The 'Trendiness' of Sleep: An empirical investigation into the cyclical nature of sleep time

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June 20, 2009§

Abstract

Using Canadian time use data, we exploit exogenous variation in local unemployment rates to investigate the cyclical nature of sleep time and show that for both men and women, sleep time decreases when the economy is doing relatively better. Our results suggest that in a recession Canadians will sleep an average of 2 hours and 34 minutes more per week, or roughly 20 minutes more per day. The effect is strongest for those of prime-age and is present for both men and women, but is experienced through different channels.

This finding contributes to two distinct literatures. First, given the importance of even small changes in sleep time on such measures of cognitive functioning as reaction time and concentration, our findings may help explain the countercyclical nature of mortality found in the works of Ruhm (2000, 2007) and Gerdtham & Ruhm (2006). These papers show that overall and cause specific mortality increases as economic conditions improve - and the effect is largest for fatalities disproportionately experienced by younger adults: motor vehicle accidents and other accidents. Accidents of all kinds are more likely to occur and perhaps be more severe when sleep times are lower. Second, as we find that sleep is affected by the same economic variables (notably the unemployment rate) that affects market work time, our results also contribute to the works of Szalontai (2006) and Biddle & Hamermesh (1990) who show that the quantity of sleep time should not be treated as exogenously determined as is the norm in standard economic models, but, like any other resource, determined by its relative cost.

Keywords: business cycles, health, sleep.

JEL classification: E32, I12, J22.

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§This work has benefited from comments from Sonia Laszlo, Kate Rybczynski and participants of CHESG.

1 Introduction

Inadequate sleep time has been shown to affect many dimensions of cognitive functioning (reaction time, memory, and concentration in particular), and greatly inhibit our bodies' ability to defend against illness and disease. In short, adequate sleep time is essential for maximizing ones' productivity when awake.

Particularly striking is the impact of sleep on decision making and productivity. A randomized study of medical students in residency training found that those working a 'traditional schedule' made 36 percent more serious medical errors in comparison to the students working the 'intervention schedule' that allowed more time for sleep (Landrigan et al. 2004). Even small changes in quantity of sleep have been found to generate measurable effects. Kamstra et al. (2000) find that the two weekends involved with daylight savings time changes have negative effects on the functioning of financial markets which they attribute to sleep desynchronosis.[1] These daylight savings effects are estimated to be 200 to 500 percent of the usual weekend effect, a one day loss equivalent of $31 billion in the US markets alone.

The effect of sleep on accidents is equally remarkable. Police reports indicate that drowsiness or fatigue is responsible for over 56,000 crashes annually and approximately four percent of crash fatalities on US highways (Knipling & Wang 1994).[2] Powell et al. (2001) find that the potential risks of driving deprived of one night's sleep or driving short two hours of sleep each night for one week is not significantly different from driving with a blood alcohol level above the legal limit with respect to the 11 indices of driving performance considered. And again, even small changes in sleep generate measurable effects: increased motor vehicle accidents are documented following both weekends involved with the one hour daylight savings time changes (Monk 1980, Hicks et al. 1983, Coren 1996).

Using Canadian time use data, we exploit exogenous variation in local unemployment rates to show that sleep is a resource, like any other, that gets sacrificed when the value of one's time becomes more attractive; when the economy is doing relatively better as measured by lower unemployment rates. Our findings contribute to two distinct literatures.

The first is the literature that examines the relationship between health and the business cycle. While wealthier people/countries are in general healthier people/countries, it is not the case that health improves in 'good times'. In a series of papers (Gerdtham & Ruhm (2006), and Ruhm (2000, 2003, 2007)) Ruhm demonstrates that health (as measured by mortality in particular as well as various measures of general health) improve during recessionary periods.

[1] Sleep desynchronisis is the disruption of the 'dark/light' cycle of the body's circadian rhythms, the 24 hour cycle of the body's biochemical, physiological and behavioral processes.

[2] These figures are argued to be conservative due in part to reporting differences across states and lack of evidence regarding the cause of the crashes (Knipling & Wang 1994).

The most significant fluctuations in mortality are found for those of prime-age and for causes of death disproportionately experienced by this age group: motor vehicle and other accidents (Ruhm 2000).

Three hypotheses are proposed for this countercyclical relationship (Ruhm 2003). First, leisure time becomes more costly during economic upturns, making time intensive, but health enhancing activities like exercise and medical visits relatively more expensive. Using American micro data, he demonstrates that lifestyles do become unhealthier during economic expansions as measured by increased smoking, decreased physical activity and increased obesity (Ruhm 2000). Second, he suggests that workers' health may be inputs the production process of goods and services. Increased hours of work associated with economic expansions increase exposure to hazardous working conditions and increase job related stress; both of which have been shown to have deleterious effects on health. This is particularly relevant to cyclically sensitive sectors such as construction, where accident rates are higher. Third, risky activities such as drinking and driving may be normal goods. As such, in times of economic expansion, the incidence of motor vehicle fatalities should increase.[3]

We show that sleep is another time intensive/health enhancing behaviour that responds to economic conditions. The associated decrease in cognitive functioning (concentration and reaction time in particular) due to lower sleep times might help explain the increased accidents in 'good times' – in particular in accident-prone and cyclically sensitive sectors like construction. Similarly, decreased sleep time may exacerbate the effects of increased drinking and driving in 'good times' with respect to motor vehicle accidents and fatalities.

This work also contributes to the literature which questions the assumption of exogeneity of sleep time found in most economic models. In the seminal work of Gary Becker (1965) on the theory of the allocation of time, utility yielding commodities are produced using combinations of market goods and time. The cost of these commodities thus includes both the costs of the market goods and the costs of one's time, including non-monetary costs such as the costs associated with raising children. Consumers allocate their time between work, leisure and sleep to maximize utility.

While this theory is no longer new, economic models most often consider sleep time to be exogenously determined, and question only the allocation of the remaining two thirds of our days between market and non-market (leisure) activities (Biddle & Hamermesh 1990). Most models thus exclude the possibility that sleep may generate utility, that sleep may be affected by other factors in the model (for example earnings potential), and that sleep may

[3]Ruhm & Black (2002) verify that alcohol consumption is in fact procyclical. While stress induced drinking may increase during recessionary periods, it is found to be offset by reduced consumption due to lower incomes and other economic factors.

also directly affect such factors (through say productivity). The authors show that such omissions bias estimates of labour supply elasticities.[4]

Two economic studies empirically examine this assumption of exogeneity of sleep time. Biddle & Hamermesh (1990) develop a utility based demand model for the allocation of time across three uses: market work, sleep and leisure time, in which sleep is a choice variable that enhances both productivity and utility. Using 1975-76 American time use data, they confirm that sleep is in fact a choice variable affected by the same economic variables (namely wages and household income) affecting market work and leisure time. Szalontai (2006) replicates the analysis of Biddle and Hamermesh using South African time use data and finds robust evidence that wages and education have negative effects on sleep, suggesting again that sleep time is a resource like any other that gets sacrificed when the value of one's time becomes more attractive.

We find that sleep is a choice variable affected by the same economic variables (here, the UR) that affect market work time. Thus our results also contribute to the works of Szalontai (2006) and Biddle & Hamermesh (1990) who show that the quantity of sleep time should not be treated as exogenously determined as is the norm in standard economic models, but, like any other resource, determined by its relative cost.

In sum, we find that sleep time is countercyclical. Our results suggest that in a recession Canadians will sleep an average of 2 hours and 34 minutes more per week, or roughly 20 minutes more per day.[5] The effect is strongest for those of prime-age and is present for both men and women, but is experienced through different channels. The change in sleep time for women appears to be driven by movement in and out of the labour force, but for men it is also driven by changes (voluntary and/or involuntary changes) in the amount of time spent working.

Evidence of the countercyclical nature of sleep time can help direct policy - particularly for maintaining population health and reducing risks of accidents and illness. Further, to the extent that sleep time affects productivity, understanding the determinants of sleep can help employers encourage behaviours that promote productive workforces.

[4]Gronau (1986) provides a good overview of the theoretical literature that examines the optimal allocation of non-market, non-sleep time.

[5]Following Oreopoulos et al. (2006), we assume that the unemployment rate increases by five percentage points during a recession.

2 Data and Basic Patterns

Our main source of data is three time use cycles of Statistics Canada's General Social Surveys (GSS) corresponding to the years 1992, 1998, and 2005.[6] The data are based on telephone interviews which inquire about activities during the previous day in a diary format. Information on activities done on one's own and with others, as well as socio-demographic characteristics of the household are recorded. These data are particularly useful in that they cover an expansionary period (2005) and a recessionary period (1992).[7,8,9]

GSS interviews are carried out throughout the survey year. There is time-use information for each day of the week, and also for each month of the year. This paper explores how sleep varies with the business cycle, as proxied by monthly, provincial unemployment rates. Unlike most surveys which collect data over a short period of time, monthly data provides us with additional variation (i.e. variation across months) when identifying the effect of the unemployment rate on time spent sleeping.

The provincial unemployment rates are estimated using the public use Labour Force Survey (LFS) files. The LFS is a large monthly household survey that gathers information on the labour market activities of Canadians. The LFS is used by Canada's statistical agency to compute official labour force statistics (e.g. unemployment rate).

We restrict our sample to the working age population, individuals 20 to 69 years of age. We replicate the analysis in age ranges to investigate whether the UR has stronger effects for those of prime working age, those most likely to be affected by economic conditions due to their higher rates of labour force participation. Students and observations with missing information are excluded from the analysis. A detailed description of the sample restrictions is provided in Appendix A.

[6] Statistics Canada's General Social Surveys are annual telephone surveys that "gather data on social trends in order to monitor changes in the living conditions and wellbeing of Canadians over time... and provide immediate information on specific social policy issues of current or emerging interest" (Statistics Canada 2006). Each year a different topic is considered. Time use has been the topic at regular intervals since the inception of the GSS program in 1985.

[7] This is an advantage over the new American Time Use Survey, which began only in 2003 which to date does not include any recessionary periods.

[8] There is a 1986 GSS time-use survey, but two key data limitations prevent us from using it. First, the only measure of health status available in the surveys is measured very differently in the 1986 survey, as compared to the other years. As health is theoretically one of the most important determinants of sleep time, we felt it important to be controlled for the in the regressions. But as only the later surveys allow for comparable measures of health, the 1986 survey is excluded from the analysis herein. Second, the 1986 survey was carried out over a six week period - unlike later time-use surveys which were carried out throughout the survey year. As such, the inclusion of the 1986 adds little variation for identifying the key unemployment rate effect. We have verified that the exclusion of the 1986 survey (N=7,429) does not drive our results in models excluding controls for health. These regressions are available from the authors upon request.

[9] Comparing different sources of information on time use, Juster & Stafford (1991) conclude that time diaries, like the GSS, provide the most valid measures of time use.

Figure 1 shows the periods for which we have time use data (vertical bars) – superimposed over provincial unemployment rates for a few select provinces (i.e. Ontario, Alberta and British Columbia). Figure 1 demonstrates considerable variation in unemployment rates over time and across provinces. Such variation is critical to our analysis as our regressions include both provincial dummies and a fully flexible time trend to remove systematic differences across provinces, and common time effects.[10] As such, we rely on movements within each province relative to a common trend to identify the unemployment rate effect. This allows us to disentangle pure labour market condition effects from seasonal effects (e.g. people sleep more during winter months) and from common long-term trends (e.g. changing social norms regarding sleep).

Basic summary statistics for the three time-use surveys can be found in Table 1. The sleep variable is defined to include only essential sleep. The GSS codebook defines essential sleep as "the longest sleep of the day (usually at night); including "in bed" but not asleep, trying to sleep".[11] We re-normalize activity time in terms of hours per week. This is done as to more easily compare our results with the labour time-use literature (e.g. Biddle & Hamermesh (1990)).[12] Table 1 shows that on average, women sleep more than men; sleep time tends to decrease with education level; and finally, individuals that work or have young children also sleep less.

3 Empirical Strategy

We estimate the impact of the unemployment rate on time spent on different activities using the following model

$$act\_time_{ipt} = \beta_0 + \beta_1 UR_{pt} + X_{ipt}\gamma + \delta_p + \phi_t + \epsilon_{ipt} \tag{1}$$

[10] Our time trend is fully flexible in the sense that we include a time dummy for each month of each year.

[11] The variable 'Essential sleep' reflects the relevant sleep time in the 24 hour window. Recall that the data are constructed from individual recollections about a 4am to 4am period. There are three alternative measures of sleep available in the GSS. 'Incidental sleep' includes time lying down, napping and resting. We do not use this as our preferred measure of sleep as napping, resting etc are more akin to leisure time. Next, individuals asleep at the beginning of the reference day were asked at what time they fell asleep the night before. Individuals asleep at the end of the reference day were asked at what time they woke up the next morning. These are also not our preferred measures of sleep as they are available only for respondents who were asleep at 4am. In addition, one cannot be sure if these two measures account for the full sleeping time. How respondents have addressed sleep interruptions cannot be inferred from the two measures. Our main results remain essentially unchanged when any of these alternative measures are used.

[12] The time diaries cover a 24-hour period - where each activity is measured in minutes. We convert the activity time into hours per week by multiplying by 7 and dividing by 60. The work variable is broadly defined to include all time spent at work (including breaks). It does not, however, include time spent traveling to and from work.

where act_time_{ipt} is the hours spent per week on a particular activity (sleep, work or leisure) for individual i in province p, and at time t. The unit of time is the month/year. As such, individuals whose time diaries were held in the same month and year will have the same t in our regression analysis. The key explanatory variable of interest, UR_{pt} , is the unemployment rate for province p in period t.

The vector of controls (X_{ipt}) in our main specification includes controls for gender, age, education, marital status, the presence of young children in the household (number of children under four and under 18), self-reported poor health, reference diary day of the week and a dichotomous variable taking the value one if the individual's main activity is paid work but he did not work on the reference day (day off).

Data is available for each day of the week, with equal probability. While we are perhaps more interested in learning about the responsiveness of sleep to the UR during work days, we include data for weekends as well as 1) not everyone works and 2) not everyone works only on week days. The day off variable will help control for the likely higher amount of sleep time on non-work days (primarily weekends) and days taken off from work due to illness. Finally we include both provincial and time (month/year) dummies.

The analysis in this paper relies on normalized GSS weights. The sample weights sum to unity within each survey, giving each of the three surveys equal weight.[13] In addition, we cluster our standard errors (by province, month and year) in all our regression specifications.

3.1 The Possible Endogeneity of Health

In this sub-section we investigate the severity of potential biases due to the endogeneity of individuals' health: reverse causality and omitted variable bias. While poor health affects one's sleep requirement, a lack of sleep may seriously affect one's health (reverse causality). Unobserved factors that affect health (e.g. exercise, and dietary habits) may also directly impact sleep (omitted variable bias). These causal links, and the problems they generate, can be shown in the simple model below

$$sleep_i = \alpha_0 + \alpha_1 UR_i + \alpha_2 phealth_i + \varepsilon_i \quad (2)$$

$$phealth_i = \beta_0 + \beta_1 UR_i + \beta_2 sleep_i + \nu_i \quad (3)$$

[13]Our results are robust to the choice of normalization. We repeated our analysis using weights which were normalized to sum to one across all surveys, thus putting considerably more weight on the larger survey (2005). This did not materially affect our findings.

where $sleep_i$ is time spent sleeping by individual i, and $phealth_i$ is a measure of his poor health.[14] The key parameter of interest is α_1 which measures the direct effect of an increase in the unemployment rate (UR_i) on sleep time.

In this simple framework, there is reverse causality if $\beta_2 \neq 0$. Omitted variable bias is present if $cov(\varepsilon_i, \nu_i) \neq 0$. Estimating only Equation (2) where we ignore both reverse causality and omitted variable bias will bias our estimate of α_1. See Appendix B for a detailed derivation of the biases.

If reverse causality is the more serious problem ($|\phi_1 var(\varepsilon_i)| > \phi_2 cov(\varepsilon_i, \nu_i)$) our estimate of α_1 will be downward biased; we will be underestimating the true impact of the unemployment rate on sleep.[15] In the case where omitted variable bias is the more serious problem, the bias remains downward so long as $cov(\varepsilon_i, \nu_i) < 0$; that is, so long as the unaccounted factors that positively impact sleep decrease poor health (i.e. lead to better health). This is a plausible relationship as for example a person who exercises more will both be healthier and require more sleep. Therefore, if we find that that the unemployment rate has an economically significant effect on sleep (which we do), we can be reasonably sure that our estimate is in fact a conservative estimate of the true effect.

An alternative estimation strategy would be to omit one's health status from Equation (2); regress sleep on UR only (i.e. putting the poor health variable in the error term). In this case, the sign of the bias would again be negative regardless of the covariance between ϵ_i and ν_i (see Appendix B for details). Although results from estimating a sleep equation without any controls for health status will not be our main specification, we can use this strategy to get another conservative (downward biased) estimate for the effect of unemployment rate on sleep.

4 Results

We start by estimating Equation (1) with essential sleep as the dependent variable. Table 2 shows the impact of the UR when we introduce controls sequentially. Specification (1) controls for day, month-year, and province only. In Specification (2), we add gender, age and education controls. Specification (3) adds controls for marital status and the presence of children, and whether the diary is a day is a day off (if employed). Finally, Specification (4) adds a control for health status to investigate whether the impact of unemployment on sleep is mainly due to changes in health status.

[14] For ease of notation, we abstract from the time dimension and use the subscript i for the unemployment rate (UR) variable.

[15] Where $\phi_1 = \frac{\beta_2}{1-\beta_2\alpha_2}$ and $\phi_2 = \frac{1}{1-\beta_2\alpha_2}$.

Two important conclusions can be drawn from Table 2. First the unemployment rate effect is robust to the choice of controls. The unemployment rate coefficient ranges from 0.493 to 0.513 depending on the specification; implying that a 1 percentage point increase in the unemployment rate will increase sleep time by approximately half an hour per week.[16] Following Oreopoulos et al. (2006), if the unemployment rate increases by 5 percentage points in a typical recession, we can interpret the coefficient of 0.512 in Specification (4) as implying that in a typical recession, Canadians sleep on average 2 hours and 34 minutes more per week.

Second, the 0.512 estimate can be interpreted as conservative due to the possible endogeneity of sleep and health. We have shown in Appendix B that when health is included as a control, in all realistic cases, the true impact of the UR on sleep will be underestimated. We have also shown that when health is excluded as a control (Specification (3)) we will unequivocally be underestimating the true effect. That the UR coefficients in Specification (3) (excluding any control for health) and Specification (4) (including health) are essentially the same we feel confident that we have in fact a downward-biased estimator of the effect of unemployment on sleep.

Results from Table 2 suggest that the labour market conditions have an impact on sleep time for the general adult population (aged 20 to 69). Next we verify whether the effect of economic conditions is larger for those with stronger ties to the labour market, those with the higher labour force participation rates. Table 3 replicates the sequential addition of controls (as shown in Table 2), but for a more restricted sample: individuals aged 30 to 49.[17] The unemployment rate findings are again very stable across specifications. More importantly, these results indicate that prime-aged individuals respond more to changes in unemployment rate.

With respect to covariates, Tables 2 and 3 suggest that females sleep on average two hours more per week than males. Not surprisingly, these tables also suggest that the presence of children, decreases sleep time and poor health significantly increases sleep time.

In Table 4, we re-estimate the full model (Specification (4) in Table 3) by gender. This table shows some differences between males and females. The UR coefficient of 0.741 implies that in a typical recession men aged 30 to 49 years of age sleep on average three hours and forty two minutes more per week. It would appear that women are less affected by a recession than males, although the difference is not statistically significant.[18]

[16] A coefficient of 0.5 represents half an hour.

[17] Ruhm (2003) finds that the effect of the unemployment rate on general health is larger for individuals aged 30 to 55.

[18] We tested for whether the male-female difference was statistically different from zero by including a full

4.1 Channels

Labour market conditions may affect individuals' sleep time through multiple channels. First, as documented in Ruhm (2003), labour market conditions may affect people's health and consequently, their sleep. Second, increased stress due to economic downturns may lead to increased difficulties sleeping and thus longer periods of essential sleep, which include time lying down, trying to sleep. Third, some employees will be laid off as the economic conditions deteriorate thereby increasing the amount of time available for other activities such as leisure and sleep. Lastly, employees who are not laid off may also see their amount of time spent working decrease as a consequence of an intentional choice (as the marginal benefit of working may decrease) or as a consequence of unintentional (imposed) changes in work schedules. We will refer to these mechanisms as the 'health', 'stress', 'layoff' and 'hour adjustment' channels, respectively.[19]

Table 5 investigates the importance of these potential channels by comparing the estimates of the effect of UR on sleep under different specifications switching on and off controls for these potential channels (health, stress, and employment). Regressions are reported for the prime age sub-sample and for men and women separately. Specifications 1 are reference regressions from Table 4.

To investigate the importance of the health channel we consider two exercises. First, we 'shut down' the channel by estimating the model for the sub-sample of healthy individuals only (Specification 2). For both men and women, the estimated UR coefficients remain significant suggesting that the 'health channel' is not driving our results. Second, we remove the control for poor health from the analysis. The idea is that when health is not included as a control, the UR coefficient captures both the positive effect of the labour force channels (higher URs lead to layoffs and decreased work hours and thus more sleep) and the negative effect of the health channel (higher URs lead to improved health and thus lower sleep requirements) on sleep time. We would thus expect that the UR coefficient would increase when the health control is included (Specification 1). The UR coefficients for both men and women are essentially unchanged (increased for females and decreased for males, both only at the third decimal place). Importantly, that the UR effect remains significant again suggests that the health channel is not driving our results.[20]

set of gender interaction terms. We could not reject the null hypothesis that the unemployment rate effect was the same across gender.

[19] While we use the term 'layoff' adjustment to refer to unintentional movements out of the labour force, we recognize the possibility that some workers might rationally choose to leave the labour market, as for example due to decreased wages in bad times.

[20] That the UR coefficient essentially does not change going from a regression excluding health as control to one including health as a control suggests that the Ruhm story - that health improves during recessions - does not hold. If in fact poor health, the only measure available in our data was a perfect measure of the

To investigate the stress channel we consider two alternative specifications. First we add a dichotomous indicator for self-reported difficulty sleeping (Specification 4). To the extent that this variable captures the negative effects of cyclically induced stress, the UR coefficient should be void of the stress channel. Having difficulties sleeping is found to be significantly associated with reduced sleep time. The UR effect is dampened slightly but remains statistically and economically significant suggesting that the 'stress channel' may be influencing our results but not driving them.[21] Next, we rerun the analysis using an alternative measure of sleep as the dependent variable: sleep duration from the time the individual fell asleep the night before the reference day and the time she woke up on the reference day, provided it was after 4am (Specification 5). Recall this is not our preferred measure sleep as it is only defined for anyone who was asleep at 4am when the 24 time diary began (see footnote 12). If the stress channel is driving our results then this pure sleep duration specification should find no effect of UR on sleep time. For both men and women the UR effect remains in large and statistically significant.

Specification 6 and Tables 6 and 7 provide a series of exercises in which we explore the 'layoff' and hours' channels. In Specifications (6) we shut down the UR 'layoff effect' channel by excluding unemployed respondents. The results suggest that the roles of these channels differ for males and females.

For males, the UR estimate found when restricting the sample to employed individuals is smaller but still statistically and economically significant. This suggests that the effect of unemployment on males' sleep time goes through both the 'layoff' and the 'hour adjustment' channels.

On the other hand, for females the effect of unemployment rate on sleep seems to go solely through changes in employment situation (i.e. the 'layoff' channel). The UR coefficient in the reference Specification (1) is significant but becomes small and statistically insignificant once we restrict the sample to employed women (Specification 6).

These finding are further corroborated by examination of the impact of UR on time spent

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'health' affected by economic fluctuations then this would be true. However, the literature indicates that mortality is the main measure of health affected and no paper to our knowledge has documented the impact of UR on poor health as defined herein. A dichotomous indicator of poor health is unlikely to be the best proxy for the measure health affected by economic conditions. While it would be reassuring to see the UR coefficient fall when health is included as a control, it does not detract from our findings, or cause concern regarding the procyclical nature of mortality.

[21]We also run a probit model with difficulty sleeping as the dependent variable and the same set of covariates. We find that the probability of reporting difficulty sleeping is negatively correlated with the UR as opposed to positively as the 'stress channel' would predict. The UR point estimate is statistically significant but small in magnitude. This again points to the insignificance of the 'stress channel' in explaining our findings.

working (Table 6) [22] In Panel A, we restrict our attention to workers only. In Panel B, we use the full sample (workers and non-workers).

Similar to the effect of UR on sleep, the magnitude of the effect of UR on work for males is larger for the full sample than for workers only. These findings again support the conjecture that, for males, the effect of the UR on sleep goes through both the 'hours adjustment' and 'layoff' channels. Recall that the full sample coefficient captures the effects of both channels while the workers only sub-sample captures the 'hours adjustment' channel only.

For females, the UR coefficient in the work regression is not significant in either regression (full sample or workers only). That the UR coefficient is not significant in the workers only regression supports our story that the adjustment does not occur through adjustment in hours. However, in the full sample regression where the UR coefficient should pick up both channels we might have expected the effect to be more significant.[23]

Table 7 further explores the 'hour' and 'layoff' adjustment channels. Changes in the UR lead to changes in wages - the most commonly used measure of individuals' opportunity cost of time. If all the changes in sleep we observe over the business cycle reflect intentional responses to changes in wages - then we are capturing nothing more than the same 'opportunity cost of time' story as in Biddle & Hamermesh (1990) and Szalontai (2006). In this case, the estimated effect of the UR should fall to zero when wages are included in the regression. If, including wage does not fully explain away the UR effect, then there is evidence of some unintentional effects (layoffs or reduced hours) on sleep time.

In this table we include personal income as a proxy for opportunity cost of time (wages) in the regressions.[24] We find that for males the income effect is both economically and statistically significant, and of the expected sign. This is further evidence that sleep time is

[22]The work variable is broadly defined to include all time spent at work (including breaks). It does not, however, include time spent traveling to and from work. The reported coefficients are obtained from separate regressions.

[23]As females tend to work less in general, in particular during child-bearing years, there is a significant amount of zero hours worked. We have run a Tobit model and found that the UR coefficient is more negative but remain insignificant.

[24]Respondents' wages are the main measures of opportunity cost of time used in Biddle & Hamermesh (1990) and Szalontai (2006). To replicate the results of their studies we would want to include the same measure. Unfortunately, wage data is not available in the Canadian GSS. We thus rely on total personal income as a proxy. Personal income is likely correlated with wages but includes all sources of income including for example: social assistance, rental and interest income. Income is not measured continuously but only in ranges, and has a 22% non-response rate. Following Phipps et al. (2001) we create a continuous measure of income using the midpoints of the ranges and inflating the 1992 and 1995 values to 2005 dollars, and control for missing income using a dummy variable. To deal with top-coding, we use 1.5 times the highest bracket (ie. for incomes in excess of $80,000, we input $120,000). As a robustness exercise we use the fact that we can identify the main source of income in the 1998 and 2005 surveys to more precisely estimate the effect of 'wages' on sleep time. We replicate our analysis using only the 1998 and 2005 surveys, for two different samples: the base group of workers, and the group of workers whose main source of income comes from wages and salaries. The log income and UR coefficients were not found to be materially different.

a function of one's opportunity cost of time as shown in Biddle & Hamermesh (1990) and Szalontai (2006). The UR effect is dampened but remains economically significant. We again conclude that for men both the intentional (opportunity cost argument) and the unintentional (layoffs and reduced hours brought about by recessionary times) effects matter. For females, the statistical insignificance of the log income variable confirms our earlier findings that the impact of unemployment rate on sleep goes through (unintentional) movements in and out of employment.

5 Discussion and Conclusion

Using Canadian time use data, we exploit exogenous variation in local unemployment rates to investigate the cyclical nature of sleep time and show that for both men and women, sleep time decreases when the economy is doing relatively better. A five percentage point increase in unemployment rate (equivalent to the average change in unemployment rate during a recession) is associated with 2 hours, 34 minutes more sleep per week. The effect is present for both males and females, though is experienced through different channels. The change in sleep time for women appears to be driven by movement in and out of the labour force, but for men it is also driven by changes (voluntary and/or involuntary changes) in the amount of time spent working.

Our findings contribute to two distinct literatures. First, given the importance of even small changes in sleep time on such measures of cognitive functioning as reaction time and concentration, our findings can help explain the countercyclical nature of mortality found in the works of Ruhm (2000, 2007) and Gerdtham & Ruhm (2006). In particular Ruhm shows that overall and cause specific mortality increases as economic conditions improve - and the effect is largest for fatalities disproportionately experienced by younger adults: motor vehicle accidents and other accidents. Accidents of all kinds are more likely to occur and perhaps be more severe when sleep times are lower.

Second, we show that part of the effect of UR on sleep for males occurs through the effect of UR on personal income - through changes in individual's opportunity cost of time. Our results thus also contribute to the works of Biddle & Hamermesh (1990) and Szalontai (2006) who show that the quantity of sleep time should not be treated as exogenously determined as is the norm, but, like any other resource, determined by its relative cost.

These results are also consistent with the recent work of Miller et al. (2009) who use American mortality data from 1972 to 2004 to investigate possible mechanisms to help explain the pro-cyclicality of mortality.[25] The authors hypothesize that procyclical motor vehicle

[25] They find, like in the Ruhm papers, that the estimated effect of business cycles is largest in magnitude

fatalities may be due to either changes in individual behaviour or externalities such as the increased number of vehicles on the road in good times. They report that the estimated effect of the UR on motor vehicle fatalities is of similar magnitude across all age groups, and take this to suggest that the externalities explanation is the more reasonable. However, because accidents often involve other vehicles, it is plausible that even if the increase in dangerous driving in good times is primarily experienced by those of prime age - a situation possibly exacerbated by increased number of vehicles on the - adverse affects on all motorists would still be expected. The increase in the number of motor vehicle fatalities would be expected to be highest for prime aged individuals (which they predict) but be affecting all age groups (which they predict as well).

Evidence of the countercyclical nature of sleep time can help direct policy – particularly for maintaining population health and reducing risks of accidents and illness. Further to the extent that sleep time affects productivity, understanding the determinants of sleep can help employers encourage behaviours that promote productive workforces.

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for motor vehicle fatalities as compared to 11 other causes of death. The largest decline in motor vehicle fatalities, resulting from a one percentage point increase in the UR, is predicted for individuals 18-54 years of age and accounts for 73 percent of the overall decrease.

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Appendix

Appendix A– Sample Restrictions

We excluded from our sample individuals that were younger than 20, and older the 69. We also excluded those whose main activity was studying, as identified by the ACT7DAYS variable.

In addition to the above restrictions, we dropped observations

1. if there is missing information for age, gender, marital status, education, student status, the presence of children 4 years and under, province of residence, or the day of the time diary, or;

2. if the unaccounted time exceeded 15 minutes. This unaccounted time could be due to a missing gap in time or to the fact that the respondent refuses to account for a period of time, or;

3. If the phone interview day is more than two days apart from the diary day. One would expect more recall problems the further apart are the diary and interviewer day.

Following the sample restrictions mentioned above, we are left with a sample of 28,380 individual observations.

Appendix B - Reverse Causality and Omitted Variable Problems

Assume the following simple model:

$$sleep_i = \alpha_0 + \alpha_1 UR_i + \alpha_2 phealth_i + \varepsilon_i \quad (4)$$

$$phealth_i = \beta_0 + \beta_1 UR_i + \beta_2 sleep_i + \nu_i \quad (5)$$

If we were to regress

$$\tilde{sleep}_i = \alpha_1 \tilde{UR}_i + \alpha_2 \tilde{phealth}_i + \tilde{\varepsilon}_i \quad (6)$$

$$\tilde{\mathbf{sleep}} = \tilde{\mathbf{X}}\alpha + \tilde{\varepsilon}$$

where $\tilde{z}_i = z_i - \bar{z}$, and

$$\tilde{\mathbf{X}} = \begin{bmatrix} \vdots & \vdots \\ \tilde{UR}_i & \tilde{phealth}_i \\ \vdots & \vdots \end{bmatrix},$$

the OLS estimator for α would be defined as

$$\begin{aligned} \hat{\alpha} &= (\tilde{\mathbf{X}}'\tilde{\mathbf{X}})^{-1}\tilde{\mathbf{X}}'\tilde{\mathbf{sleep}} \\ &= \alpha + (\tilde{\mathbf{X}}'\tilde{\mathbf{X}})^{-1}\tilde{\mathbf{X}}'\tilde{\varepsilon} \end{aligned}$$

Then,

$$\begin{aligned} plim\ \hat{\alpha} &= \alpha + plim\left(\frac{\tilde{\mathbf{X}}'\tilde{\mathbf{X}}}{n}\right)^{-1} plim\left(\frac{\tilde{\mathbf{X}}'\tilde{\varepsilon}}{n}\right) \\ &= \alpha + Q^{-1} plim\left(\frac{\tilde{\mathbf{X}}'\tilde{\varepsilon}}{n}\right) \end{aligned}$$

Since

$$\frac{\tilde{\mathbf{X}}'\tilde{\varepsilon}}{n} = \begin{bmatrix} \sum(\tilde{UR}_i\tilde{\varepsilon}_i)/n \\ \sum(\tilde{phealth}_i\tilde{\varepsilon}_i)/n \end{bmatrix},$$

then

$$plim\left(\frac{\tilde{\mathbf{X}}'\tilde{\varepsilon}}{n}\right) = \begin{bmatrix} 0 \\ cov(phealth_i, \varepsilon_i) \end{bmatrix}.$$

Therefore

$$plim\ \hat{\alpha} = \alpha + Q^{-1}\begin{bmatrix} 0 \\ cov(phealth_i, \varepsilon_i) \end{bmatrix}$$

Now,

$$\tilde{\mathbf{X}}'\tilde{\mathbf{X}} = \begin{bmatrix} \sum \tilde{UR}_i^2 & \sum \tilde{UR}_i \tilde{phealth}_i \\ \sum \tilde{UR}_i \tilde{phealth}_i & \sum \tilde{phealth}_i^2 \end{bmatrix}$$

$$(\tilde{\mathbf{X}}'\tilde{\mathbf{X}})^{-1} = \frac{1}{\sum \tilde{UR}_i^2 \sum \tilde{phealth}_i^2 - (\sum \tilde{UR}_i \tilde{phealth}_i)^2} \begin{bmatrix} \sum \tilde{phealth}_i^2 & -\sum \tilde{UR}_i \tilde{phealth}_i \\ -\sum \tilde{UR}_i \tilde{phealth}_i & \sum \tilde{UR}_i^2 \end{bmatrix}$$

$$plim \left(\frac{\tilde{\mathbf{X}}'\tilde{\mathbf{X}}}{n} \right)^{-1} = \begin{bmatrix} \left[var(UR_i) - \frac{(cov(UR_i, phealth_i))^2}{var(phealth_i)} \right]^{-1} & \left[cov(UR_i, phealth_i) - \frac{var(phealth_i)var(UR_i)}{cov(UR_i, phealth_i)} \right]^{-1} \\ \left[cov(UR_i, phealth_i) - \frac{var(phealth_i)var(UR_i)}{cov(UR_i, phealth_i)} \right]^{-1} & \left[var(phealth_i) - \frac{(cov(UR_i, phealth_i))^2}{var(UR_i)} \right]^{-1} \end{bmatrix}$$

Finally, we get

$$plim \ \hat{\alpha} = \alpha + \begin{bmatrix} \left[cov(UR_i, phealth_i)(1 - 1/\rho^2) \right]^{-1} cov(phealth_i, \varepsilon_i) \\ \left[var(phealth_i)(1 - \rho^2) \right]^{-1} cov(phealth_i, \varepsilon_i) \end{bmatrix} \tag{7}$$

where $\rho = corr(UR_i, phealth_i)$.We care about the top element of the vector in equation (7). If we believe Ruhm's findings, then we'd expect to have

$$\left[cov(UR_i, phealth_i)(1 - 1/\rho^2) \right]^{-1} \geq 0$$

Now if we plug equation (4) in equation (5), we get

$$phealth_i = \left(\frac{\beta_0 + \beta_2 \alpha_0}{1 - \beta_2 \alpha_2} \right) + \left(\frac{\beta_1 + \beta_2 \alpha_1}{1 - \beta_2 \alpha_2} \right) UR_i + \left(\frac{\beta_2 \varepsilon_i + \nu_i}{1 - \beta_2 \alpha_2} \right) \tag{8}$$

Hence,

$$cov(phealth_i, \varepsilon_i) = cov \left(\frac{\beta_2 \varepsilon_i + \nu_i}{1 - \beta_2 \alpha_2}, \varepsilon_i \right)$$

if we assume $cov(UR_i, \varepsilon_i) = 0$. We get

$$cov(phealth_i, \varepsilon_i) = \frac{\beta_2}{1 - \beta_2 \alpha_2} var(\varepsilon_i) + \frac{1}{1 - \beta_2 \alpha_2} cov(\varepsilon_i, \nu_i)$$

We expect $\beta_2 < 0$ and $\alpha_2 > 0$. Then $1 - \beta_2 \alpha_2 > 0$. Let

$$\begin{aligned} \phi_1 &= \frac{\beta_2}{1 - \beta_2 \alpha_2} \\ \phi_2 &= \frac{1}{1 - \beta_2 \alpha_2} \end{aligned}$$

Then,

$$\begin{aligned} cov(phealth_i, \varepsilon_i) &= \phi_1 var(\varepsilon_i) + \phi_2 cov(\varepsilon_i, \nu_i) \\ &= (-)(+) + (+)(?) \end{aligned}$$

If $cov(\varepsilon_i, \nu_i) \leq 0$, then $plim\hat{\alpha} < \alpha$. Also, if $cov(\varepsilon_i, \nu_i) > 0$ but $|\phi_1 var(\varepsilon_i)| > \phi_2 cov(\varepsilon_i, \nu_i)$ (i.e. the reverse causality problem dominates the omitted variable problem), then $plim\hat{\alpha} < \alpha$. The only problematic case is when $|\phi_1 var(\varepsilon_i)| < \phi_2 cov(\varepsilon_i, \nu_i)$ (i.e when the omitted variable problem dominates the reverse causality problem).

If instead of estimating equation (6) we estimated the reduced form equation

$$sleep_i = \omega_0 + \omega_1 UR_i + u_i \tag{9}$$

where

$$\begin{aligned} \omega_0 &= \frac{\alpha_0 + \alpha_2\beta_0}{1 - \beta_2\alpha_2} \\ \omega_1 &= \frac{\alpha_1 + \alpha_2\beta_1}{1 - \beta_2\alpha_2} \\ u_i &= \frac{\alpha_2\nu_i + \varepsilon_i}{1 - \beta_2\alpha_2} \end{aligned}$$

and again assume assume that $cov(UR_i, \varepsilon_i) = cov(UR_i, \nu_i) = 0$, then we would expect to have $plim\ \hat{\omega}_1 = \omega_1$. Of course, except under very special circumstances (e.g. $\alpha_2 = 0$), we should have $\omega_1 \neq \alpha_1$. We can still say something about α_1 if we are willing to make some common sense assumptions about some parameters. First, we have to assume, as we did above, that sleep is good for your health (i.e. $\beta_2 < 0$) and that illness forces you to sleep more (i.e. $\alpha_2 > 0$). We also assume that the Ruhm (2000) findings are correct; bad economic outcomes are good for your health (i.e. $\beta_1 < 0$). Then, we can see that

$$plim\ \hat{\omega}_1 = \omega_1 < \alpha_1$$

Hence, OLS estimates of ω_1 in the reduced form equation (9) should give us a conservative estimate of α_1 regardless of the correlation between the error terms ε_i and ν_i.

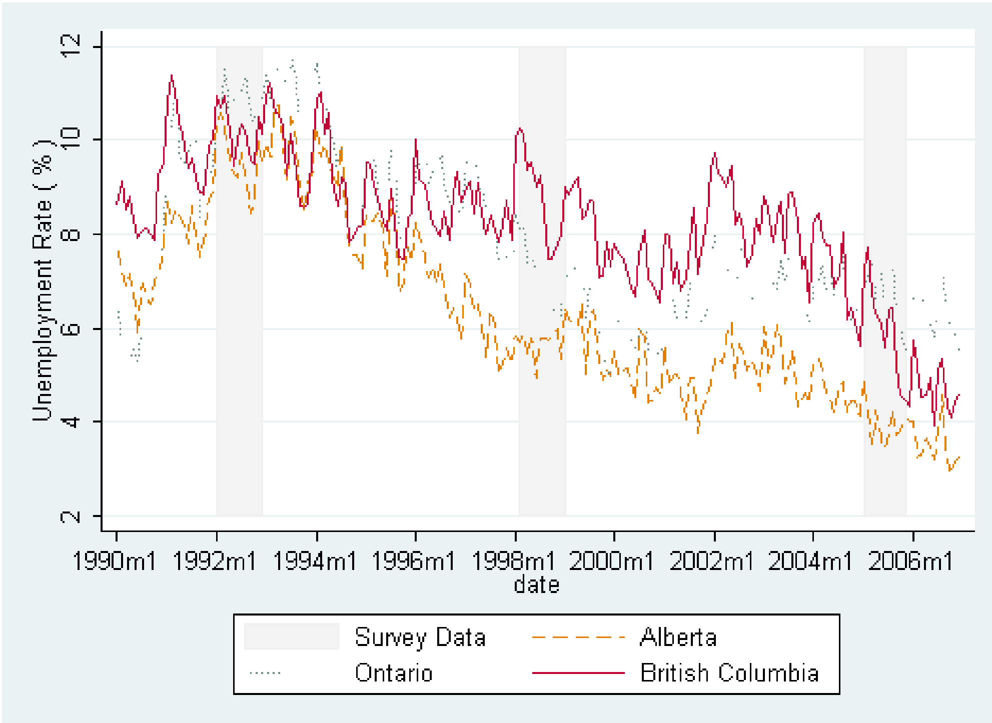

Figure 1: Provincial Unemployment Rates Across Time

Table 1: Summary Statistics for Sleep: Mean and standard deviations in brackets

	Men (n=12,988)	Women (n=15,392)
Whole Sample	55.091	56.907
	(13.602)	(12.281)
Married	54.675	56.836
	(12.794)	(11.559)
With Children < 5	53.748	56.243
	(12.850)	(11.684)
HS Dropout	55.579	58.197
	(13.697)	(12.460)
HS Graduate	56.127	57.609
	(14.882)	(12.263)
Some Post Secondary	55.069	56.519
	(14.173)	(12.157)
College Graduate	54.544	56.257
	(12.865)	(12.208)
Employed	54.282	55.953
	(13.532)	(12.349)

*Using individuals 20 to 69 years of age. The summary statistics are weighted. The weights are normalized to sum up to one for each time-use survey.

Table 2: Overall Results

	(1)	(2)	(3)	(4)
Unemployment Rate	0.500***	0.493***	0.513***	0.512***
	(0.112)	(0.107)	(0.104)	(0.104)
Male	-	-1.805***	-2.035***	-2.015***
	-	(0.208)	(0.210)	(0.209)
Married	-	-	0.336	0.394*
	-	-	(0.233)	(0.233)
Children Under 4	-	-	-0.531*	-0.535*
	-	-	(0.288)	(0.287)
Children Under 18	-	-	-0.857***	-0.840***
	-	-	(0.264)	(0.263)
Dayoff	-	-	5.985***	6.035***
	-	-	(0.306)	(0.307)
Poor Health	-	-	-	1.380***
	-	-	-	(0.263)
Province Fixed Effects	Yes	Yes	Yes	Yes
Month-Year Fixed Effects	Yes	Yes	Yes	Yes
Day Fixed Effects	Yes	Yes	Yes	Yes
Age and Education Controls	No	Yes	Yes	Yes
Observations	28,380	28,380	28,380	28,380
R-squared	0.07	0.09	0.12	0.12

Dependent variable: Weekly Hours of Sleep
Standard errors clustered at the province-month level
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 3: Overall Results Aged 30-49

	(1)	(2)	(3)	(4)
Unemployment Rate	0.628***	0.606***	0.596***	0.593***
	(0.143)	(0.141)	(0.141)	(0.141)
Male	-	-1.828***	-2.054***	-2.038***
	-	(0.252)	(0.249)	(0.246)
Married	-	-	-0.087	-0.048
	-	-	(0.329)	(0.328)
Children Under 4	-	-	-0.581*	-0.573
	-	-	(0.350)	(0.351)
Children Under 18	-	-	-0.765**	-0.750**
	-	-	(0.309)	(0.307)
Dayoff	-	-	6.098***	6.132***
	-	-	(0.392)	(0.392)
Poor Health	-	-	-	1.100***
	-	-	-	(0.394)
Province Fixed Effects	Yes	Yes	Yes	Yes
Month-Year Fixed Effects	Yes	Yes	Yes	Yes
Day Fixed Effects	Yes	Yes	Yes	Yes
Age and Education Controls	No	Yes	Yes	Yes
Observations	14,008	14,008	14,008	14,008
R-squared	0.09	0.10	0.13	0.13

Dependent variable: Weekly Hours of Sleep
Standard errors clustered at the province-month level
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Male-Female Comparison - Prime Age (30 to 49 years of age)

	Overall	Male	Female
	(1)	(2)	(3)
Unemployment Rate	0.593***	0.741***	0.438**
	(0.141)	(0.202)	(0.172)
Male	-2.038***	-	-
	(0.246)	-	-
Married	-0.048	0.193	-0.250
	(0.328)	(0.511)	(0.431)
Children Under 4	-0.573	-0.618	-0.638
	(0.351)	(0.564)	(0.482)
Children Under 18	-0.750**	-1.091**	-0.481
	(0.307)	(0.463)	(0.442)
Dayoff	6.132***	7.272***	4.982***
	(0.392)	(0.644)	(0.511)
Poor Health	1.100***	0.738	1.255***
	(0.394)	(0.687)	(0.476)
Province Fixed Effects	Yes	Yes	Yes
Month-Year Fixed Effects	Yes	Yes	Yes
Day Fixed Effects	Yes	Yes	Yes
Education Controls	Yes	Yes	Yes
Age Controls	Yes	Yes	Yes
Observations	14,008	6,478	7,530
R-squared	0.13	0.15	0.12

Dependent variable: Weekly Hours of Sleep
Standard errors in parentheses. The standard errors are clustered at the province-month-year level.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 5: Robustness Check - Prime Age (30 to 49 years of age)

	(1)	(2)	(3)	(4)	(5)	(6)
				A. Men		
Unemployment Rate	0.741***	0.707***	0.743***	0.731***	0.506**	0.518**
	(0.202)	(0.211)	(0.202)	(0.201)	(0.237)	(0.206)
Married	0.193	0.386	0.167	0.140	-0.005	0.718
	(0.511)	(0.535)	(0.507)	(0.511)	(0.534)	(0.534)
Children Under 4	-0.618	-0.377	-0.626	-0.611	-0.510	-0.731
	(0.564)	(0.565)	(0.563)	(0.562)	(0.541)	(0.573)
Children Under 18	-1.091**	-1.128**	-1.092**	-1.128**	-0.264	-1.136**
	(0.463)	(0.486)	(0.464)	(0.463)	(0.534)	(0.471)
Dayoff	7.272***	7.298***	7.250***	7.261***	3.616***	8.865***
	(0.644)	(0.702)	(0.644)	(0.647)	(0.562)	(0.687)
Poor Health	0.738	-	-	1.072	-0.153	-0.553
	(0.687)	-	-	(0.689)	(0.614)	(0.796)
Problem sleeping	-	-	-	-1.374***	-	-
	-	-	-	(0.473)	-	-
Observations	6478	5757	6478	6472	5989	5701
R-squared	0.15	0.15	0.15	0.15	.07	0.18
				B. Women		
Unemployment Rate	0.438**	0.495***	0.437**	0.411**	0.402**	0.169
	(0.172)	(0.169)	(0.172)	(0.172)	(0.163)	(0.194)
Married	-0.250	-0.190	-0.295	-0.332	-0.210	0.325
	(0.431)	(0.438)	(0.432)	(0.428)	(0.411)	(0.417)
Children Under 4	-0.638	-0.761	-0.645	-0.733	-1.145**	-1.461**
	(0.482)	(0.509)	(0.483)	(0.487)	(0.507)	(0.658)
Children Under 18	-0.481	-0.190	-0.512	-0.515	-0.540	-0.508
	(0.442)	(0.473)	(0.446)	(0.437)	(0.420)	(0.436)
Dayoff	4.982***	4.832***	4.944***	4.930***	2.561***	7.511***
	(0.511)	(0.517)	(0.507)	(0.503)	(0.551)	(0.534)
Poor Health	1.255***	-	-	1.899***	0.155	-0.173
	(0.476)	-	-	(0.513)	(0.523)	(0.662)
Problem sleeping	-	-	-	-2.368***	-	-
	-	-	-	(0.442)	-	-
Observations	7530	6619	7530	7521	7102	5105
R-squared	0.12	0.13	0.12	0.13	0.07	0.18

Dependent variable: Weekly Hours of Sleep. For Specification (5) we use an alternative measure of sleep
All specifications includes education, age, day, province and month-year controls
Specification (2) excludes individuals in poor health; Specification (6) excludes those that are unemployed
Standard errors in parentheses. The standard errors are clustered at the province-month-year level
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 6: Sleep, Work, and Leisure 30 to 49 Years of Age

	Males		Females	
Dependant Variable	Sleep	Work	Sleep	Work
		A. Workers Only		
Unemployment Rate	0.518**	-0.581*	0.169	0.218
	(0.206)	(0.311)	(0.194)	(0.303)
		B. Full Sample (No Employment Status Control)		
Unemployment Rate	0.741***	-1.526***	0.438**	-0.016
	(0.202)	(0.410)	(0.172)	(0.503)

All specifications include controls for marital status, presence of children under 4, presence of children under 4, presence of children under 18, dayoff, health status, province fixed effects, month-year fixed effects, and day fixed effects. Standard errors clustered at the province-month level
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 7: UR, Wages and Education 30 to 49 Years of Age

	Males				Females			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Unemployment Rate	0.522**	-	-	0.503**	0.181	-	-	0.159
	(0.203)	-	-	(0.206)	(0.193)	-	-	(0.194)
ln(income)	-	-	-0.883***	-0.918***	-	-	-0.235	-0.133
	-	-	(0.275)	(0.271)	-	-	(0.164)	(0.166)
HS Graduate	-	0.695	-	0.792	-	-1.119	-	-1.134
	-	(0.850)	-	(0.849)	-	(0.843)	-	(0.837)
Some Post Secondary	-	-1.031	-	-0.865	-	-1.159	-	-1.103
	-	(0.747)	-	(0.742)	-	(0.918)	-	(0.910)
College Graduate	-	0.123	-	0.433	-	-2.073**	-	-1.976**
	-	(0.655)	-	(0.657)	-	(0.840)	-	(0.842)
Observations	5,701	5,701	5,701	5,701	5,105	5,105	5,105	5,105
R-squared	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18

Dependent variable: Weekly Hours of Sleep
All specifications include controls for marital status, presence of children under 4, presence of children under 18, dayoff, health status, province fixed effects, month-year fixed effects, missing income, and day fixed effects.
Standard errors clustered at the province-month level
* significant at 10%; ** significant at 5%; *** significant at 1%