_2 \geq -\alpha_2 + \beta_2 + \theta_2) \\ H_2(\alpha, \beta, \theta) &= Pr(\epsilon_1 \geq -\alpha_1 + \beta_1 + \theta_1, \epsilon_2 \leq -\alpha_2 + -\beta_2 + \theta_2) \\ H_3(\alpha, \beta, \theta) &= Pr(\epsilon_1 \geq -\alpha_1 - \beta_1 + \theta_1, \epsilon_2 \geq -\alpha_2 - \beta_2 + \theta_2) \\ H_4(\alpha, \beta, \theta) &= Pr(\epsilon_1 \leq -\alpha_1 + \beta_1 + \theta_1, \epsilon_2 \leq -\alpha_2 + \beta_2 + \theta_2) \end{aligned} \tag{4}$$

so that

$$
\begin{aligned}
Pr(0,1) &= H_1 \\
Pr(1,0) &= H_2 \\
H_3 - H < Pr(1,1) &< H_3 \qquad (5) \\
H_4 - H < Pr(0,0) &< H_4.
\end{aligned}
$$

$$(6)$$

We use Figure 2 and these boundary conditions to examine the impact of changing parameters on the probabilities of observing different equilibria. Consider first α_i, the return to inter-regional coordination. As α_1 increases, Worker 1 is more likely to work during Period 1 either with or without Worker 2. If the two were previously coordinating during Period 2, Worker 1 is more likely to move to Period 1 alone in order to coordinate inter-regionally, or the two workers might both move to working in Period 1. As β_i, the return to intra-regional coordination, increases, the probability that the two workers coordinate in either period increases. For example, if the two workers were previously not coordinating and β_1 increases, Worker 1 is more likely to work in the same period as Worker 2. Finally, as θ_i, the preference for Period 2 increases, Worker i is more likely to work during Period 2.

As documented in the empirical literature on discrete games of market entry (see, e.g., Bresnahan and Reiss (1991) and Ciliberto and Tamer (2006)), the existence of a non-unique solution as represented by the middle square of Figure 2 presents challenges in defining a likelihood function and empirically identifying the parameters of interest. In our case, however, we use this type of model only to motivate consideration of incentives for both local and external coordination. We do not attempt to identify the parameters but only to infer their relative size by the nature of observed coordination.

In order to do this, we introduce the consideration of "cues" for coordination. We view cues as the exogenous signals that influence timing decisions. For instance, time zones may serve as external cues to those who are coordinating with other regions. Those in the Central time zone may go to work at 8 a.m. because easterners have just arrived at 9 a.m. in their region. This model implies that individuals who benefit more from synchronization of activities with workers in other regions (high α_i) are more likely to coordinate inter-regionally. It also indicates that even individuals who derive very small direct benefits from such coordination may also end up synchronizing with the other region because of the need to coordinate with other local residents. Hence, a waiter may have a small α_i because his productivity is not directly dependent on workers in other regions, but a large β_i because his productivity is influenced by other local residents, such as call center workers. He may therefore end up rising early because others in his area are doing so. The observer, however, can only identify that he is responding to a cue for inter-regional coordination, not the underlying parameter that is driving this response. One interesting way in which insight might be gleaned, however, is by examining the impact of the cue of television scheduling. Because we can identify viewers and non-viewers, any impact that television cues have on non-viewers can be assumed to enter through the need for intra-regional coordination.

If we consider θ_i as accounting for personal preference for working in Period 2, then factors that tend to diminish this preference will increase the level to which our worker is driven by coordination concerns. For instance, to the extent that household production by an unmarried individual depends less on timing by others in his household, he may be more likely to engage in inter-regional coordination.

We do not explicitly inquire into the welfare effects of changes in coordination that arise endogenously through changes in the parameters underlying this model. To the extent that governments can manipulate coordination by altering cues, however, one must conclude that this can alter welfare. That a number of governments have homogenized timing incentives within their boundaries suggests at least that people believe greater coordination enhances welfare.[2]

3 Background on Time Zones and Television

The discussion above suggests that we might observe coordination arising from local external cues, such as television programming and sunlight, and from inter-regional external cues, such as time zones. In this section we discuss the exogenous determination of these cues.

From early childhood every American knows that the United States is divided into time zones. What is less known to most Americans is that until the growth of railroad traffic after the Civil War scheduling was not uniform, and different areas, even those in close proximity, operated on different times (O'Malley, 1990). With the Standard Time Act of 1918 the current four contiguous U.S. time zones (Eastern, Central, Mountain and Pacific), were established and have been in effect since then, with only minor changes at the edges of the zones.[3] The current division of the country is shown by the state-county map reproduced in Figure 3. The nominal times in the other three time zones differ from that in the Eastern zone at the same real time by one, two and three hours respectively.

Daylight Savings Time (DST) was introduced in the U.S. and many other parts of the world as an effort to save energy during times of war. The U.S. adopted a formal DST plan in 1918, but it was repealed after the end of World War I because of its inconvenience and unpopularity. The current U.S. DST plan was signed into law by President Johnson in 1966 as the Uniform Time Act. Each state or possession, however, is able to supersede the law by passing its own act. Since then, amendments have been enacted to modify DST for states in multiple time zones and/or to change the beginning and ending dates of DST. Indeed,

[2]The decision early in the existence of the People's Republic of China to have one time zone covering a country whose expanse previously had five time zones was clearly political and designed to enhance control and perhaps economic well-being. In 1992 Argentina switched from two time zones (with each going on daylight saving time) to one zone with only standard time, apparently as a coordination mechanism.

[3]For example, in 2005 there was a proposal to place five counties in northern Maine in the Atlantic time zone (with eastern Canada).

effective 2007 the period of DST will be lengthened by four weeks.[4]

Twelve of the 48 contiguous states are in more than one time zone, as is Alaska (most of which is one hour behind the Pacific zone). All of Hawaii is two hours behind Pacific time. Most of the United States goes on DST in early spring and goes off it (onto standard time–hereafter ST) in mid-autumn. Certain areas, particularly the entire states of Arizona and Hawaii, and many parts of Indiana (including the Indianapolis metropolitan area) remained on standard time all year at the time our data were collected, although Indiana began observing DST in 2006.

Most young children in the United States also learn the mantra announcing prime-time television shows, "10 p.m. Eastern and Pacific, 9 p.m. Central and Mountain." Television shows from late afternoon onwards appear one nominal hour earlier in the middle two time zones than in the other two zones. This difference is a relic of the technology of radio transmission (Winston, 1998). During the late 1920s, when the radio networks were being developed, the technology was such that the signals could not be sent across the whole country. Thus one broadcast was produced and performed live to serve both the Eastern and Central time zones, appearing at the same real time in both zones, but an hour earlier in nominal time in the Central zone. For the other two zones (which encompassed at that time only tiny fractions of the population) the shows were performed live a second time until re-broadcasts of recorded shows began in the 1940s. The essential point is that the television time-zone mantra precedes television and was dictated by people's preferences for live performances at desirable times that are no longer relevant but that still influence the timing of presentations in radio's main successor medium.

[4]Kamstra et al. (2000) discussed the negative financial consequences of desynchronization caused by changing to and from DST. They claimed the existence of losses of tens of billions of dollars in several stock markets due to switching on and off DST.

4 Time-Use Data and the Distribution of the Population by Time Zone

Most of the analyses that we present are based on the American Time Use Survey, an ongoing Bureau of Labor Statistics effort that began in 2003 and that currently collects roughly $13,000$ time diaries per year, $1,100$ each month, from recent participants in the Current Population Survey (see Hamermesh et al., 2005, for a description). Each of the selected respondents (one per CPS household) is asked to complete a diary for the most recent day (4 a.m.–3:59 a.m.) in which the respondent lists when each activity undertaken began and what it was. The activities are coded into 406 separate categories. We use data from the twenty-four months of diaries collected in 2003 and 2004, which yield 20,790 and 13,973 observations respectively. Because the observations are chosen from recent respondents to the Current Population Survey, all the usual CPS demographic information is available on the respondents and their spouses and children (if any). In addition to information from the ATUS and CPS, sunrise and sunset data were collected from the United States National Observatory website and matched to the day and location of each observation.[5]

We focus here on three activities: market work, sleeping and watching television. These activities comprise a large fraction of the typical respondent's day: on a representative day they totaled 226, 509 and 158 minutes respectively, thus accounting for 62 percent of the available time on the days surveyed. They are undertaken by 39.7, 99.9 and 78.5 percent of the sample respectively on the representative day. In addition, these three activities are by far the most important single activities undertaken, with even television-watching accounting for over twice as much time as the next most time-consuming activity.

While our use of residents in a particular time zone as first-movers in our model was an expositional convenience, in reality the Eastern zone is and has been dominant. As Table

[5]That daylight affects the kinds of activities undertaken is starkly demonstrated by patterns of crime (Voth, 2000) and people's scheduling activities in response to fears of crime (Hamermesh, 1999).

1 shows, nearly half the country's population is currently in the Eastern zone (and not in Indiana). That is true today, and its importance was even greater in 1920, the Census year nearest the date when time zones became more or less fixed by statute. The major change in the past 85 years is that the relative importance of the Eastern and especially the Central time zone has diminished, with the increase taken up by the Pacific zone. Nonetheless, the Eastern zone remains dominant.

Choosing a sample for the analysis is rendered difficult by the inability to classify exactly in which time zone each respondent in the ATUS resides. In the samples used in most of the analyses for the U.S. we include only those individuals in the contiguous states whose time zone can be identified with certainty from the state or metropolitan area where they are located, and for whom DST applies during part of the year. The distribution of the sample is shown in Table 1. Six percent of the respondents cannot be classified, and 0.1 percent are in Alaska. Ninety-one percent can be classified into zones that switch from DST to ST, while 2.7 percent are in identifiable zones that remain on ST all year.

5 Do Cues Matter?

As a set of initial examinations we consider whether the ATUS data show evidence that the cues of time zone, television and daylight matter.[6] Finding differences in the timing of activities across time zones would not demonstrate the importance of coordination and its determinants through external cues. Rather, inferring their existence is possible only if we see behavior that is consistent with the generation of differential cues across time zones arising from the timing of television broadcasts, variation in daylight, and the relation of real to nominal times across the zones.

[6]We ignore differences in timing that may arise from variations in the weather. These may affect day-to-day variations in individual labor supply (see Connolly (2005)), but are hardly likely to alter long-term differences across regions. Average climates across time zones in the contiguous United States do not differ greatly, in any event, as the time zones run within roughly the same ranges of latitude.

5.1 A Natural Experiment

As we noted above, Arizona, Hawaii and much of Indiana do not go on DST. Thus while the rest of the nation is on DST, these areas are respectively 3, 6 and 1 hours behind Eastern time; while the rest of the nation is on ST, they are respectively only 2, 5 and 0 hours behind Eastern time. Moreover, in each of the non-daylight saving locations, as in the rest of the nation, the nominal time at which television broadcasts appear does not change during the year in response to nominal time changes. Thus for example, Arizona is essentially on Mountain time during the winter, but is on Pacific time during the summer when it does not "spring forward" with the rest of the Mountain time zone. However, its television schedules remain at the nominal Mountain times. This allows us to construct a double-difference estimator of the effect an hour shift in time zone, holding nominal television times constant:

$$\Delta^2 = (p_{DST} - p_{ST})_{exper} - (p_{DST} - p_{ST})_{control} \tag{7}$$

where p is the proportion of individuals performing a particular activity during a 15-minute interval, and *exper* indicates "experimental" locations that do not observe DST while *control* locations do. Δ^2 is a measure of the impact of the exogenous shock to cues in Arizona, Hawaii, and Indianapolis that occurs when most of the U.S. resets their clocks for daylight saving time. This shock, moreover, does not involve a change in the television cue.

Table 2 presents the estimated single- and double-differences describing sleep, work and television time for the quarter-hour 7:30-7:45 a.m. and for sleep and television time at 10:30-10:45 p.m. The differences look quite similar at the quarter-hours adjacent to these two. People in these three unusual localities are roughly 50 percent more likely to be working early in the morning when the rest of the country is on DST than when the entire nation is on ST. Moreover, in the rest of the country there is no seasonal difference in the propensity to work at this early hour. Together these single-differences generate a double-difference that is large and highly significant statistically.

The ability of workers in these areas to shift their schedules is generated mainly by their choosing to alter their sleep patterns. The fraction of respondents who are still asleep at 7:30 a.m. in these areas is much lower when the rest of the country is on DST than when it is on ST. The fraction asleep at 10:30 p.m. is only slightly higher on those days, but in the rest of the country fewer people are asleep when DST is in effect than during ST. Thus the double-differences on the timing of sleep are statistically significant, and they too indicate the role of the benefits of coordinating work activities with the rest of the country.

While the rest of the country is slightly (but significantly) more likely to watch television in the late evening during DST, the experimental areas are less likely to watch than when DST prevails elsewhere. Since the nominal timing of television programs does not change over the year, this shifting of viewing habits is also consistent with the changed cue resulting from the benefits of inter-regional coordination of work timing.

The time-zone cue clearly changes differentially between the area that remains on ST all year and the rest of the country. Given the more southerly location of the areas that are always on ST, whether the effects of the daylight cue change differentially over the year depends on the timing of these activities in response to changes in the amount of daylight. It is unclear a priori in what direction these effects might go. To examine whether our results are being generated by the benefits of coordinating work inter-regionally or from local cues from daylight, we restricted the sample to the 106 days in the two years during ST when the amount of daylight was the same as that on the 106 days when most of the nation was on DST. We then recalculated Δ^2 for this reduced sample.

When we quarter the samples so that *both* television cues and light cues are held constant, the point estimates hardly change. The adjustments in schedules in the areas that do not switch to DST result from the benefits of coordinating work schedules with the rest of the country, not from differences in available daylight between ST and DST (and clearly not from television schedules, since the latter do not change over the year).

5.2 Separating the Cues

While our double-difference estimates of the effect of remaining on standard time suggest that coordination with other regions is a significant determinant of schedules, they do not address the impact of local cues on coordination. In order to take the three cues (time zone, television zone, and sunlight) into account simultaneously, we use probit models for each of the 96 fifteen-minute periods into which we use the ATUS to divide the day. The cue variables are: *time-zone cue*, which is 0 for the Eastern time zone, 1 for Central, 2 for Mountain, and 3 for Pacific; *tv cue*, which is 0 for the two coasts and 1 for the middle of the country (where television schedules are an hour earlier nominally); and, *sunrise* and *sunset*, which measure the hour of the observation day when the National Observatory calculates that each occurred.[7] We also include various demographic variables as well as one-digit occupation and industry indicators in the work probits. Finally, we control for the total number of minutes in the day devoted to a given activity, allowing us to isolate the impact of these cues on scheduling, holding total consumption of the particular activity constant.[8]

Table 3 reports estimates of the average marginal effect from representative probits for television viewing, sleeping, and working, Monday through Friday at two early-morning and one late-evening time. (The results are qualitatively the same for quarter hours near those included in Table 3.) Note that the sample in the work probits is restricted to those who worked at some point during the observation day. Not surprisingly, the more time in the day a person devotes to television, sleep, or work, the more likely he is to be performing each activity at any given time. However, holding total consumption constant, we find that the probability that an individual is watching television between 11 and 11:15 p.m. decreases

[7] The variables *time-zone cue* and *tv cue* describe the four time zones. If we replace these two by indicator variables for three time zones, likelihood ratio tests do not imply an improvement in our ability to describe variations in the probabilities.

[8] The central results change only slightly if these totals are not held constant.

with age, while the probability that he is awake between 7 and 7:15 a.m. and at work between 8 and 8:15 a.m. increases until retirement age. In addition, as education levels increase, individuals are more likely to be watching television at a late hour, more likely to sleep in, and less likely to be at work early.

Marital status and children do not appear to have any impact on the scheduling of television viewing at 11 p.m., but married individuals are less likely to be sleeping at 7 a.m. and more likely to be at work at 8 a.m., an effect that is magnified considerably for married males. Finally, to save space, indicator variables for industry and occupation are not reported for the work probits, but their estimated coefficients suggest the expected results. Individuals whose occupation is maintenance, management, business, or financial-related tend to be at work early, while those who are in sales and services are less likely to be at work at 8 a.m.. By industry, those employed in agriculture, mining, construction, and public administration are more likely to be at work at 8 a.m. than workers in other sectors.

Turning to the cues, individuals who are in the early television zones are about 5 percentage points less likely to be watching television between 11 and 11:15 p.m. than those who are in later television zones (for whom the late news is just beginning). Given that about 17 percent of people in the East are watching television at this time, this corresponds to nearly a one-third drop in the proportion viewing television in the middle of the country, bolstering our assertion that television schedules serve as a cue for intra-regional coordination, as people in earlier television zones tend to watch television earlier. Moreover, for a one-hour shift west in time zone, individuals are about 1 percentage point less likely to be watching television at this time. Finally, as the sunset gets later, people are more likely to be up watching television at 11 p.m., but the magnitude of the effect is quite small. If sunset is pushed back by an hour, the probability of watching television at 11 p.m. only increases by about half a percentage point.

While the effects of sunrise and sunset cues are minimal for all three activities, those of work and television cues are large. Individuals in the early television zones are 3.9 percentage points less likely to be asleep at 7 a.m. and 3.5 percentage points more likely to be at work at 8 a.m. In addition, for a one-hour increase (shift west) in the time zone cue, the probability of being asleep then drops by 1.6 percentage points, although there is no significant effect on the timing of work.

Within each time zone, both the television cue for intra-regional coordination and the time zone cue for inter-regional coordination help to determine scheduling. As a linear approximation, compared to the Eastern time zone, an individual in the Central zone is, on average, 5.4 percentage points more likely to be awake at 7 a.m. and an individual in the Mountain zone is 7.0 percentage points more likely to be awake. While the television cue for those in the Pacific time zone is identical to that in the East, the effect of being three hours earlier leaves residents there 4.7 percentage points more likely to be awake at this time than those in the East. These effects are quite large relative to the roughly 34 percent of easterners who asleep between 7 and 7:15 a.m. Central time zone inhabitants differ from the East primarily because of their earlier television schedule, while residents in the Pacific time zone differ in their schedules due to the combined effects being three time zones away from the East.

Turning to all 96 periods in the day, the estimated average marginal effects and 95–percent confidence bands for the cues are presented in Figures 4 and 5. Figure 4 summarizes how both natural and artificial cues affect sleep schedules. Sunlight and circadian rhythms have the anticipated effects on sleep scheduling. If sunrise occurs one hour later, sleep probabilities are higher in the morning and lower in the evening as people shift their schedules later. Similarly, if sunset occurs one hour later, people again rise later and go to sleep later. It is artificial rather than natural cues, though, that have the larger effects. Being in the early television zones of the United States makes one significantly more likely to be awake in the morning and less likely to be awake in the evenings. The relative probability of being asleep in the evening for the early TV zones begins to spike at 10 p.m. with the end of prime time there, but it peaks at 11 p.m. as prime time ends on the coasts. At this time, people in the center of the country are 10 percentage points more likely to be asleep than people on the coasts, demonstrating the importance of television cues to sleep schedules. Turning to the time-zone cue, we see that for a shift one time zone west (to an earlier nominal schedule), individuals are less likely to be sleeping in the morning and more likely to be sleeping in the evening, holding television schedules constant. While the effects of this cue for coordination with other regions are significant, they tend to be about half the magnitude of the television cue for intra-regional coordination.

Figure 5 shows the marginal effects of the same cues on the timing of work. Although the trends for sunlight cues are again as anticipated— later sunrises or sunsets result in later starting times and ending times of work— the individual effects are insignificant. Similarly, a hour shift west to an earlier time zone leads to being at work earlier and leaving earlier; but, again, most of the individual effects are insignificant. Estimates of the effect of the television cue on work, however, show an interesting pattern. Individuals in the middle of the country are as much as 3.5 percentage points more likely to be working at 8 a.m. and as much as 3 percentage points less likely to be working at 5:30 p.m. However, there is a dramatic downward spike in the middle of the workday. People in early television zones are far less likely to be working at mid-day than people on the coasts. One possible explanation is that people in the center of the country may work closer to home or to other locations where they take a non-working lunch break, while people on the coasts may be more likely to live in large cities where commuting home for lunch is difficult. However, linking these data to 2000 Census data on commuting times by MSA suggested that this explanation could not be accounting for much of the difference. Another explanation is that because they arrive at work earlier, these groups also eat lunch earlier in the day. If we examine the timing of other activities, we find that indeed the probability of eating at this time is significantly higher in the central regions than on the coasts.

6 Are Some Groups More Responsive to Cues?

Thus far we have observed average sleep and work coordination both within and between regions of the country for the population as a whole. As our theoretical discussion implied, however, the returns to coordination may vary across demographic groups. Motivated by this prediction, we ask four questions about demographic differences in cue sensitivity: Do single people respond differently to coordination cues than people who share a household with somebody? Are the effects of time zone cues on sleep scheduling stronger for the employed than for those who are not working? Are people who do not watch television still responsive to television cues? Does responsiveness to cues differ by industry?

6.1 Household Status

Our model assumes that scheduling decisions are influenced by returns to both intra- and inter-regional coordination as well as by taste factors such as a desire to be at home with family at certain times. Individuals who have fewer personal or household scheduling demands may therefore be more strongly influenced by cues for intra- and inter-regional coordination. Figure 6 shows the relative impacts of television and time-zone cues on scheduling decisions by people who are married and/or who have children under 17 living in the household ("non-singles") and for "singles," who are not married and do not report living with children.[9] Looking at sleep scheduling, we see that the effects of time zone on sleep are virtually identical throughout the day for both singles and non-singles. The effect of television cues tends to be stronger for non-singles than for singles, however. As an example, at 7 a.m. there is no significant difference in the proportion of singles who are sleeping on the coasts

[9] We also analyzed this by further decomposing non-singles into two groups: married with no children and living with children. These two groups looked fairly similar to each other in terms of their responsiveness to cues.

and in the center of the country. Married people in the center of the country are a significant 2.8 percentage points less likely to be sleeping at this time. It seems plausible that non-singles are engaging in greater household coordination and that, in particular, they are more likely to watch television with others, amplifying the effects of television cues rather than dampening them.

Turning to the work schedules of singles and non-singles, for much of the day we see little difference in responses to cues. At certain key times, however, there is some evidence that singles are more responsive to cues for intra- and inter-regional coordination than are non-singles. In particular, note that at 7 a.m. there is no significant effect of television cues on work probabilities for non-singles, while singles are 3.7 percentage points more likely to be at work if they live in the early television zones. Looking at time zone, at 5 p.m. there is no significant effect of time-zone cues on work probabilities for non-singles, while singles are 1.8 percentage points less likely to be working at this time.

6.2 Employment Status

We have assumed throughout that it is the need for work coordination across time zones that drives scheduling differences with each hour shift in time zone. If this is indeed the case, then we would expect that individuals who are currently employed will be more responsive to the time-zone cue than individuals who are not working. Figure 7 presents the marginal effect of the time-zone cue on sleep probabilities for both groups of individuals. Contrary to our expectations, employed persons are not uniformly more responsive. In particular, between about 6 a.m. and 10 a.m. employed persons are notably less responsive to time-zone cues than those who are not working. Perhaps this is because longitudinal cues operate through more than returns to inter-regional work coordination and those with jobs have relatively less scheduling flexibility than those who are not working. This would also be consistent with the larger effects of cues on sleep schedules than on work schedules.

6.3 Television Viewership

The television cue is particularly interesting because it may directly affect scheduling for viewers but, because of a need for intra-regional coordination, it may alter non-viewers' schedules as well. By examining the relative responsiveness of viewers and non-viewers to television cues, we can begin to separate the direct effect of the cue on scheduling from the indirect effect that it provides through intra-regional coordination concerns. We divide our sample into "viewers," who watch half an hour or more of television on the reference day (77 percent of the sample) and "non-viewers," who watch less than half an hour of television.[10] Figure 8 shows the relative responsiveness to television cues in work and sleep scheduling by these two groups.

Looking first at the effect of television cues on sleep schedules, we see that viewers tend to be more influenced by these cues, but non-viewers are responsive as well. For example, at 11 p.m., the peak of the spike induced by differences in prime-time television schedules, television viewers in the middle of the country are 6.6 percentage points more likely to be asleep than those on the coasts. The non-viewers in the middle of the country are 4.2 percentage points more likely to be sleeping than those on the coasts.

Turning to the effect of television cues on the work schedules of the two groups, the pattern of differences is less readily discernable. When some pattern does seem manifest, it suggests that non-viewers are actually more responsive to television cues in their morning work schedules. Most of the differences between the two, though, are not significant.

6.4 Industry

It seems plausible that returns to local and external coordination might vary by industry or occupation. We compare responsiveness for two relatively large industry groups: information, financial, professional, and business services, hereafter called "business services"

[10]The results do not differ greatly if we define non-viewers as those who watch less than one hour per day.

(approximately 20 percent of sampled workers) and other service-related industries, which include educational, health, leisure, and hospitality services (approximately 35 percent of sampled workers).[11] We expect that workers in the first group will be more likely to coordinate inter-regionally than those in the second group.

Figure 9 shows the relative responsiveness of workers in these two industry groups to local and external cues. As a whole, workers in the first group– business services– are more responsive to time-zone cues for coordination, while workers in the second group– other service industries– are more responsive to television cues. For instance, looking at responsiveness to time-zone cues at 10 p.m., for a one hour shift west in time zone, workers in business services are 4.3 percentage points more likely to be sleeping, while workers in other services are 2.0 percentage points more likely to be sleeping. Moreover, at 7 a.m., for a one hour shift west in time zone, workers in business services are 2.7 percentage points more likely to be at work, while workers in other services do not show a response. Examining responsiveness to television cues, we see little difference for work activities. However, workers in other service industries are more responsive to television cues in sleep scheduling than are workers in business services. At 7 a.m., other service industry workers in the middle of the country are 4.8 percentage points less likely to be sleeping than those on the coasts while the effect for business service workers is 3.6 percentage points.

These relative differences suggest that workers in business services have higher returns to inter-regional coordination and lower returns to intra-regional coordination than do workers in other service industries. They provide direct evidence of the role of an increase in α_i in our model. That workers in other services do show some response to time-zone cues may be due to the existence of a direct return to inter-regional coordination or could simply reflect the need to coordinate with other local workers who, in turn, have gains to inter-regional

[11] More specifically, 'business services' include the 2002 Census industry codes 6470–6780, 6870–7190, and 7270–7790. 'Other services' include industry codes 7860–8470, 8560–8690, and 8770–9290.

coordination.

7 A Natural Experiment in Australia

Australia, Brazil, Canada, Indonesia, Mexico, and Russia are the only countries other than the U.S. that have two or more time zones and that thus allow the kind of analysis we have undertaken here. In order to examine the robustness of our results, we thus take advantage of the Australian Time Use Survey of 1992 (Australian Bureau of Statistics, 1993), a random stratified sample of roughly 7000 individuals on two days each. Individuals listed when they began a new activity, with responses then coded into 280 categories of activities. The activities could encompass as few as 5 minutes, with the upper bound being the full 24 hours.

There are three time zones in Australia, but unfortunately the data set only gives identifiers for the three largest states, New South Wales (NSW), Victoria (VIC) and Queensland (QLD), all of which are in the same time zone (GMT+10). Fortunately, however, while the first two of these go on DST at the end of October and return to ST at the end of March, Queensland remains on ST all year long. Moreover, the survey collected data in four two-week periods over the year, including February 24 through March 7, when the two biggest states were on DST, and September 28 through October 10, when they were not. Because the main cities in each state are at nearly identical longitudes, and because these two two-week periods stand in the same relation to the nearby equinoxes, during these periods the times of sunrise and sunset differed among the three cities by no more than eight minutes. Times of sunrise and sunset thus provide no differences in cues across the three states.

The longest-operating television stations in Australian are those affiliated with the Australian Broadcasting Corporation. As television was growing up in Australia, the ABC made the decision to broadcast its programs at the same nominal time in each state. Thus, for example, the nightly news is presented at the nominal time of 10 p.m. in all states, regardless of time zone or the existence of DST. There is thus no television cue in Australia. The only cue that matters is time zone, including the existence or lack thereof of DST. We can thus isolate the effect of time zone in this sample by comparing Queensland to the other two large states, during the period when the latter are on DST and during the period when they are not. Indeed, the comparison is identical to the natural experiment analyzed in Section 5, with QLD substituted for Arizona-Indianapolis-Hawaii, and NSW and VIC substituted for the rest of the United States.

Table 4 presents calculations for weekdays in Australia that are analogous to those we presented in Table 2. We calculate single- and double-differences for the same time periods, and the same three activities-sleeping, working and television watching-that we include in that table. The samples sizes for NSW and VIC are much smaller than those for the rest of the U.S. in the ATUS, so that standard errors on the single- and double-differences are larger than in Table 2. The estimates, however, have identical implications. When NSW and VIC go on DST, residents of Queensland wake up earlier and go to sleep earlier, and shift their television watching from late evening to early morning, compared to what was observed when all three states were on ST. The directions of the effects are nearly identical to those found in the American experiment.[12] Clearly, the U.S. results do not result from anomalies particular to our data or to the U.S.

8 Conclusion

We have investigated how and why synchronicity might arise through responses to both local and inter-regional cues. Of course, synchronous behavior will be productive because of complementarities in generating output and consuming goods and services; but the exact nature of the jointness of timing does not simply arise randomly— it may be affected by

[12]The impacts on work timing are smaller than in Table 2 for the U.S., partly because relatively few Australians are at work at 7:30 a.m. If we estimate the double-difference in the fraction of people at work between 8:00 a.m. and 8:05 a.m., it becomes .029, much closer to, albeit still smaller than the effect in the U.S.

natural factors such as sunlight and by man-made changes such as time zones and television schedules. The latter may arise from decisions that were made independent of any considerations of their impacts on the timing of activities, or they can be instruments through which policy might operate to alter behavior.

Because of its vast distances, both north-south and east-west, and because of political decisions taken nearly a century ago, examining the timing of the three most important (in terms of time spent) activities that people undertake— sleep, work and television-watching— in the U.S. offers the opportunity to analyze potential cues for coordination. Our results, using the first large-scale data set providing information on how Americans spend their time, indicate that the natural cue of daylight has some effects, and that the entirely artificial cue of the timing of television programs has still larger effects on the coordination of activities. Impacts of the benefits of coordinating the timing of activities across time zones are also apparent throughout. For instance, our estimates indicate that in response only to artificial cues, residents of the Central time zone are 16 percent more likely to be awake at 7 a.m. than residents of the Eastern time zone, with about 2/3 of the effect attributable to differences in television schedule and 1/3 of the effect attributable to the difference in time zone.

While the roles of these three cues for coordination– sunlight, television, and time zone– are evident, there is little sign that their importance differs greatly across individuals who differ in their marital status or employment status. Television viewers appear to be slightly more responsive to television cues, but non-viewers also react. There are some differences across industry and occupation, but all show similar trends of responsiveness. In those industries, however, that we would think would require more inter-regional contacts, we do in fact find greater impacts of time zones. Nonetheless, by inference one must conclude that other factors, perhaps social norms, that are established by natural cues, by the benefits to inter-regional coordination of employment, and by television programming dominate any consistent individual variations.

Prompted by the recent rapid growth of surveys offering large samples of individuals whose timing of activities is now available, research on the nature of temporal coordination should burgeon in the next decade. Examining the synchronicity of activities is the obvious complement to the vast literature on the quantity of different activities, particularly those in the market, that has been such a huge component of labor economic and macroeconomic research.

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Figure 1: **Payoffs to Period of Market Work**

	Period 1 $y_2 = 1$	Period 2 $y_2 = 0$
Period 1 $y_1 = 1$	$1 + \alpha_1 + \beta_1, 1 + \alpha_2 + \beta_2$	$1 + \alpha_1, 1 + \theta_2$
Period 2 $y_1 = 0$	$1 + \theta_1, 1 + \alpha_2$	$1 + \beta_1 + \theta_1, 1 + \beta_2 + \theta_2$

Figure 2: **Coordination Game Equilibria**

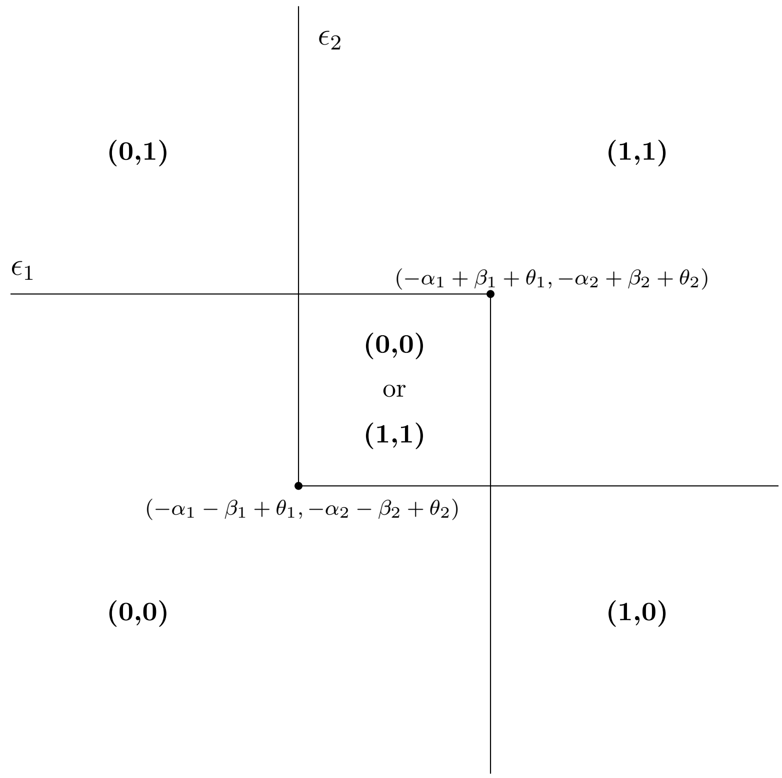

Figure 3: **Time Zones within the Contiguous United States**

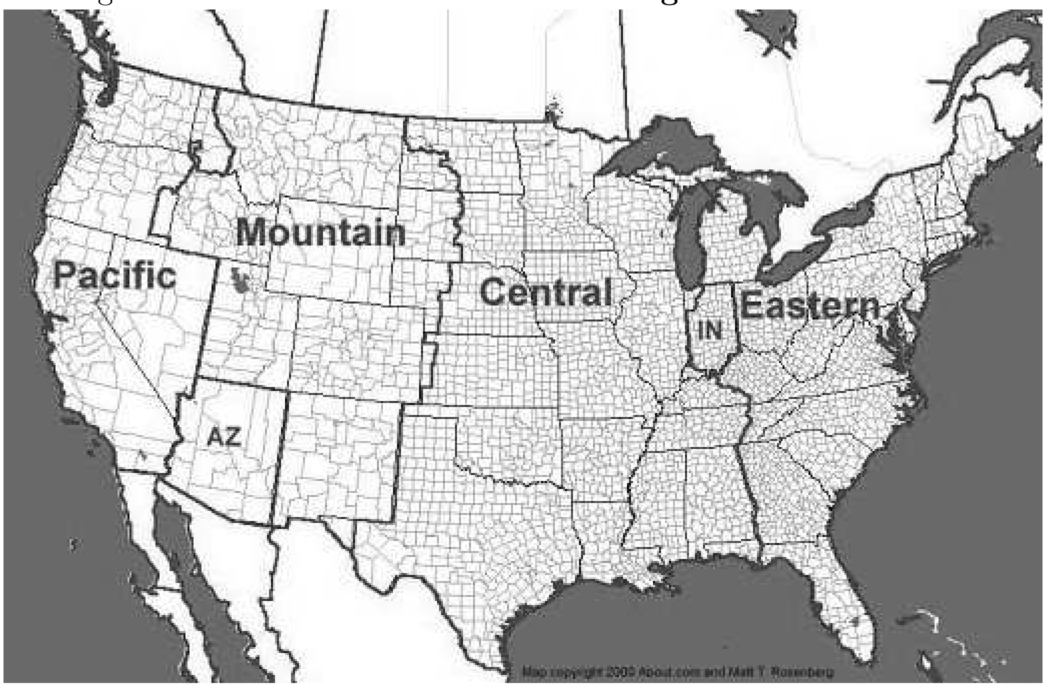

Table 1: **Population Distribution by Time Zone**

Time Zone	Census Bureau 1920	Census Bureau 2004	ATUS 2003-2004
Eastern	50.1	44.7	45.9
Central	33.4	26.5	27.4
Mountain	3.4	4.3	4.7
Pacific	5.3	16.4	13.1
Non-Classifiable	7.8	8.1	8.9

**Non-classifiable states are AK, AZ, HI, IN, KY, and TN*

Table 2: **Double-Difference Estimates of the Effect of a Shock to the Time-Zone Cue in the United States on Proportion Sleeping, Working, and Watching Television**

Time	Experimental Locations (don't observe DST)			Control Locations (observe DST)			
	ST	DST	Δ	ST	DST	Δ	Δ^2
7:30-7:45 a.m.							
Sleep	**0.303**	**0.247**	-0.056	**0.318**	**0.323**	0.005	**-0.061**
	(0.021)	(0.020)	(0.029)	(0.004)	(0.004)	(0.005)	(0.015)
Work	**0.170**	**0.252**	**0.082**	**0.214**	**0.217**	0.003	**0.079**
	(0.018)	(0.020)	(0.027)	(0.003)	(0.003)	(0.005)	(0.014)
Television	**0.046**	**0.035**	-0.011	**0.041**	**0.035**	**-0.006**	-0.005
	(0.010)	(0.009)	(0.013)	(0.002)	(0.001)	(0.002)	(0.006)
10:30-10:45 p.m.							
Sleep	**0.567**	**0.588**	0.021	**0.531**	**0.498**	**-0.033**	**0.054**
	(0.023)	(0.022)	(0.032)	(0.004)	(0.004)	(0.006)	(0.016)
Television	**0.188**	**0.162**	-0.026	**0.211**	**0.222**	**0.011**	**-0.037**
	(0.018)	(0.017)	(0.025)	(0.003)	(0.003)	(0.005)	(0.014)
number obs.	460	491		15,589	18,153		

* *Bold difference estimates are significant at 5% level. Standard errors are in parentheses.*

Table 3: **Average Marginal Effects for Select Television, Sleep, and Work Weekday Probits**

	Pr(Television) 11-11:15p.m.		Pr(Sleeping) 7-7:15a.m.		Pr(Working) 8-8:15a.m.	
	coef	*se*	*coef*	*se*	*coef*	*se*
hours tv	**0.0318**	0.0009	-	-	-	-
hours sleep	-	-	**0.0701**	0.0042	-	-
hours work	-	-	-	-	**0.0625**	0.0015
age 20–29	-0.0235	0.0130	**0.0462**	0.0183	**0.1389**	0.0280
age 30–39	**-0.0297**	0.0129	**-0.0427**	0.0168	**0.1909**	0.0281
age 40–49	**-0.0329**	0.0127	**-0.0556**	0.0165	**0.1780**	0.0295
age 50–59	**-0.0418**	0.0119	**-0.0714**	0.0157	**0.1856**	0.0277
age 60–69	**-0.0437**	0.0118	-0.0072	0.0173	**0.1689**	0.0268
age >70	**-0.0537**	0.0108	-0.0065	0.0164	**0.1336**	0.0356
educ 12	**0.0604**	0.0110	**0.0384**	0.0116	-0.0048	0.0200
educ 13–15	**0.0725**	0.0117	**0.0538**	0.0120	**-0.0470**	0.0208
educ 16	**0.1186**	0.0142	0.0238	0.0131	**-0.0484**	0.0227
educ >16	**0.1321**	0.0168	**0.0316**	0.0150	**-0.0689**	0.0255
married	-0.0040	0.0074	**-0.0243**	0.0092	**0.0399**	0.0136
male	0.0125	0.0078	0.0072	0.0098	-0.0148	0.0152
married*male	-0.0039	0.0104	**-0.0371**	0.0132	0.0231	0.0192
kids age 0-5	-0.0105	0.0071	-0.0044	0.0090	**-0.0485**	0.0114
kids age 6-17	-0.0020	0.0059	**-0.0709**	0.0081	0.0168	0.0096
black	0.0109	0.0082	0.0145	0.0106	-0.0138	0.0156
other	-0.0104	0.0161	**0.0814**	0.0227	**-0.0781**	0.0289
hispanic	-0.0099	0.0088	0.0105	0.0112	-0.0133	0.0161
year 2004	-0.0056	0.0052	**-0.0136**	0.0066	0.0045	0.0094
Cues						
tv cue	**-0.0519**	0.0053	**-0.0385**	0.0070	**0.0354**	0.0099
time-zone cue	**-0.0128**	0.0025	**-0.0157**	0.0032	0.0069	0.0046
hour of sunrise	0.0051	0.0046	0.0069	0.0060	-0.0050	0.0083
hour of sunset	**0.0081**	0.0025	**0.0065**	0.0032	-0.0034	0.0045
number obs.	16,604		16,604		8,249	

**Bold coefficients are significant at 5% level. Standard errors are robust.*

***Work probits also included indicator variables for industry and occupation.*

Figure 4: **Marginal Effects of Coordination Cues on Sleep Schedules**

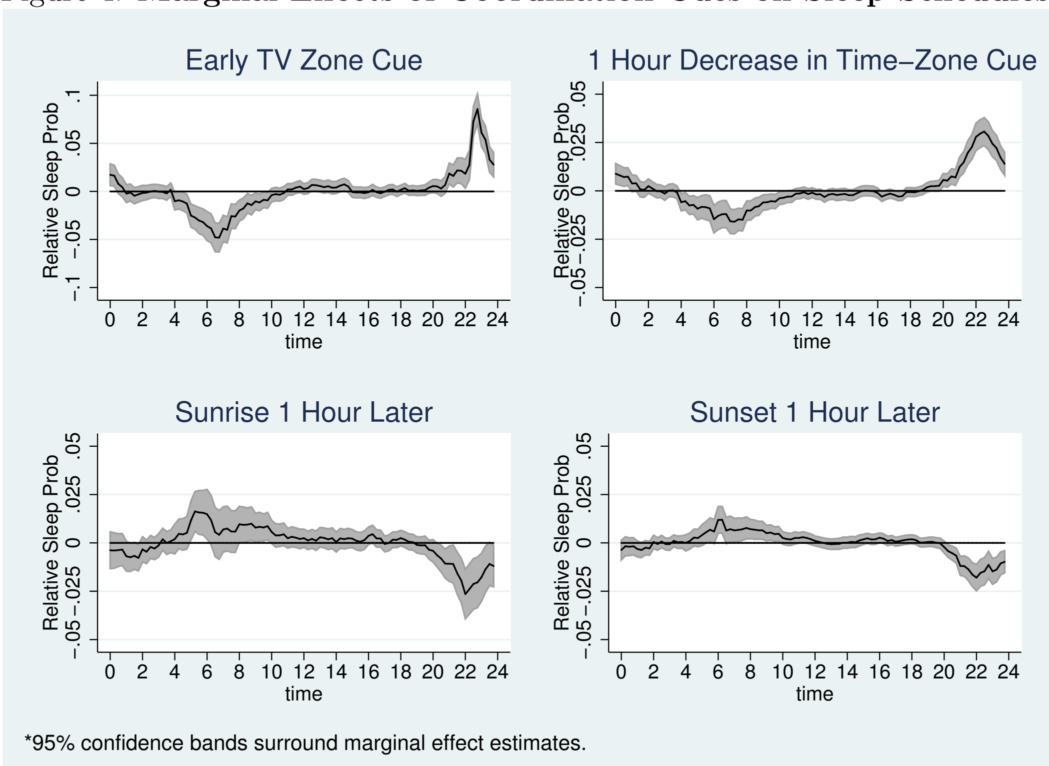

Figure 5: **Marginal Effects of Coordination Cues on Work Schedules**

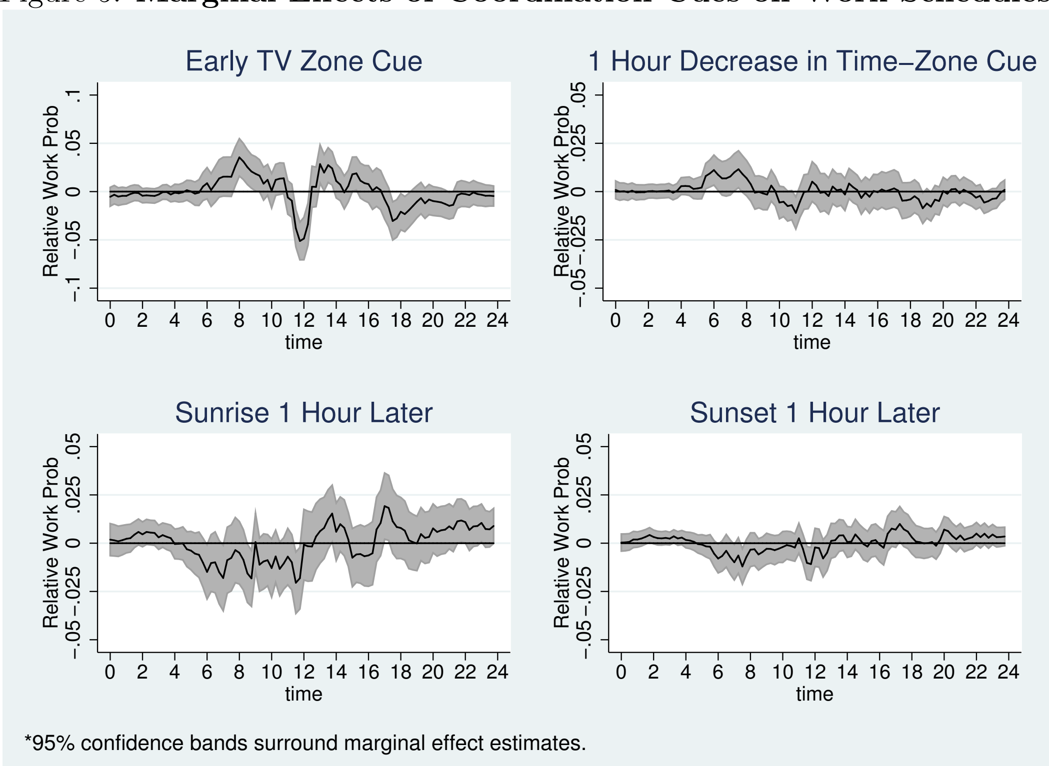

Figure 6: **Marginal Effects of Coordination Cues by Household Status**

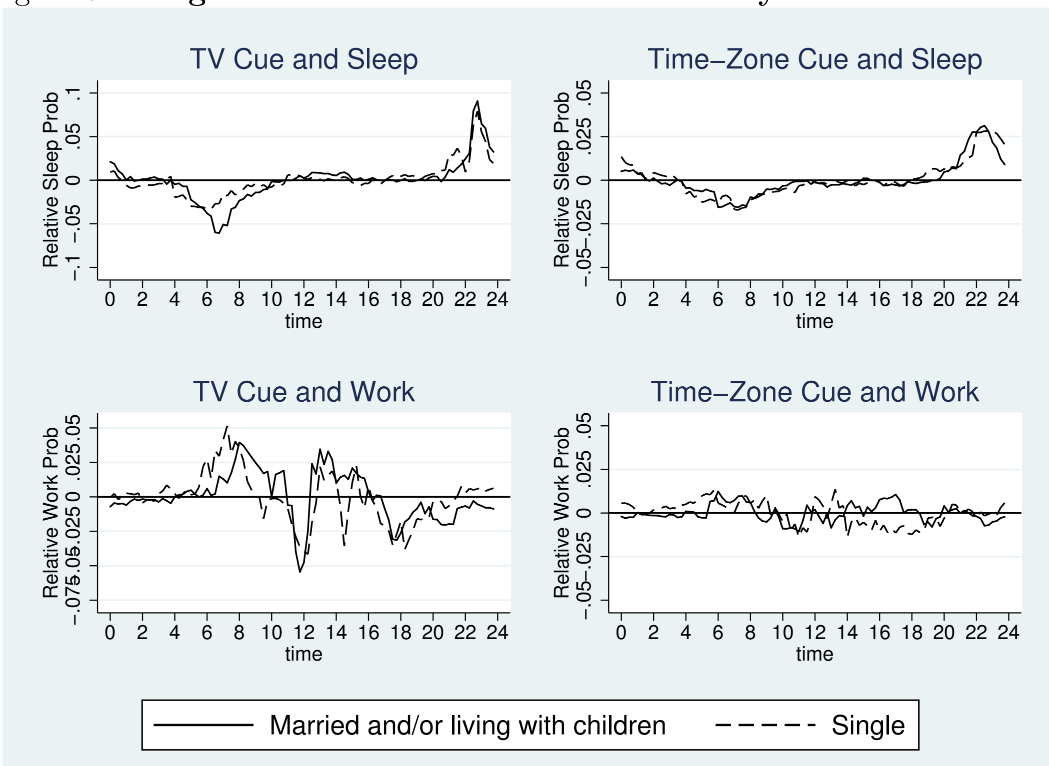

Figure 7: **Marginal Effects of Coordination Cues on Sleep by Employment Status**

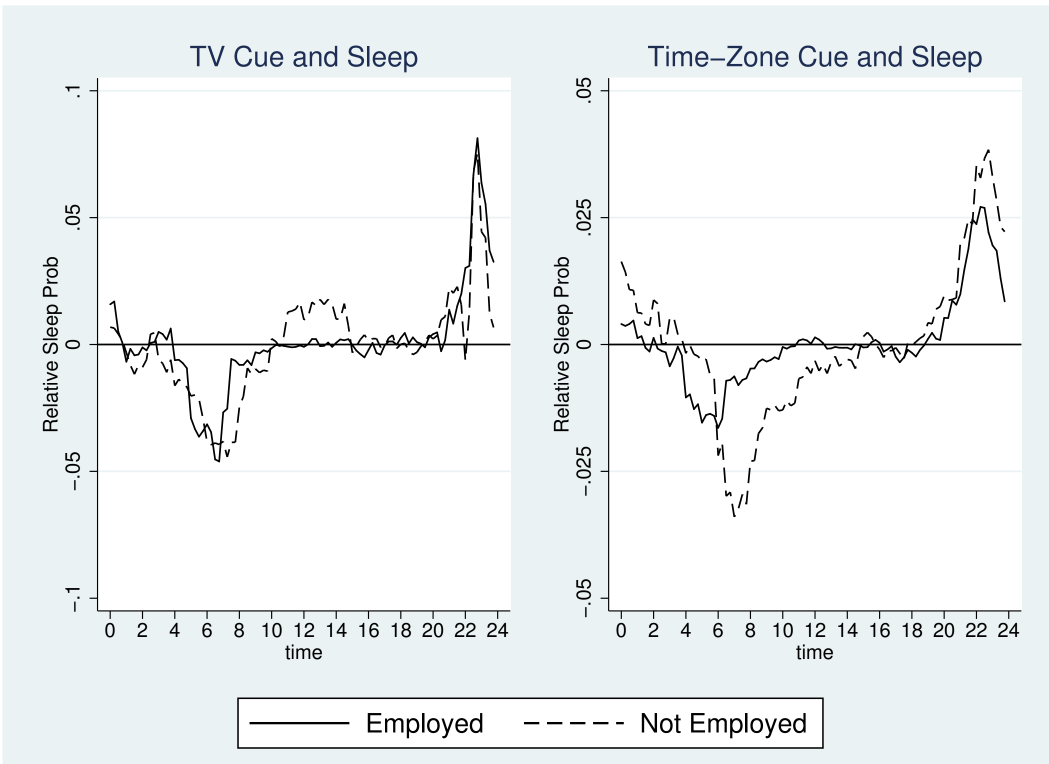

Figure 8: **Marginal Effects of Television Cues by Viewership Status**

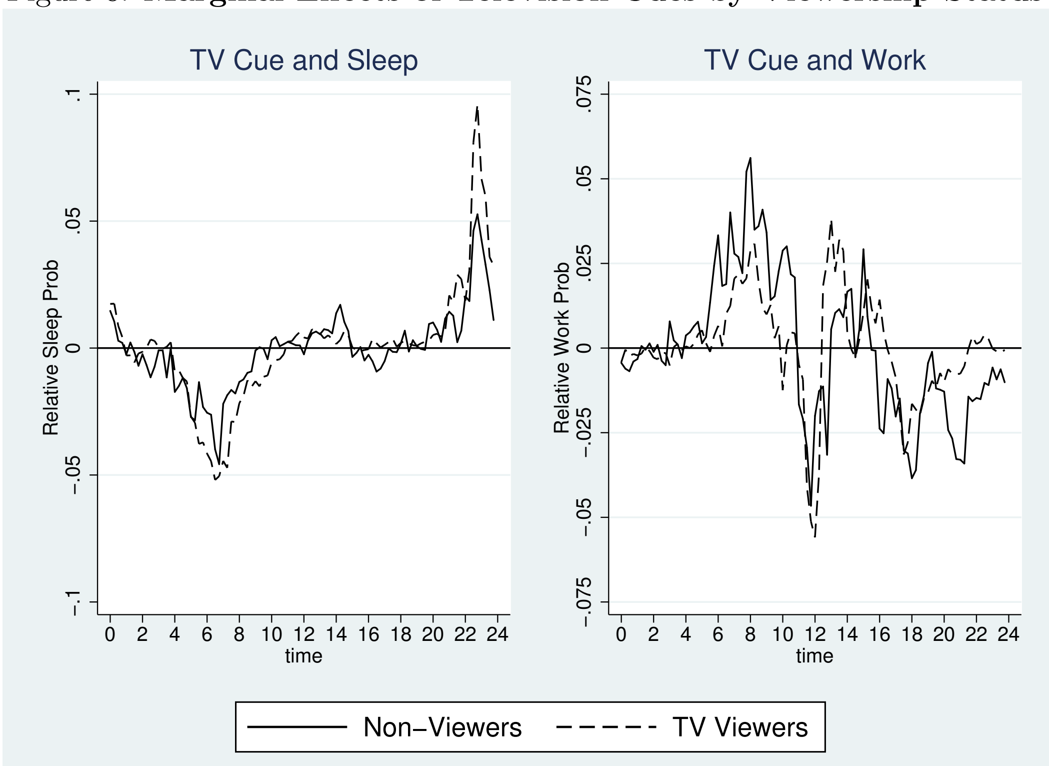

Figure 9: **Marginal Effects of Television Cues by Industry**

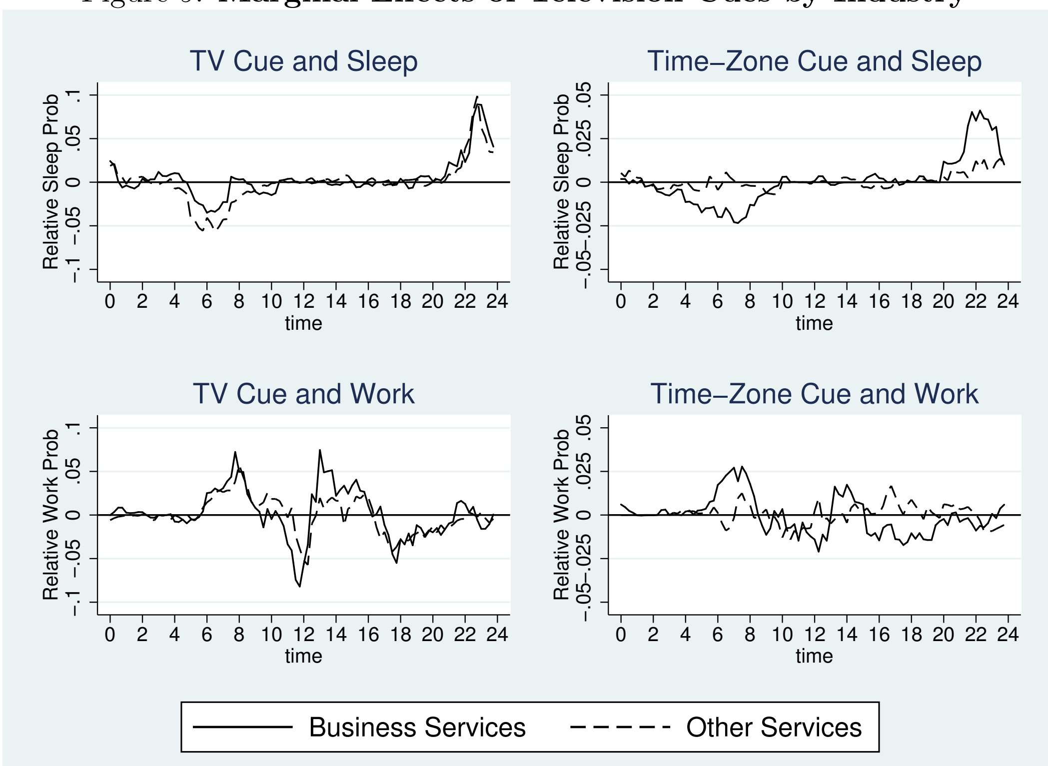

Table 4: **Double-Difference Estimates of the Effect of a Shock to the Time-Zone Cue in Australia on Proportion Sleeping, Working, and Watching Television**

	Experimental Locations (don't observe DST)			Control Locations (observe DST)			
Time	ST	DST	Δ	ST	DST	Δ	Δ^2
7:30-7:35 a.m.							
Sleep	**0.476**	**0.334**	-0.041	**0.566**	**0.584**	0.018	-0.059
	(0.029)	(0.024)	(0.037)	(0.017)	(0.015)	(0.022)	(0.044)
Work	**0.062**	**0.084**	0.022	**0.081**	**0.096**	0.015	0.006
	(0.014)	(0.014)	(0.019)	(0.009)	(0.009)	(0.013)	(0.023)
Television	**0.029**	**0.062**	**0.033**	**0.073**	**0.050**	**-0.023**	**0.056**
	(0.010)	(0.012)	(0.015)	(0.009)	(0.006)	(0.011)	(0.019)
10:30-10:35 p.m.							
Sleep	**0.544**	**0.566**	0.024	**0.515**	**0.441**	**-0.074**	**0.098**
	(0.028)	(0.024)	(0.037)	(0.017)	(0.015)	(0.022)	(0.044)
Television	**0.186**	**0.153**	-0.033	**0.173**	**0.222**	**0.050**	**-0.082**
	(0.022)	(0.018)	(0.028)	(0.013)	(0.012)	(0.018)	(0.033)
number obs.	307	419		891	1124		

**Bold difference estimates are significant at 5% level. Standard errors are in parentheses.*