Timing Matters:
Worker Absenteeism in a Weekly Backward Rotating Shift Model

Abstract

Objectives: We analyze the impact of the positioning of shifts (morning, afternoon, night) on worker absenteeism in a large German automobile plant.

Methods: Using a completely balanced panel of 153 organizational units over the two-year-period 2009 to 2010 (i.e. 104 consecutive weeks with 15,912 unit-week-observations) we estimate a series of GLM and Fixed Effects models.

Results: Our main finding is that during afternoon shifts absence rates are significantly higher than during either morning or night shifts and that absence rates are particularly high during the afternoon shift immediately following the three weeks of consecutive night shifts. We attribute our first finding to the “social opportunity costs” of working and the second one to a “tax evasion effect”.

Conclusions: When designing new shift models, firms should try to anticipate their workers’ reaction to avoid unintended incentives.

Keywords: Shiftwork, Absenteeism, Pay Premium, Tax Incentives

JEL-Code: M54, J22, L62

Declarations

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Introduction

Shift work is widely used in most industrialized countries. In the EU for example about 17 percent of the entire workforce do shift work (Eurofound 2012). In the US, the share of employees doing shift work is nearly identical at 18 percent (McMenamin 2007). The widespread use of shift work is due to the fact that in many industries such as health care, food services, police and fire departments as well as in large sectors of the manufacturing industry (e.g. steel, chemicals and automobiles) productive activities have to be organized on a 24-hour basis – be it for safety reasons or due to the capital intensity of production. Thus, shift work is often indispensable due to social as well as economic reasons. However, shiftwork is clearly associated with a number of health risks for workers. These include sleeping problems, gastrointestinal and cardiovascular diseases (Åkerstedt 2003, Nakata et al. 2004, Knutsson, 2003 and Knutsson and Bøggild 2010) plus compromised pregnancy (Knutsson, 2003). Since shift work has been found to increase the risk for several negative health outcomes, many occupational medicine and public health specialists conjecture that it will also be associated with higher absence rates for shift workers compared to those working regular hours (Kleiven et al. 1998).

Research findings from the occupational medicine and public health literatures point to a lack of straightforward association between shift work and absenteeism. The meta study by Merkus et al (2012) found that fixed evening work was positively associated with sick leave amongst female healthcare workers. However, the authors concluded that there was inconclusive evidence from the selected studies for an association between fixed night shift work and sick leave. This points towards a need for further research that distinguishes closely between types of shift work and rotational shift patterns. These arguments were echoed by the work of Catano and Bissonnette (2014) who used Canadian data from three national surveys of 14 occupational groups. Contrary to the above prior conjecture, the authors found that shift workers took less paid sickness than day workers. However, working rotating shifts was a positive and significant predictor of sickness absence. Rotating shift patterns is a particular focus of our study. Moreover, unlike the studies noted above we use employee personnel records as our data source rather than self-reported survey data.

Focusing on short absence spells Böckerman and Laukkanen (2010) as well as Ropponen et al. (2019) found a positive association between shift work and absence rates. Frick et al. (2018) found that a change from a shift schedule that is considered by occupational medicine specialists to be associated with relatively high health risks for workers (backward rotation, three weeks of night work) to an ergonomically more advantageous schedule (weekly forward rotation) leads to an immediate decrease in workers' absence rates. This finding suggests that the design of the particular shift model (e.g. forward vs. backward rotation) can potentially have an adverse impact on workers' physiological health outcomes (for similar findings on psychological health outcomes see Van Amelsvoort et al. 2004). However, due to the structure of the data used in Böckerman and Laukkanen (2010), Ropponen et al. (2019) and Frick et al. (2018), it was not possible to separate the effects of the different positioning of the shifts (i.e. morning, afternoon, night) on worker absence rates and this remains a gap in the absenteeism literature.

Hence, in this study we focus on how the different positioning of shifts (morning, afternoon, night) within a particular shift model influences absence rates, defined in our case as proportion of potential worker-hours in a production unit declared by the firm as absences in a given week, where absences are for any reason and not just for reasons connected to illness.[1] We use a unique data set from one plant of a large German automobile manufacturer with complete information on weekly unit-level absence rates for 153 organizational units over a period of 104 consecutive weeks. Over this period the units worked in a shift model of six weeks of weekly rotation from afternoon shift to morning shift and three consecutive weeks of night shift, after which the nine-week cycle started all over again.

[1] In Germany, workers do not have to present a doctor's certificate stating that they are unable to come to work for absence spells shorter than three days.

As a preview of our empirical results, we find morning and night shifts to be associated with reduced absence rates compared to afternoon shifts. The first afternoon shift week following three weeks of night shift stands out prominently and is associated with the highest absence rates of all weeks in the shift model under consideration. At first sight, two competing explanations for this result seem equally plausible. One explanation is that high absence rates in the first afternoon shift may be due to the stress and strain accumulated over the course of the three consecutive weeks of night shift. Another (alternative) explanation is that workers "postpone" absences from the night shift towards the first week of afternoon shift to avoid taxation of the night shift premium.

The remainder of the paper is structured as follows: Section 2 provides a review of the relevant literature and section 3 presents the data including a description of the shift model used in the respective plant of the automobile company. Subsequently, section 4 presents the hypotheses guiding our study. In section 5 we display descriptive evidence while section 6 provides the econometric evidence on the absence effects of the different positioning of the shifts. Finally, section 7 concludes.

Background

There is substantive evidence that shift work is detrimental to worker health due to both, the impact changing working hours and working at uncommon times have on the circadian rhythm of psychophysiological functions (Harrington 2001). This negative impact seems to occur in the short term as well as in the long term (Knutsson 2003, Kantermann et al. 2010). Moreover, shift work has been found to be associated with a number of negative health consequences, in particular including a higher probability of experiencing sleeping problems, such as shortened sleep, insomnia and the resulting fatigue (Åkerstedt 2003, Drake et al. 2004, Sallinen and Kecklund 2010). Furthermore, shift work is considered to increase the risk of physical health problems such as gastrointestinal diseases, e.g. stomach pain, ulcer or diarrhoea (Knutsson and Bøggild 2010). Moreover, there seems to exist a robust relation between shift work and the symptoms of the metabolic syndrome, e.g. obesity or elevated blood pressure (Esquirol et al. 2009, Canuto et al. 2013), as well as between shift work and cardiovascular diseases (Angersbach et al. 1980, Bøggild and Knutsson 1999). A study by Wang et al. (2011) found the relationship between shift work and coronary heart diseases to be spurious at best. However, more recently, Vetter et al. (2016) and Abu Farha and Alefishal (2018) found evidence of a positive association between shift work and risk of cardiovascular disease. The former study showed that a longer duration of rotating night shifts was positively and significantly associated with increased risk of cardiovascular disease. The latter study on Jordanian workers found that performing night shift work irrespective of its duration significantly raised the risk of cardiovascular disease.

There is, therefore, a plethora of literature going beyond effects of shift work on health outcomes related to circadian rhythms. This literature even extends to risk of mortality of shift workers. These latter papers not only consider the impact of shift work on all-cause mortality, but also how various sources of mortality risk, such as diabetes and dementia, can be exacerbated by shift work. The results of these studies are, however, difficult to reconcile. Based on a large sample of nearly 9,000 male manual workers in England and Wales, Taylor and Pocock (1972: 207) conclude "that shift work appears to have no adverse effect upon mortality". Using an even larger sample of some 18,000 Danish nurses, Jørgensen et al. (2017), however, found that working night or evening shifts was associated with a significant increase in all-cause mortality when compared to working day shift.

Over and above the documented negative health effects, shift work is considered as a risk factor for the social and psychological well-being of employees (Costa 2003). People working in shifts or during the night are at risk to be "socially marginalized", e.g. facing greater problems in the organization of their social lives since the majority of social activities are arranged according to the day-oriented rhythm of society (Jansen et al. 2004). Focusing on the effects of shift work on family life, Kantermann et al. (2010) argued that these have so far remained largely unexplored in academic research. However, using data from two waves of the National Survey of Families and Household in the US, Presser (2000) found night work and rotating shifts to negatively affect marital stability. Moreover, comparing a US sample of workers on rotating shifts with employees working standard hours, Grosswald (2003) found negative work-to-family spillover effects. Finally, using data from the US National Longitudinal Survey of Youth-Child Supplement, Han (2008) found that maternal shift work is associated with a significantly higher probability of behavioral problems of their children.

Given the association of shift work with negative short- and long-term health outcomes for workers, it is reasonable to hypothesize that shift work is likely to be associated with higher rates of absenteeism because diseases and illnesses are commonly considered as the main determinants of employee absence rates (Meyer et al. 2013). Some research has uncovered a relationship between shift work and absence rates attached to paid sick leave (Catano and Bisonnette 2014, Lesuffleur et al. 2014). However, Kleiven, Bøggild and Jeppesen (1998) failed to find a statistically significant difference in the probability of sick leave among shift workers and day workers in an 11-year study of workers in a Norwegian chemical plant. Similarly, Catano and Bisonette (2014) using data on more than 20,000 Canadian workers from different industries also failed to identify a robust relation between shift work and sickness absence rates. However, the authors find that working on rotating shifts increases absence rates.

Contrary to the results presented so far, Böckermann and Laukkanen (2009) identified absence rates to be eight percent higher for shift workers compared to non-shift workers among Finnish union members working in a broad range of industries. Finally, in their systematic review of nine studies on the link between shift work and sickness absence, Merkus et al. (2012) reported a statistically significant relationship between shift work and absence rates only for fixed evening work among female health care workers. No such result for an association between absenteeism and other shift schedules such as e.g. rotating shifts or fixed night shifts seems to exist. However, it is worth noting that the studies included in this meta-analysis mainly focus on absence spells of more than one week, leaving out short-term absenteeism that may also be associated with shift work.

The available research only focuses on the comparison of health risks between shift and non-shift work. The existence of differences in e.g. absence rates between different shift models (Barton and Folkard 1993, Hakola and Härmä 2001, Van Amelsvoort et al. 2004, Härmä et al. 2006) raises the question to what extent the particular design and the organization of shift work may have an impact on the negative health outcomes that are usually associated with shift work in general. Apart from the health consequences of shiftwork itself the question whether the different positioning of shifts – morning, afternoon or night shift – has any impact on worker well-being and health is highly relevant from a health as well as from an economic perspective. Night work has been found to be associated with reduced productivity of workers compared to afternoon and morning shifts (Vidacek et al. 1986). Moreover, accident risks have found to be higher during afternoon and night shifts compared to morning shifts (Smith et al. 1994). Finally, the risk of accidents has been found to increase significantly over the course of successive afternoon as well as night shifts (Folkard and Tucker 2003).

Summarizing, only a small portion of the available literature on shiftwork induced absenteeism takes into consideration that non-health related factors may affect the absence decisions of workers. Kristensen et al. (2006) and Løkke Nielsen (2008) emphasized the importance of motivational factors in the decision-making process of workers to absent themselves from work, but fail to document a robust relationship. We attempt to close this gap in the literature.

Data

We used a unique dataset including weekly information on absence rates in 153 organizational units with some 3,000 production workers in one particular plant of a large German automobile company to analyze the impact of the positioning of shifts (morning, afternoon or night shift) on worker absence rates as recorded by the company. We should stress that the recorded absences cover more than just sickness-related absence. They include paid leave for a variety of reasons such as parental leave, family weddings and funerals and attendance at training events. Anecdotal evidence from the company suggests that the bulk of absences were sickness-related.

Although the production units were exclusively shop-floor units, they were nevertheless heterogeneous in terms of the operational area they were located in (pressing plant, body shop, paint shop, assembly line, etc.). The observation period ranged from January 2009 to December 2010 and covered 104 consecutive weeks (yielding 15,912 unit-week observations). Work for the different shift groups started at 6:30 am, 2:30 pm and 10:30 pm. Over the entire observation period, all units worked under a shift model that required six weeks of weekly backward rotation from afternoon to morning shift followed by three consecutive weeks of night shift (see Figure 1). Rotation speed therefore was considered to be relatively slow in this particular shift model. Moreover, the shift model was classified as discontinuous with workdays ranging from Monday to Friday with weekends off.

Figure 1
The Shift Model (January 2009 until December 2010)

Week	1	2	3	4	5	6	7	8	9
Shift	Afternoon	Morning	Afternoon	Morning	Afternoon	Morning	Night	Night	Night

Furthermore, German mandatory legal requirements (Arbeitszeitgesetz (ArbZG) 1994) stipulate that employees have to be compensated for working late hours either through additional days off or through an adequate monetary premium.[2] In the plant

[2] The collective bargaining agreements the company had signed with IG Metall stipulated that the

that we study here, night shifts have always been subject to this premium and are, therefore, particularly rewarding from an income perspective.[3] If workers call in sick during night shifts, they are, of course, entitled to their full regular pay. However, the premium coming with night shift work – which is under normal circumstances exempt from personal income tax (Einkommensteuergesetz (EStG) 2009) – is then subject to taxation.[4] Thus, workers had (and still have) considerable incentives to "postpone" absences from the night shift towards the first afternoon shift to avoid taxation of their night shift premium, which would result in an income loss of around 20 € per day[5].

The data we used here came from the company's records and was provided by the Human Resource Department. This means that the quality of the data is better, in terms of accuracy, than in most studies using self-reported measures of absenteeism (Løkke and Nielsen 2008). Self-reported absence days (as used by e.g. Eriksen et al. 2003; Catano and Bisonette 2014) have been found to be biased downward because workers tend to underreport their true level of absenteeism. Johns (1994), for example, finds the level of absenteeism reported by individual workers to account for only half of the absences recorded by firms. Another advantage of our data was the inclusion of short-term absence spells, since in the data set absence spells were reported from the very first day (workers tend not to recall short absence spells of one or two days). Since shift work is related to a number of short- and long-term health consequences, it appears reasonable to conclude that including short spells of absence is advantageous compared to including only longer absence spells as has frequently been done in the literature (e.g. Bourbonnais 1992, Tüchsen et al. 2008).

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compensation for working late hours is monetary and not in the form of days off.

[3] The night shift premium in our particular case was 30% of hourly wages for the time between 8:00 pm and midnight, 45% for the time between midnight and 4:00 am and 30% for the time between 4:00 am and 6:00 am (IG Metall 2008). This implies that not only night shifts (10:30 pm to 6:30 am) were subject to a premium but also – to a lower extent – late shifts (in the time between 8:00 pm to 10:30 pm).

[4] The German income tax act states that premiums of up to 25% of hourly wages for working late hours (8:00 pm to 6:00 am) are exempt from income tax. Additionally, for the time between midnight and 4:00 am night work premiums of up to 40% of hourly wages are exempt from income tax.

[5] The calculation of the monetary incentive to postpone a sickness spell is based on the average annual income of production workers in the company, the average income tax rate and the premium paid during the respective shift.

Hypotheses

We conjecture that at least to some extent the absence rates of workers are determined by the particular incentives generated by the obligatory taxation of the night shift premium in the case of a worker being absent. The design of the shift model implemented in the plant that we study here provides us with the opportunity to test this hypothesis in detail, extending the list of factors affecting absence behavior of production workers beyond the list of health related issues already discussed in the respective literature by taking motivational aspects into consideration too.

Working night shifts is associated with a higher probability of particular health problems and/or a lower level of mental well-being especially in a shift system with three weeks of consecutive night shifts. Therefore, occupational medicine specialists expect absence rates among automobile workers to be higher during night shifts than during either morning or afternoon shifts ($H_{1.1}$). From an economics perspective, however, workers forfeit the respective pay premium by not showing up for work during night shifts. Therefore, we conjecture absenteeism to be lower in the night than during either morning or afternoon shifts ($H_{1.2}$). The question whether the (negative) "health effects" – as hypothesized in $H_{1.1}$ - dominate the (positive) "pay effect" – as hypothesized in $H_{1.2}$ – or vice versa is an empirical one that we will answer in the descriptive as well as the econometric part of our paper (sections 5 and 6 below).

Working afternoon shifts is associated with a rather low level of stress and strain (due to e.g. its compatibility with the circadian rhythm of psychophysiological functions). Hence, occupational medicine specialists expect absence rates to be lower in afternoon than during either morning or night shifts, which both interfere substantially more with the circadian rhythm ($H_{2.1}$). From an economics perspective, however, the "social opportunity costs" of working are particularly high in the afternoon and the evening (when family and friends are enjoying their leisure time). Thus, we expect absenteeism to be higher in the afternoon than during either morning or nights shifts ($H_{2.2}$). Thus, the question, whether the (positive) "health effects" ($H_{2.1}$) dominate the (negative) "social opportunity cost effect" ($H_{2.2}$) or vice versa is again an empirical one that we seek to answer below.

Finally, since stress and strain associated with working night shifts accumulate over time, occupational medicine specialists expect absence rates to increase over the three consecutive weeks that automobile workers are on night shift with the highest absence rate in the very last week (H_3). From an economics perspective, the "incentive effect" of the pay premium will dominate the (negative) health effects of working in the night. Thus, we conjecture that absenteeism will be more or less constant across the three night shift weeks and particularly high in the first week after these night shift weeks. This is due to the fact that workers have a monetary incentive to postpone sickness spells from the night shift period to retain their full pay premium (H_4).

Descriptive Analysis

It is worth pointing out that the data we use here includes only a small number of "internal" explanatory variables, such as the number of employees per unit and the respective units' projected absence rate. The latter variable mirrors the differences in socio-demographic characteristics between the units in the sense that projected absenteeism is calculated (and constantly updated) by the company's human resource department taking into account the age, gender and qualification of the units' members: A 35 year-old female production worker for example is expected to be absent from work 5.2 percent of the time while a 25 year-old male white-collar employee is expected to be absent from work only 1.0 percent of the time. Since for data protection reasons the socio-demographic characteristics of the units were not available to us, we consider the projected absence rate a good proxy for the respective units' composition. Overall, the lack of controls appears not to be a serious problem since personnel turnover is – with less than 4% annually – unusually low at this company. This implies that the composition of the teams in the units remains relatively stable over the entire observation period. In addition, we use various external sources to add additional control variables such as the amount of rain and snow, the average weekly temperature and a proxy for the general level of flus and colds in the area surrounding the plant.

Table 1
Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Observed Absence Rate (in %)	5.75	5.82	0.00	50.00
Projected Absence Rate (in %)	3.65	0.72	1.90	6.68
Number of Employees in Unit	19.96	6.44	8.00	49.00
Air Temperature (in Celsius)	9.32	7.64	-5.84	23.43
Precipitation (Amount of Rain and Snow)	1.75	2.07	0.00	16.43
Flus & Colds (Infected in % of Population)	0.52	0.29	0.18	1.42

Note: Absence rate is defined as proportion of potential worker-hours in a production unit declared by the firm as absences in a given week, expressed as percentage.

Figure 2 displays the development of the weekly absence rates in the different shifts over the observation period. The nadirs in weekly absenteeism occurring during the summer weeks (around week 30 and 80) as well as during the winter weeks (around weeks 1, 52 and 104) stand out remarkably. These low levels of absence during the respective periods are due to the fact that the plant shuts down its operation almost entirely during this time for summer and winter holidays. Furthermore, a seasonal pattern with higher absence rates during the winter weeks (e.g. weeks 45 to 60) compared to lower absenteeism in the warmer summer months (e.g. weeks 25 to 35) emerges. A final observation from the graph is that absenteeism during afternoon shifts (blue line) is higher than during the other shifts for most of the observation period. The initial impression of considerable differences in the absence rates during morning, afternoon and night shifts is supported by the descriptive statistics. On average, morning (5.58%-5.71%) and night shifts (5.25%-5.65%) exhibit lower levels of absence than afternoon shifts (6.00%-6.38%).

Figure 2

Average Percentage Absence Rates in Units over the Different Shifts

These results indicate that the (positive) health effect of working at daytime appears to be dominated by the (negative) social opportunity cost effect – favoring hypothesis $H_{2.2}$ over $H_{2.1}$. Furthermore, the health risks that are (presumably) associated with working night shifts do not show up in higher absence rates which seems to contradict $H_{1.1}$.

Table 2

Descriptive Statistics: % Absence Rates over the Different Shifts

Variable	Mean	Std. Dev.	Min.	Max.
Shift Week 1 (Afternoon)	6.38	6.10	0.00	35.71
Shift Week 2 (Morning)	5.58	5.46	0.00	30.71
Shift Week 3 (Afternoon)	6.00	5.88	0.00	33.33
Shift Week 4 (Morning)	5.71	5.63	0.00	43.47
Shift Week 5 (Afternoon)	6.05	6.14	0.00	50.00
Shift Week 6 (Morning)	5.51	5.74	0.00	35.71

Shift Week 7 (Night)	5.58	5.84	0.00	37.77
Shift Week 8 (Night)	5.25	5.62	0.00	30.76
Shift Week 9 (Night)	5.65	5.85	0.00	33.33

A one-way ANOVA reveals that these differences are statistically significant (F (2, 15,909) = 18.97, p = .000). Moreover, when comparing the absence rates across the different positions of the shifts (A-M-A-M-A-M-N-N-N) it appears again that these are statistically significant (F (2, 15,909) = 5.99, p = .000). Additionally, a Tukey post-hoc test reveals that absence rates are significantly higher during the first week of afternoon shift compared to the remaining morning and night shift weeks. Moreover, the test statistics indicate that there is no difference in absence rates between morning and night shift weeks[6]. Thus, the descriptive evidence suggests statistically significant differences in absence rates, pointing to potential absence effects due to the positioning of shifts.

Estimation and Results

Ideally, randomized control trials should be used to evaluate the impact of different human resource management practices in general and of different shift systems in particular on worker (health) outcomes (such as in e.g. Bloom et al. 2013). However, implementing such an experimental design in a German company appears difficult due to the strong works council influence which has the right to object, arguing that employees must not be treated like "examination objects".[7] That was the case in our study. Therefore, our empirical results below are subject to the standard caveat that they reveal correlations within a descriptive-observational setting rather than causal impacts through a natural experiment. Moreover, employees are not randomly assigned into industries, occupations and workplaces. Failure to account for sorting of employ-

6 Detailed results are available from the authors upon request.

7 The difficulties of implementing field experiments in firms are discussed in Bandiera et al. (2011). Some of the most widely cited studies in this tradition (e.g. Lazear 2000, Bandiera et al. 2005) also fail to estimate difference-in-difference models as they also lack randomly selected control groups of workers for whom no change in the institutional setting was implemented.

ees into shift work could lead to biased estimates where the size of the bias is not known. This problem is addressed in some studies of absenteeism by using information on employees' wage and work histories (Böckerman et al. 2012). In our study, such information was deemed to be private and could not be made available to researchers.

In order to analyze the association between the positioning of shifts within a particular shift model and absence rates we estimate a generalized linear model (GLM) to account for the proportional nature of our dependent variable. We examine the relationships between the different positioning of shifts and absence rates of workers by assuming the dependent variable "absence rate" to be a continuous variable. A dependent variable which is bounded between 0 and 1 requires the estimation of a fractional response model along the lines proposed by Papke and Wooldridge (1996, 2008). Furthermore, fixed-effect estimation with clustered standard errors is used as a robustness check.

In our estimations, the observed absence rate serves as the dependent variable. Predictor variables include the number of employees per unit (unit size), the projected absence rate (the calculation of which has been explained above) as well as control variables for the average weekly temperature, the rainfall per week as well as a variable indicating the prevalence of flus and colds. These latter variables are used to control for external effects that may influence absence rates of workers. The average weekly temperatures as well as the amount of rain were retrieved from the website of Deutscher Wetterdienst (DWD 2013). We use daily information that we subsequently aggregated to average weekly information to make it compatible with the remaining data. Thus, our dataset includes the average weekly temperature in degrees Celsius. Analogously, precipitation was calculated as the mean weekly rainfall measured in millimeters. The influence of the two variables on absenteeism is likely to be different. On the one hand, temperature is expected to be negatively correlated with absenteeism since low temperatures are associated with higher risks for minor diseases. On the other hand, rainfall levels are expected to have a positive impact on absenteeism since increased rain levels are associated with higher risks, again, particularly for minor diseases. The variable measuring the prevalence of flus and colds is based on data made available by Techniker Krankenkasse (TK), one of the largest German health insurers. TK collects data on over 8 million employees subject to social security contributions and publishes an annual health report for Germany. The TK report includes information on the average daily absence rates caused by flus and colds in Germany from 2009 to 2010. The data was again aggregated to the weekly level in order to meet the requirements of the dataset. Moreover, month dummies are included to account for seasonal and business cycle effects.

Table 3
GLM and FE Estimation (With Clustered Standard Errors, Dependent Variable: Observed Absence Rate)

Variable	GLM	FE
Unit Size	-0.020+	0.083+
Projected Absence	1.299***	0.054+
Temperature	-0.010+	-0.010+
Precipitation	0.087***	0.086***
Flus & Colds	4.893***	4.884***
Afternoon shift	0.644***	0.635***
Morning shift	0.105+	0.096+
Night shift	reference category	
Month-Year Dummies	Included	
Constant	-1.420+	0.537+
R2*100		2.71

*** p< 0.01; ** p < 0.05; * p < 0.1 + n.s.

Table 3 displays the results of our analysis. A first result worth mentioning is that unit size seems not to have a statistically significant effect on absence rates. This contradicts most of the available literature on absenteeism assuming group size and absence rates to be positively correlated (e.g. Løkke Nielsen 2008), but is in line with more recent findings (e.g. Frick et al. 2013). Moreover, the projected absence rate has a significantly positive effect on a unit´s observed absence rate (a one point increase in projected absenteeism is associated with a 1.30 percentage point increase in observed absenteeism). However, this effect can be observed in the GLM estimation only, but not in the FE estimation (representing the only substantial difference between the two estimations). The insignificant coefficient in the FE estimation appears plausible because the projected absence rates are adjusted at the beginning of each calendar year based on changes in the gender composition and the age and qualification structure of the units (and remain constant for the rest of the particular year), suggesting that projected absenteeism is a (more or less) time-invariant variable.

The coefficients for the control variables (rainfall, temperature, flus and colds) all have the anticipated signs. However, the average air temperature appears not to have a statistically significant influence on absence rates. In contrast, rainfall significantly increases absence rates by 0.08 percentage points. The large coefficient of the flus and colds variable is somewhat surprising and indicates that workers at the plant seem to be disproportionally affected from waves of flus and colds. A potential explanation may be the fact that workers at the manufacturing plant work closely together in their teams providing nearly "ideal" conditions for the transmission of minor diseases.

Finally, the main result of our estimation is that absence rates are highest during afternoon shifts and lowest during morning and night shifts. The afternoon shifts are associated with an 0.64 percentage point increase in absenteeism compared to night shifts. Hence, hypothesis $H_{2.1}$, which assumes lower levels of absenteeism during afternoon shifts due to a better fit with the human circadian rhythm, has to be rejected. At the same time, absence rates during morning shifts appear not to be significantly different from absence rates during night shifts. While these results may seem counterintuitive since night work is associated with higher accident risks as well as other health risks compared to morning and afternoon shifts, we offer a plausible and straightforward explanation. Afternoon shifts start at 2:30 pm and end at 10:30 in the evening, thus covering most of the socially valuable time (i.e. the "social opportunity costs" of working in the afternoon are far higher than working either in the morning or during the night). Thus, workers may have a disproportionate incentive to report sick while on afternoon shifts as they can recover from work with family and friends. Hence, our hypothesis $H_{2.2}$ is confirmed. This explanation is in line with a particular strand of the absence literature emphasizing that absenteeism is not only a function of an individual's health, but also of motivational factors (Kristensen et al. 2006, Løkke Nielsen 2008).

The structure of our data provides us with the opportunity to further evaluate the roots of the spike in absence rates during afternoon shifts. Since we have information on absenteeism on a weekly basis and we know exactly in which shift each unit worked at any given point in time during the observation period, we include the respective weeks of the shift schedule (week 1 (evening), week 2 (morning) … week 9 (night)) as separate dummy variables in our estimations (with the third week of night shift as the reference category).[8] This enables us to identify which weeks of the shift model are the most susceptible to worker absenteeism. Table 4 displays the results of this analysis. It appears that for most variables the coefficients differ only marginally when compared to the earlier estimations (Table 3 above). However, the inclusion of the shift week dummies yields some interesting results. In particular, the first afternoon shift following the three weeks of consecutive night shifts is associated with significantly higher absence rates compared to all other weeks – including the other two afternoon shift weeks which also display significantly higher absence rates than the reference week (last week of night shift), but in a substantially less pronounced way.

The first afternoon shift (week 1) sees an 0.71 percentage points increase in comparison to the last night shift week of the complete cycle (week 9), leading us to accept H_4. A comparison of the regression coefficients reveals that the coefficient for the first afternoon shift (week 1) is significantly different from the coefficients for the second (week 3) and third (week 5) afternoon shift of the particular shift model in use here ($F(1, 152) = 4.83$ | $F(1, 152) = 3.55$). At the same time, the coefficients for the second

[8] The results are stable upon changes in the reference group.

and third afternoon shift do not differ significantly (F (1, 152) = 0.06).

Table 4
GLM and Fixed Effects Estimation
(With Clustered Standard Errors, Dependent Variable: Observed Absence Rate)[9]

Variable	GLM	FE
Unit Size	-0.020+	0.083+
Projected Absence	1.298***	0.051+
Temperature	-0.007+	-0.007+
Precipitation	0.083***	0.083***
Flus & Colds	4.782***	4.773***
Afternoon shift (Week 1)	0.705***	0.707***
Morning shift (Week 2)	-0.081+	-0.079+
Afternoon shift (Week 3)	0.348**	0.346**
Morning shift (Week 4)	0.043+	0.025+
Afternoon shift (Week 5)	0.391**	0.389**
Morning shift (Week 6)	-0.134+	-0.128+
Night shift (Week 7)	-0.085+	-0.071+
Night shift (Week 8)	-0.405***	-0.400***
Night shift (Week 9)	reference category	
Month-Year Dummies	Included	
Constant	0.734+	0.647+
R2		4.33

*** p < 0.01; ** p < 0.05; * p < 0.1 + n.s.

Two competing explanations seem plausible. First, increased levels of stress and strain during the three consecutive weeks of night shift may result in higher absence rates in the subsequent afternoon shift. This explanation is supported by findings indicating an increased accident risk during evening and night shift (Smith et al. 1994) and an increase in the relative risk of accidents over the course of successive evening and night shifts (Folkard and Tucker 2003). However, a second line of interpretation appears more convincing: Workers have pronounced incentives to "postpone" absences from

[9] The complete estimation results including the standard errors of the coefficients are, of course, available from the authors upon request.

the night shift towards the first afternoon shift. These incentives arise from the considerable premiums paid for night shifts (between 30 and 45 percent of hourly wages (IG Metall 2008).[10] If a worker calls in sick during night shifts, she/he is entitled to continued (sick) pay.[11] However, the premium for the respective shift – which is under normal circumstances exempt from personal income tax – is then subject to taxation (Einkommenssteuergesetz (EStG) 2009). On average, this incentive amounts to approximately €20 per day. Thus, our interpretation is in line with previous evidence (e.g. Broström et al. 2004) that economic incentives have a major impact on individuals' absence behavior.

The €20 per day can be seen as the "reward" to workers for "postponing" health-related absenteeism in order to avoid taxation of the night shift premium. This explanation receives additional support by the finding that absence rates decline in any other week of the shift cycle compared to the first afternoon shift (week 1). Moreover, HR managers at the plant also clearly favor this interpretation over the first alternative. Thus, apart from the "social opportunity costs" of working afternoon shifts we find a sizeable "tax evasion effect" of delaying absence spells from night to afternoon shifts (with both effects being approximately equal in size).

Night and morning shifts, in turn, appear not to be significantly different in terms of absence rates. Therefore, the pay premium effect that we assume in $H_{1.2}$ to exist for night shifts appears ambiguous since absence rate levels are only different between night and afternoon, but not between night and morning shifts.[12] Moreover, the higher probability of experiencing health and social problems when working in the night compared to morning and afternoon fails to translate into higher absence rates for night shifts ($H_{1.1}$). Finally, no cumulative effect of the three successive night week shifts on

[10] The night work premium is a mandatory legal requirement in Germany (Arbeitszeitgesetz (ArbZG) 1994). However, the exact amount of the premium is specified in binding collective bargaining agreements.

[11] In Germany, most employees are by law entitled to six weeks of sick pay covered by the employer.

[12] The only exception here is the second night shift week (week 8) as it has significantly lower absence rates compared to all other weeks. This result remains puzzling and further analysis is required to identify the (potential) causes of this effect.

absence rates seems to exist and, therefore, hypothesis H_3 is to be rejected. The non-existence of increasing absence rates over the three consecutive night shifts may be explained by the discontinuous nature of the shift model, which offers recovery time during the weekends.

Summary and Conclusion

Using a comprehensive dataset from a single plant of a large German automobile manufacturer (with more than 15,000 unit-week-observations), we find that within a particular shift model absence rates of workers differ substantially. Surprisingly, night shifts have the lowest absence rates while afternoon shifts feature the highest rates of worker absenteeism. This is unexpected from an occupational medicine perspective since night shifts are associated with increased health risks as well as increased risks of work related accidents. However, afternoon shifts are associated with the highest "social opportunity costs" of going to work, which may explain the higher probability of workers reporting sick during this shift period. Summarizing, in a shift system consisting of six weeks of alternating shifts between afternoon and morning shift and a subsequent period of three weeks of night shift it appears that absence rates are highest during afternoon shifts while morning and night shifts display similar levels of absenteeism. The difference between afternoon and night shifts (the reference category in our estimations) is 0.64 percentage points or more than 11 percent Table 3). Furthermore, the shift from the final night week to the first afternoon week sees a massive increase in absence rates of 0.71 percentage points, which is tantamount to a 12 percent increase in absence rate levels compared to the night shift (Table 4).

This observation is consistent with workers' incentives to "postpone" absenteeism away from the night shifts towards the first afternoon shift. Night shifts come with a considerable pay premium (between 30 and 45% of hourly wages). If the worker calls in sick during night shifts, she/he is entitled to continued sick pay. However, the premium – which is under normal circumstances exempt from personal income tax – is then subject to taxation. Hence, the increased absence rates during the first afternoon shift may be driven by this incentive for workers to "postpone" health-related absenteeism in order to avoid taxation of the night shift premium. This result is subject to the caveat noted above that we can only derive associations between variables rather causal effects from our study.

Thus, our results indicate that the debate about the design of shift work and its association with health risks and accompanying absence rates may usefully be complemented by motivational aspects of absence behavior as well. Moreover, absenteeism may not be a reliable indicator of the ergonomic quality of a shift model since absence rates differ even within shift models. These findings can be of practical relevance to management when designing new shift models since unintended incentives need to be taken into account. In addition to taking account of economic incentive effects on worker absence rates, we concur with research that shows the benefits for organizations of promoting increased leisure-time physical activity, both inside and outside of the workplace (López-Bueno, Calatayud et al. 2020, López-Bueno, Sundstrup et al. 2020).

Finally, it is important to point out that due to the insider econometrics approach followed in this study the findings may be limited to the specific setting that we had the opportunity to analyze. Nevertheless, we are confident that our study can serve as a useful starting point guiding future research exploring the potential impact of the design of shift models on health and productivity outcomes of workers in other firms and industries[13].

[13] A major shortcoming of our data is – as already mentioned above – the lack of information on the age, gender, subjective health conditions and family obligations of the different team members. This is an issue insofar as Jacobsen and Fjeldbraaten (2018) show that it is not shiftwork per se that is associated with worker absenteeism. Instead, there is an indirect effect particularly through work-life-conflict and perceived health.

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