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Article

The cost of shift work: Absenteeism in a large German automobile plant

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Abstract
Using a balanced panel of some 400 organizational units in a large automobile plant, we analyse changes in absenteeism following a company innovation intended to improve worker health and well-being. During the period under consideration (January 2009–December 2011) the firm replaced its traditional shift schedule associated with high health risks for workers with an ergonomically more advantageous system. Our findings show that this innovation was accompanied by a statistically significant and economically relevant decrease in absenteeism. However, when workers started to express discontent with the new system, management after a few months implemented another shift system that was, from an ergonomical perspective, again associated with higher health risks than those associated with the second one. Absentee figures quickly returned to their initial levels. This suggests that short-term leisure preferences can override long-term health concerns in worker responses to the implementation of different shift schedules.

Keywords
Shift work, absenteeism, organizational change

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Introduction

Shift work is common in many industries around the world. Capital-intensive production in, for example, automobile and steel plants on the one hand and the *uno actu* provision of services in, for example, hospitals, emergency rescue services, police and fire departments require around-the-clock presence of workers. In Germany, more than 17% of the workforce have recently been reported to work shifts (Statista, 2018). Furthermore, 65% of all metal firms use some sort of shift work and about 32% of the workforce in this sector work rotating shifts (see Paul and Kaufmann, 2017). However, although widespread, the impact of different shift schedules/shift systems on worker well-being and individual health outcomes has not yet been studied extensively by economists (exceptions include Backes-Gellner et al., 1999, and Brachet et al., 2012). The topic has until recently remained a domain of occupational medicine.

The term 'rotating shift work' covers a wide variety of shift schedules and implies that shifts change according to a (company)-specific schedule. These shifts can be either continuous, running 24 hours per day, 7 days a week (as in steel production and in hospitals, for example), or semi-continuous, running two shifts per day, with or without weekends. The length of a shift typically varies between 8 and 12 hours, but in some cases, it can be as long as 24 hours (in emergency rescue units, for example). Moreover, the direction of rotation can be either forward (with the clock, i.e. from morning to afternoon to night shift) or backward (against the clock, i.e. from morning to night to afternoon shift) and it can be either fast (every 1–3 days) or slow (every week or even slower).

Occupational medicine specialists have for a long time been (and continue to be) interested in the effects of shift work as they expect negative consequences for individual employees' physical and mental health due to disruptions to the 'circadian rhythm' as a result of working unusual hours.[1] Given the negative consequences of shift work that have been emphasized by occupational medicine specialists, it is certainly surprising that economists and human resource specialists have so far neglected these effects, because they are most likely associated with higher labour costs due to, for example, lower productivity, poorer product/service quality, more errors and lower client/customer satisfaction. However, evaluating the labour cost effects of rotating shift work has been (and continues to be) difficult, because nearly all available studies looking at the health effects of shift work rely on self-reported outcome measures. More recently, however, the research strategy asking shift workers to self-assess, firstly, their working conditions and, secondly, the impact of these conditions on themselves has been considered a 'major weakness' even by those working in the tradition of asking people about their subjective evaluations and mental dispositions instead of watching what these people do (e.g. Wagstaff and Sigstand-Lie, 2011: 181).

To the best of our knowledge, we are the first to study the impact of a change in shift schedule on worker absenteeism – a measure we consider 'objective' in the sense that it reflects workers' response to alternative shift schedules – in one particular plant of a large automobile manufacturer in Germany. The data we use gives us the opportunity to analyse the impact of a change from an ergonomically 'problematic' shift system to a more 'advantageous' one and vice versa (a few months after its implementation the advantageous system was again replaced by a more 'problematic' one).

Our paper fits into the field of 'insider econometrics' that has grown in personnel economics following the seminal work on steel plants in the United States (US) by Ichniowski, Shaw and Prennushi (1997) and on windshield installers in a large US firm by Lazear (2000). This approach emphasizes rigorous econometric analysis of panel data generated within one company or a few companies to evaluate, for example, the impact of specific human resource management practices on various measures of firm profitability and/or worker well-being (for surveys of the literature see Ichniowski and Shaw, 2013; Bloom and Van Reenen, 2010; Lazear and Shaw, 2007; and Shaw, 2009).

The remainder of the paper is structured as follows: section 2 provides a review of the relevant literature while section 3 describes the three different shift systems used in the respective plant of the automobile company. In section 4 we present the data and some descriptive evidence while section 5 includes our econometric evidence documenting the changes in worker behaviour following the implementation of a new shift system that specialists from occupational medicine strongly favour over its predecessor as it is considered to foster worker health and well-being. Section 6 presents the conclusion.

Literature review

A broad consensus seems to exist on the negative consequences of rotating shift work: firstly, people working on rotating shifts report more sleeping problems, poorer physical health and poorer psychological well-being than non-shift workers (e.g. Angersbach et al., 1980; Knauth et al., 1980; Koller, 1983; Martens et al., 1999; Costa, 1996, 2003; Åkerstedt, 2003; Nakata et al., 2004). Secondly, shift work has been found to be detrimental to family and social life (e.g. Jansen et al., 2004; Root and Wooten, 2008) and to lead to higher voluntary employee turnover (e.g. Askildsen et al., 2003). Moreover, accident risks at work have been found to be significantly higher during the hours of the night period (e.g. Hänecke et al., 1998) and the retirement age of shift workers is younger than that of non-shift workers (e.g. Shen and Dicker, 2008). Less consensus seems to exist on the positive and neutral effects of shift work. It appears, however, that shift work has no significant impact on work attitudes (e.g. Blau and Lunz, 1999). Moreover, if chosen voluntarily, working night shifts seems to have no negative effects on cognitive and psychomotor performance either (e.g. Petru et al., 2005). One of the few positive effects of shift work is that for many workers with low daytime earnings an opportunity exists to self-select into shift work and supplement their earnings (e.g. Kostiuk, 1990). Summarizing the available evidence, Dall'Ora et al. (2016) as well as Kecklund and Axelsson (2016) have recently argued that working on rotating shifts is – irrespective of speed and direction – associated with poorer employee performance and well-being.

However, an important issue that has rarely been addressed in the literature is the impact of different shift systems/schedules on worker behaviour (such as turnover and absenteeism, for example).[2] Using a randomized clinical trial with 85 chemical workers (33 in the control and 52 in the treatment group), Czeisler et al. (1982) were among the first to show that workers experiencing a change in the direction of rotation (i.e. moving from a backward (counterclockwise) rotating to a forward (clockwise) rotating shift schedule) experience a statistically significant increase in work schedule satisfaction and subjective health (for similar results, see Van Amelsvoort et al., 2004; Viitasalo et al., 2008). Moreover, these workers' productivity increased and their turnover decreased, suggesting that subjective and objective changes in behaviour seem to coincide. More recently, it has been shown in laboratory experiments that workers on a fast-forward rotating system perform significantly better in a simulator driving exercise than those on a slow-backward rotating system (De Valck et al., 2007). Also, working on a fast backward rotating schedule is associated with significantly higher levels of salivary cortisol during morning and night shifts, indicating insufficient recovery from the previous shift, than working on a fast forward rotating schedule (Vangelova, 2008). Finally, when given the choice, workers clearly prefer a rapidly forward rotating shift system with at least 16 hours of rest between shifts over its alternatives (Kecklund et al., 2008).

Summarizing the available evidence, it appears that from an occupational medicine perspective shift schedules should be designed according to now commonly accepted ergonomic criteria, recognized to limit the adverse effects on individual employees' health and well-being (Bambra et al., 2008; Costa, 2010; Harrington, 2001): firstly, quickly rotating (1–3 days) systems should be preferred over slowly rotating systems (weekly or longer). Secondly, clockwise (forward) rotation should be preferred over counterclockwise (backward) rotation, and thirdly, a large number of consecutive night shifts should be avoided. Taking these recommendations into account, the negative consequences of shift work that typically translate into higher unit labour costs, can perhaps not be avoided completely, but they can at least be considerably reduced.

Research context: the different shift systems

It is now accepted in the literature that one of the side effects of (rotating) shift work is absenteeism. This can be real in terms of genuine sickness, but it can also be due to opportunistic behaviour. For workers, health disruptions caused by shift work may have long-term consequences that eventually lead to early retirement. For companies, absenteeism is costly, inducing firms to consider the implementation of a shift system that is less detrimental to worker health (using forward rotation as opposed to backward rotation and avoiding consecutive weeks of night shift work).

Absenteeism has always been, and continues to be, a 'top priority' in this particular large German automobile company studied here. Apart from changes in shift schedules, management has, for example, implemented various health training measures in select service units to reduce worker absenteeism. In the plant we study here, a backward rotating system with three consecutive weeks of night shift was replaced by a forward rotating shift schedule that was considered by occupational medicine specialists to cause fewer health risks for workers. However, the new shift system was repealed after a few months because workers started to express their (leisure-related) discontent with the new schedule very soon after its implementation. In particular, workers disliked the new schedule because it resulted in a comparatively short weekend following the week working night shifts. Due to the forward rotation, workers return home from the night shift early Saturday morning and have to be back at work early Monday morning, leaving them with less than 48 hours for recovery as well as leisure and social activities on that particular weekend.

Week	1	2	3	4	5	6	7	8	9
Shift	D	M	D	M	D	M	N	N	N

Figure 1. Initial backward rotating shift system (regime 1: January 2009–December 2010).
D: day; M: morning; N: night.

Week	1	2	3	4	5	6	7	8	9
Shift	M	D	N	M	D	N	M	D	N

Figure 2. New forward rotating shift system (regime 2: January 2011–August 2011).
D: day; M: morning; N: night.

All the organizational units in our study are located in the body shop, the paint shop or the assembly in the same plant of this large German vehicle manufacturer.[3] Irrespective of the shift system in use, work for the different shift teams starts at 6.30 a.m., 2.30 p.m. and 10.30 p.m. At the beginning of our observation period, all units worked under a shift system that required six weeks of weekly rotation from day shift (D) to morning shift (M) followed by three weeks on night shift (N). Thus, the shift system is discontinuous with work days ranging from Monday to Friday with weekends off (Figure 1). This system was criticized by employee representatives because of the three weeks of consecutive night shifts and because of its 'violation' of generally accepted health-related guidelines for the design of shift systems.[4]

A new system was imposed, associated with lower health risks for workers. Moreover, this change was considered beneficial from the standpoint of occupational medicine experts, who expected the shift-coping problems accompanying the original backward-rotating pattern to disappear. The new system started on 1 January 2011 and abandoned the extensive continuous night shifts. Moreover, a forward rotation was implemented. Under the new system, workers were also required to work a 5-day-week starting in the morning, then switch to the day shift for week two before working five days on the night shift in the third week. In the week following the night shift, the cycle starts again (Figure 2). Note that Friday night shifts finish on Saturday morning.

A few months later, the decision was repealed following worker complaints to the works council and the shift plan was modified again. Soon after the workers started to voice their complaints, the chairman of the local works council announced in the regional newspapers that the system would be changed again – without prior consultation with management. In German firms, the works council typically negotiates over a bundle of company policies. On some issues, it has the right to information and consultation, on others it can veto management initiatives, on still others it has the right to codetermination in the design and implementation of policy. Its rights are strongest in social and personnel matters such as the introduction of new payment methods, the introduction of technical devices designed to monitor employee performance and – particularly important in our context – the allocation of working hours, including the design of the shift schedule to be used.[5]

Week	1	2	3	4	5	6	7	8	9
Shift	M	N	D	M	N	D	M	N	D

Figure 3. New backward rotating shift system (regime 3: September 2011–December 2011). D: day; M: morning; N: night.

This time, the rotation direction of the system was changed. The new shift system was implemented following the company's summer break on 15 August 2011 and included a weekly backward rotating long cycle (5 days) system, starting with the morning shift, followed by a week working night shifts and then a week working day shifts (Figure 3). The system remained in practice until after the end of the observation period (December 2011).

Although forward rotating systems are considered to provide more recovery time between different shift spells (e.g. Härmä et al., 2006: 71), backward rotation was preferred by workers and their representatives because of its impact on the rather long break on weekends. However, over a complete three week shift cycle, both systems (forward versus backward) provide the same total amount of leisure time at weekends.[6] What is different, however, is the distribution of the leisure periods, resulting in one rather short weekend during the forward rotating cycle, which is considered by many workers to be incompatible with their preference for equally long weekends.

Moving from night shift to morning shift on the third weekend is associated with 48 hours of leisure time during which workers have to recover from their shifts. Therefore, the time available for recovery (sleep), leisure and social activities is limited on that particular weekend. In contrast, the backward rotating system replaced the night-to-morning change-over on the third weekend with a night-to-day adjustment on the second weekend. This results in 56 hours of leisure time. So although the total available time is the same in both systems over a 4-week period, workers placed a premium on the extra recovery/leisure time derived from the night-to-day adjustment rather than night to morning. This gave workers more time for recovery and *useable* leisure time when coming off a night shift. That is, workers would have more time for sleep, home production and 'pure' leisure on their weekend break following a night shift when moving back to a day shift rather than the morning shift. Summarizing, the difference in the distribution in recovery time at weekends – in particular after night shifts – should be considered as the main reason for the second adjustment of the shift system.[7] Hence, lack of acceptance by workers and the resulting pressure from the works council induced management to return to a backward rotating system while simultaneously avoiding the problems associated with the original discontinuous system.

Given the evidence in the occupational medicine literature (see section 2 above), we expect absence rates to be lower in regime 2 (a forward rotating discontinuous cycle) compared with regime 1 (a discontinuous system with six weeks of weekly rotation from morning to day shift followed by three weeks of night shift) as the forward rotation is considered less detrimental to worker health than backward rotation. Moreover, we expect absence rates for regime 3 to be lower than for regime 1 (because the discontinuous backward rotating system has been replaced by continuous backward rotation), but higher than for regime 2 (because workers prefer continuous backward to continuous forward rotation).

Data and descriptive evidence

In order to analyse the impact of a change in the shift schedule on absenteeism we use a balanced panel including monthly data on absenteeism from 409 organizational units in one particular plant of a large German automobile company over an extended period of time (January 2009–December 2011) during which no other changes in the production process occurred that could have affected worker absenteeism (such as the start of the production of a new car). Our study design has a number of advantages: firstly, the required information is completely available for all units over a period of 36 consecutive months and, secondly, the set-up resembles a quasi-experimental design allowing us to identify the effects on worker absenteeism of a move towards a shift schedule that is considered as beneficial by all experts. Our focus on finely tuned data from within a large company enables us to analyse the impact of different shift systems on worker absenteeism with a precision that would be lacking in broader establishment-based surveys.[8]

Our initial data set included 1031 organizational units performing a variety of different tasks in the production process (body shop, paint shop, assembly, quality management as well as supporting activities). For half of these units (n=509) information on the number of workers and/or monthly absenteeism was not available at all, leaving us with 522 units. Construction of a balanced panel resulted in a data set including 451 organizational units (information on the remaining 71 units was incomplete because of structural changes in the organization of approximately half of the units, e.g. elimination of some units, creation of new units, mergers of existing units). Moreover, before estimating our models we performed a series of plausibility checks that led to the elimination of some units with massive outliers (e.g. the number of employees in a particular unit increased by more than 100% in two months and declined similarly only a month later). Finally, due to the company's data protection regulations we had to exclude units with less than five employees, leading to a further reduction in sample size to 409 organizational units. For these units we have the necessary information on the monthly observed absence rate, the monthly projected absence rate and the number of employees. In total, the units in the sample employ some 7500 workers.

Our major control variable – projected absence rate – mirrors the differences in sociodemographic characteristics between the units in the sense that projected absenteeism is calculated (and regularly updated) by the company's personnel department, taking into account the age, gender and qualification of the respective units' members. A 35-year-old female production worker, for example, is expected to be absent from work 5.2% of the time, while a 25-year-old male white-collar employee is expected to be absent from work only 1.0% of the time. The projected absence rate is, therefore, the weighted average of the expected absence rate of the unit's individual members, given their characteristics.

Fortunately, the limited number of explanatory variables and the resulting lack of controls is not a serious problem because personnel turnover is unusually low at this company, less than 4% per year, implying that the composition of the teams in the units remains fairly stable over the observation period. Furthermore, the reduction of the data set through

Table 1. Summary statistics.

Variable	Mean	Std. Dev.	Min.	Max.
Number of employees in unit	17.99	7.69	5	49
Observed absence rate	6.25	5.38	0.00	56.00
Projected absence rate	3.69	0.90	1.00	7.90
White-collar absence rate	2.45	0.51	1.50	3.70

Number of organizational units: 409; n of unit-month-observations: 14,724.

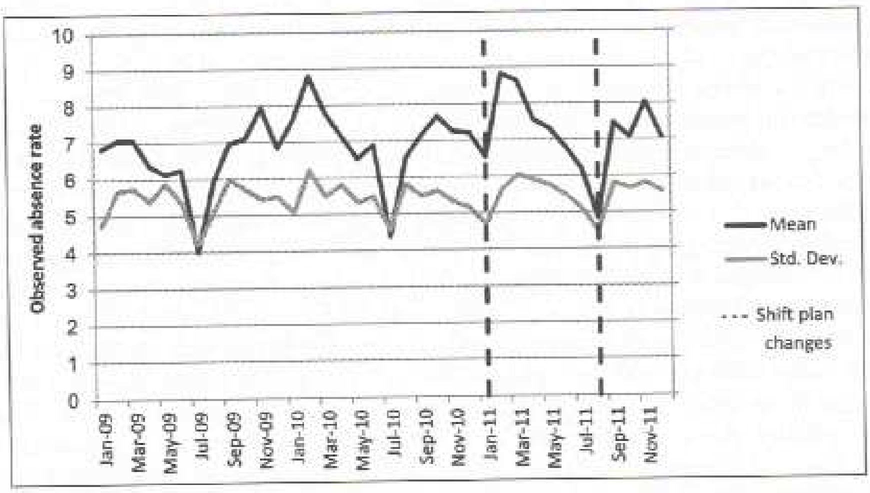

Figure 4. Absence rates by month.

elimination of units with incomplete data does not bias the results since the characteristics of the excluded units resemble those of the units that are included. The data were obtained from the firm's central human resource reporting system. The monthly absence rate is measured as hours missed due to sickness in per cent of scheduled working hours. It includes both, absences attested by a physician and those where workers justified their absence with illness, without a certificate. Since we have 409 organizational units in the sample that we observe over a 36-month period, our data set consists of 14,724 unit-month-observations. It appears from Table 1 that the average absence rate is 6.25% with a standard deviation of 5.38%, which is almost identical to the values reported in a case study from the German metal industry (see Frick, Götzen and Simmons, 2013) and the most recent aggregate figures for the German manufacturing sector (see Badura et al., 2012).

Figure 4 displays the development of the average absence rate over the observation period. As expected, average absenteeism is higher during the winter months.[9] Furthermore, the dips in absenteeism during the summer months and especially in July or August are not surprising since the plant shuts down production for three weeks during the summer.[10]

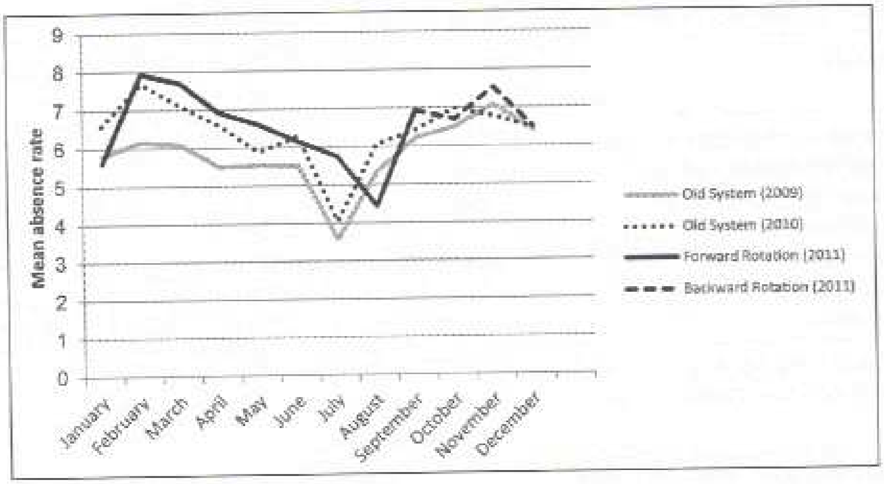

Figure 5. Monthly absence rates by shift system.

A comparison of average absence rates under the three different shift systems (Figure 5) reveals a particularly low level of absenteeism for 2009 and a high level for 2011. Most observers would attribute this to the uncertainty resulting from the aftermath of the economic crisis. In general, absence rates tend to be lower during economic downturns because a tight labour market with high unemployment offers limited alternatives to workers losing their jobs (i.e. the opportunity costs of losing the job increase).[11] However, since the company pursues a strict 'no lay-off policy', these effects must be entirely due to changes in the behaviour of temporary agency workers (about 10% of the production workers in the plant), who are worried that their contracts might not be extended due to the recession. Therefore, another – more plausible – explanation is that during the economic crisis, capacity utilization was lower and so workers were exposed to less stress.[12]

Unfortunately, we cannot empirically distinguish between these two hypotheses. However, we control for seasonal and business cycle effects by estimating our models with 35 month dummies (with September 2010 as the reference month). Moreover, the comparison seems to suggest that absenteeism was higher when the forward rotating shift system was in use (solid black line). In our econometric analysis, we check whether this difference is statistically significant and whether the second change in the shift system was associated with a statistically significant change in absenteeism. Not surprisingly, the seasonal pattern of absenteeism is similar to the one in Figure 4.[13]

A final observation that warrants some consideration in this context is the difference in the seasonal pattern of the absence rate during the summer months. While for the years 2009 and 2010 the lowest absence rates were recorded for July, in 2011 August was the month with the lowest absence rates. This strange phenomenon is easy to explain: as already mentioned above, the plant shuts down for a summer break which, in turn, coincides with the school holidays in the federal state where the plant is located.[14]

Table 2. Generalized linear model regression of shift systems on absence rate.

Variable	Coefficient	Robust standard error	T-statistic
Number of employees in unit	0.028	0.017	1.66*
Projected absence rate	2.014	0.157	12.82***
White-collar absence rate	0.007	0.186	0.04+
Month–year dummies#		Included	
Shift regime 2	−0.664	0.273	−2.43**
Shift regime 3	−0.367	0.278	−1.32+
Constant	−1.509	0.672	−2.25**

***$p < 0.01$; **$p < 0.05$; *$p < 0.10$; + not significant.
Reference month is September 2010.

Estimation and results

In order to test for the impact of the two changes in the shift system on absence rates we estimate a generalized linear model (GLM) to account for the proportional nature of our dependent variable. We investigate the effects of shift plans (i.e. 'shift regimes') on absenteeism by treating absence rate as a continuous variable. Thus, since our dependent variable is a rate that is bounded between 0 and 1, we need to estimate a fractional response model along the lines proposed by Papke and Wooldridge (1996, 2008) and used by Frick, Götzen and Simmons (2013), who analyse the impact of semi-autonomous teams and team bonuses on absence rates in a large German steel plant.[15]

In the estimation we include the observed absence rate (calculated as the ratio of missed and contracted monthly working hours) as the dependent variable and the projected absence rate,[16] the absence rate of white-collar workers of the same plant as well as the number of employees in a unit as independent variables (Table 2). Thus, the data we use here includes only a small number of 'internal' explanatory variables, of which the respective units' projected absence rate is by far the most important one.

Since for data protection reasons the sociodemographic characteristics of the units were not made available to us, we consider the projected absence rate a good proxy for the respective units' group composition. Overall, the lack of controls appears not to be a serious problem since personnel turnover is – with less than 4% annually – unusually low in this company. This implies that the composition of the teams in the units remains relatively stable over the entire observation period. Moreover, we include in our estimations month dummies to control for seasonal and business cycle effects (Figure A1 in the Appendix displays the coefficients of the month dummies). What we are most interested in are the coefficients of the two regime dummies representing the different shift systems, where the initial regime serves as our reference category.

It appears from Table 2 that the majority of the estimated coefficients are statistically significant. Firstly, absenteeism is slightly higher in larger units (a finding that is in line with the literature, e.g. Dionne and Dostie, 2007). Secondly, a 1 percentage point increase in the projected absence rate is associated with a 2 percentage point increase in the observed absence rate, suggesting that health problems of female and older workers – for whom absence rates are assumed to be significantly higher than for male and younger workers – are still underestimated by the firm's human resource management department.

Most important are the coefficients of the two regime dummies. The first change in the shift system (from regime 1, including three consecutive weeks of night shift, to regime 2, a continuous forward rotating long cycle), had a statistically significant and negative effect on absence rates, suggesting that the introduction of the new (and presumably 'healthy') shift system induced a decrease in the monthly absence rate by 0.66 percentage points.[17] On first impression, the second regime change (from the continuous forward rotating to a similar backward rotating system, i.e. regime 3) was also associated with a lower absence rate compared with the initial level. However, the latter coefficient failed to reach statistical significance at conventional levels. Moreover, the coefficients of the two regime shift dummies are significantly different, suggesting that the forward rotating shift schedule is indeed associated with lower absenteeism than the backward rotating system that replaced it. Summarizing, given the workers' opposition to regime 2, our findings suggest that they care more about the distribution of their recovery/leisure time than about the long-term health effects of alternative shift systems which, in turn, indicates that workers may discount future health problems.

Since the two different shift regimes were imposed on all production units, we do not have a natural experiment design. However, we do know the absence rate of full-time white-collar workers performing regular daytime work. We therefore introduced the monthly white-collar absence rate as an additional control variable and found that this returned an insignificant coefficient. Moreover, the white-collar absence rate was found not to vary with changes in production worker shift regime. This rules out the possibility that both white-collar and blue-collar worker types were affected by some unknown confounding factor occurring at the same time as the changes in the production worker shift pattern.

In order to check whether the findings presented in Table 2 are robust across unit size and absence rate, we split our sample at the respective variable's mean in two equally large subsamples and estimated the model presented above separately for small and large units and for those with above and below average absenteeism. It appears from Table 3 that the positive effect of the forward rotating shift regime is restricted to the large units on the one hand and to those with below-average absence rates on the other. The latter finding is due to the company's 'no lay-off' policy, which in practice means that employees with chronic health problems are relocated to production units with physically less demanding tasks, leading to the paradox that the least demanding jobs are associated with the highest absence rates – because they are being carried out by the least healthy persons.

Thus, employees with chronic health problems are less likely to benefit from the forward rotating shift schedule that is considered by occupational medicine specialists as being less detrimental to worker health (the projected absence rate in the units with above-average absenteeism is significantly higher than in the other units, suggesting that the workers in the former units are much older).

Summary and conclusions

Summarizing, our main result is that the change from a shift system considered to be ergonomically unfavourable, characterized by backward rotation and three continuous weeks

Table 3. Generalized linear model regression of shift systems on absence rate by unit size and by level of absenteeism.

Variable	Small units (fewer than 18 employees)	Large units (18 and more employees)	Low absenteeism (less than 6.25%)	High absenteeism (6.25% and more)
Unit size	0.120*	0.010+	0.033***	−0.055**
Projected absence rate	1.937***	1.725***	0.798***	1.485***
White-collar absence rate	−0.001+	−0.041+	0.492**	−0.518*
Month–year dummies#	Included			
Shift regime 2	−0.588+	−0.775***	−0.613***	−0.467+
Shift regime 3	−0.560+	−0.328+	−0.177+	−0.447+
Constant	−2.558***	−0.423+	−0.308+	4.371***

***$p< 0.01$; **$p < 0.05$; *$p < 0.10$; + not significant.
Reference month is September 2010.

of night shifts, to a forward rotating schedule that is considered an improvement from a health perspective, is associated with a statistically significant decrease in monthly absence rates. This decrease, however, is completely offset by a second modification of the shift system. Changing the direction of rotation from forward to backward is associated with an increase in monthly absence rates back to original levels. This finding confirms the expectations of occupational medicine specialists (see the literature review above) and is worrying for the company, since both the initial and the final system are backward rotating. Compared with the original system, the final regime is considered to expose workers to reduced health risks due to its shorter night shift cycle and as such it ought to deliver a lower absence rate. Yet this has not happened. Moreover, workers seem to have increased their utility through a more desirable distribution of recovery/leisure over the weekends and also reduced their hours of actual work through greater absenteeism – reducing the actual 'dose' of shift work – hence lowering their disutility of work. Unfortunately, we are unable to determine whether the greater absence rate under the third and final regime compared with the second was due to minor sickness, major sickness or shirking behaviour.

According to our estimations, the introduction of an ergonomically advantageous shift system is associated with a 0.66 percentage point decrease in monthly absenteeism, a decline of more than 10%. Evaluated at the mean of the two coefficients, we estimate the benefits due to the initial decrease in absenteeism to be about € 2.3 million (about € 300,000 per month). Since the organizational units included in our sample comprise only 30% of the workforce, the total returns are more than three times as high, nearly € 7.7 million.[18] However, these benefits were forfeited by changing the shift system again after a rather short period of time in response to groups of workers expressing their discontent with the continuous forward rotating shift system.[19] Moreover, since 2011 the company has been discussing implementations of other shift systems that are particularly designed to foster employee health and fitness by changing to a short forward rotating cycle and by adding a fourth shift. We plan to study the impact of this new ('ergonomic') shift system as soon as longitudinal data for a similarly large number of organizational units is available.

Our findings have implications for the design of shift work on the one hand and for future research on the health consequences of shift work on the other. Firstly, management should seek the support of the works council to convince workers that it is in their own best interest to work under a forward rotating shift system, as this is less detrimental to the individuals' health in the long run. As documented in the literature review, shift work can create troublesome problems for the employees' health and family life. In the German context, the works council has a specific role in the design and use of working time arrangements in the sense that it can reconcile the conflicting interests of management and employees. Duncan and Stafford (1980), for example, argue that a reduction in the disamenities of shift work is a workplace public good as it has aspects of non-rival consumption shared by many workers in the establishment. Thus, communicating aggregated worker preferences to management can help to design and implement shift schedules that are more acceptable to the workforce – even at the price of an increase in the percentage of workers suffering from long-term health problems. Convincing workers to accept a shift schedule that seems to be in conflict with their leisure preferences for equally long weekends is not at all trivial and becomes even more difficult in a company pursuing a strictly 'no lay-off' policy, the enforcement of which is closely monitored by the works council. Here, employees can be certain that they will be moved to physically less demanding jobs (in, for example, maintenance, security) in case their health does not permit working in the assembly line any longer. This, in turn, reinforces employees' preferences for shift schedules that are likely to be beneficial to their social life in the short term, but detrimental to their health in the long run.

Secondly, our findings contribute to a small body of literature documenting significant differences in worker behaviour with regard to different forms of shift work: although forward rotation is unanimously considered by occupational medicine specialists to be favourable compared with backward rotation, the latter shift system seems to be preferred by workers as reflected in lower absence rates. Thus, we find clear evidence to suggest a considerable economic impact of different forms of shift work on firms' labour costs. However, our study has a number of limitations that future research should try to avoid. While the panel data we are able to use has a number of obvious advantages compared with cross-section data (we can, for example, control for unobserved heterogeneity across teams), we are not able to distinguish between sickness-related and motivation-related absences to better identify individual workers' responses to (changes in) shift work schedules. Moreover, due to data protection rules that management and works council at the plant have agreed upon, we have limited information on the composition of the teams and no information on changes in their composition due to, for example, voluntary quits. Finally, future research should extend the quantitative approach we have taken in this paper by also adopting a qualitative approach in the sense of talking to workers and asking them for their subjective perception of the pros and cons of different types of shift work.

Notes

1. Most human physical functions follow a 24-hour cycle. This cycle is called 'circadian rhythm'. Sleeping, waking, secretion of adrenalin and cortisol, body temperature, blood pressure, pulse

and many other human bodily functions are all regulated by this 24-hour cycle to allow for high activity during the day and low activity during the night.

2. Due to differences in the data and the estimation techniques used, some papers show that shift work is associated with higher absenteeism (e.g. Chaudhury and Ng, 1992; Drago and Wooden, 1992; Dionne and Dostie, 2007) while others document that shift work has no impact on individuals' number of absence spells per year (e.g. Böckerman and Ilmakunnas, 2008). However, since none of these studies controls for self-selection of workers, the reported findings are likely to be biased.
3. Thus the organizational units that we analyse here include only blue-collar workers with physically demanding jobs. These workers cannot avoid shift work, that is to say, we can rule out that the composition of the teams we observe is the result of self-selection of those workers most able to cope with the deleterious effects of shift work.
4. The health-related guidelines of the Federal Institute for Occupational Safety and Health mandate for example that forward rotating shifts are preferable to backward rotating shifts and that working weekends is to be avoided (e.g. Beermann, 2005).
5. The works council also has consultation rights, though not as strong, in matters such as changes in equipment and working methods that affect job requirements, decisions relating to manpower planning and structural alterations to the plant. Its participation rights in financial and economic matters cover information provision. Moreover, the council can negotiate over social compensation plans. It has the right to demand compensation for the relocation caused by plant closures and major changes in the company's organization.
6. Both changes in the shift system had no effect on worker remuneration, because the number of night shifts, for which a 30%–45% premium is paid, remained the same under the three different regimes. Thus, from a purely financial point of view workers should be indifferent with regard to the three regimes.
7. The available evidence suggests that 'quick returns' (short breaks between two different shifts) are indeed associated with shorter sleep duration, they cause more disturbed sleep and increase reports of sleepiness and fatigue (Vedaa et al., 2016).
8. Admittedly, in an ideal world, 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 (e.g. Bloom et al., 2013). Implementing such an experimental design in a German company – be it rather small or very large – is virtually impossible, as the works council will always object, arguing that employees must not be treated as 'guinea pigs'. The difficulties of implementing field experiments in firms are discussed in Bandiera, Barankay and Rasul (2011). The reactions of workers (and – if present – their representatives) are likely to be similar in other highly developed economies. To the best of our knowledge, virtually all randomized control trials have been conducted in firms in developing countries (e.g. Mano et al. (2011) in sub-Saharan Africa; Valdivia (2012) in Peru; Bruhn, Karlan and Schoar (2012) as well as Calderon, Cunha and De Giorgi (2013) in Mexico; Giné and Mansuri (2011) in Pakistan; for an extensive review of the literature see Karlan, Knight and Udry (2012). 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.
9. The seasonal pattern is virtually identical with the figures reported in Badura et al. (2012), for example, for the German manufacturing sector during our observation period.
10. Due to the working time arrangements of the company a worker on a holiday leave is by definition not 'absent', because during the holiday leave he or she does no 'owe' any hours of work to the company. During the time the plant shuts down workers are required to take a

holiday leave during which they rarely call in sick. This results in low absence rates during the summer months.

11. Using data from 2006 to 2010 on individual worker productivity from a large firm, Lazear, Shaw and Stanton (2016) demonstrate that during economic downturns workers tend to work harder, that is to say, they produce more output to avoid being laid off.
12. Table A1 in the Appendix documents considerable changes in the levels of production and employment as well as profitability over the 5-year period 2007–2011: firstly, employment and production have increased considerably and secondly, return on sales has reached record levels, resulting in bonus payments of € 7500 per worker and year. Equally important, however, is the massive increase in productivity as measured by cars produced per worker and year.
13. Kernel density estimates of the observed and the projected absence rate by regime are provided in Figures A2 and A3 in the Appendix.
14. The starting date of the summer holidays (which, in general, are six weeks long) varies by federal state. They start between the middle of June (in the northern states) and the end of July (in the southern states) and end between the end of July and the middle of September. In 2011, the plant we study here closed down in August while in 2009 and 2010 it already closed down in July.
15. The fractional response model is to be preferred over its alternatives because our dependent variable is censored and about 15% of the monthly observations are clustered at zero. Papke and Wooldridge apply fractional response model estimation to employee participation rates in pension plans (Papke and Wooldridge, 1996) and school test pass rates (Papke and Wooldridge, 2008). Oberhofer and Pfaffermayr (2009) show that fractional response models can be estimated by general linearized models. Specifically, the results from the fractional response model of Papke and Wooldridge (1996) can be replicated using the 'glm' command in Stata. However, our results are virtually identical when using alternative estimation techniques such as in Kauermann and Ortlieb (2004), for example.
16. If a unit exceeds the projected absence rate (this is the case in approximately 60% of our observations) this has no consequences. The projected absence rates reflect the composition of the unit and how well it performs relative to expectations.
17. Estimation of a fixed effects model with robust standard errors delivers almost identical results. These are available from the authors on request. The most important finding here is that the coefficients of our regime dummies retain their sign as well as their magnitude. The coefficient of the predicted absence rate, however, loses its statistical significance in the fixed effects estimation, which appears plausible because the projections 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.
18. Calculated as hours lost due to additional absenteeism × gross hourly wage costs per workers.
19. We have also investigated in more detail the possibility of a 'Hawthorne effect' (e.g. Bloombaum, 1983; Franke and Kaul, 1978; Jones, 1992; Levitt and List, 2011). It has until recently been taken for granted that any organizational change will eventually lead to a short-term change in employee behaviour independent of the nature of the change and that this change will decrease over time. In our estimations including a linear time trend that starts with the implementation of each of the regime changes, we fail to find any such effect (the results of these estimations are available from the authors upon request).

Author's note:

The results, opinions and conclusions expressed in this article are not necessarily those of Volkswagen Aktiengesellschaft.

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Appendix

Table A1. Employment, production and profitability of automobile company.

Year	Employment (Germany, in 1000)	Production (Germany, in 1000)	Cars per employee	Return on sales
2007	175	2,086	11.9	6.0
2008	178	2,146	12.1	5.8
2009	173	1,938	11.2	1.2
2010	178	2,115	11.9	7.1
2011	196	2,640	13.5	11.9

Source: annual reports.

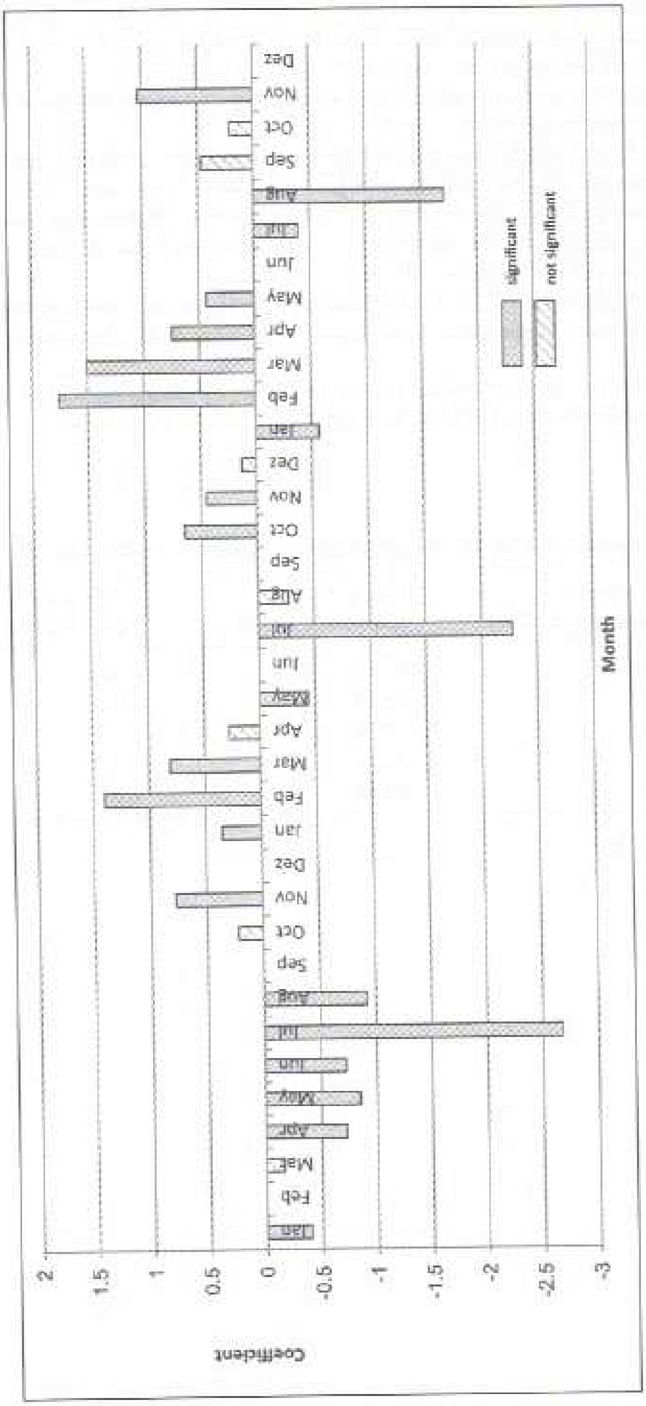

Figure A1. Coefficients of month dummies.

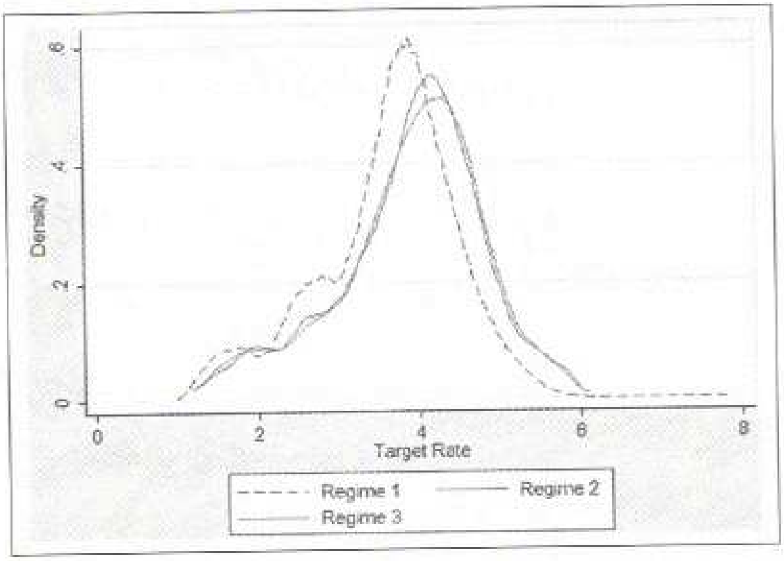

Figure A2. Density plot of projected absence rate by shift regime.

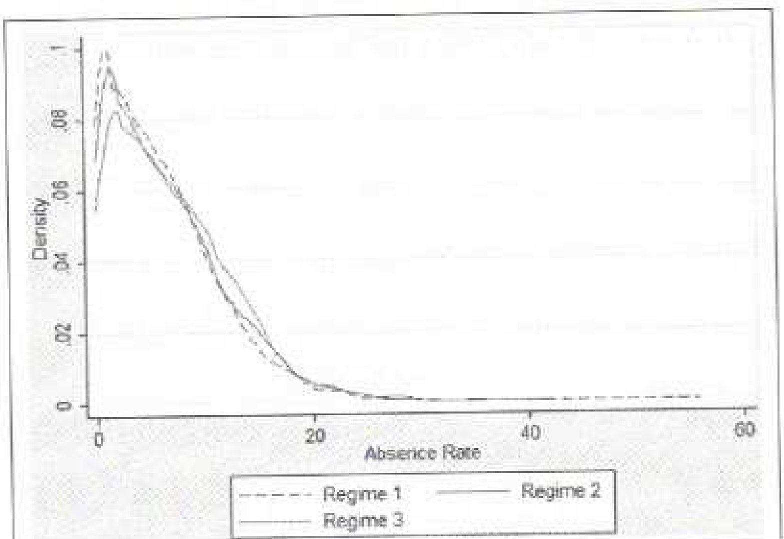

Figure A3. Density plot of absence rate by shift regime.