Fakultät für Wirtschaftswissenschaften

Lehrstuhl für Organisations-, Medien- und Sportökonomie

Shift Work Design and Worker Absenteeism – Four Econometric Case Studies

Der Fakultät für Wirtschaftswissenschaften der

Universität Paderborn

zur Erlangung des akademischen Grades

Doktor der Wirtschaftswissenschaften

- Doctor rerum politicarum -

vorgelegte Dissertation

von

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geboren am 08.09.1983 in Torgau

(2015)

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List of Abbreviations

ANOVA	Analysis of Variance
ArbZG	Arbeitszeitgesetz (Working Time Act)
BAuA	Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (Federal Institute for Occupational Safety and Health)
BCOPS	Buffalo Cardio-Metabolic Occupational Police Stress
BE	Kingdom of Belgium
BP	Blood Pressure
CI	Confidence Interval
CY	Republic of Cyprus
DL	Deciliter
E	Evening Shift
EE	Republic of Estonia
EntgFG	Entgeltfortzahlungsgesetz (German Continued Remuneration Law)
EL	Hellenic Republic
Ergo	Ergonomic
ES	Kingdom of Spain
EStG	Einkommensteuergesetz (Income Tax Act)
EU	European Union
EU27	European Union on 27 Member States
FE	Fixed Effects
FPG	Fasting Plasma Glucose
FR	French Republic
GDP	Gross Domestic Product
GLM	Generalized Linear Model
HDL	High Density Lipoprotein
HG	Mercury
HR	Hazard Rate
HU	Hungary
IARC	International Agency on Research on Cancer
IE	Ireland

ILO	International Labour Organization
IRR	Incident Risk Ratio
L	Liter
LT	Republic of Latvia
M	Morning Shift
MG	Milligram
MM	Millimeter
MMOL	Millimole
N	Night Shift
OE	Organisationseinheit (Organizational Unit)
OLS	Ordinary Least Squares
OR	Odds Ratio
OU	Organizational Unit
PL	Republic of Poland
RR	Relative Risk Ratio
SE	Kingdom of Sweden
SI	Republic of Slovenia
SK	Slovak Republic
TK	Techniker Krankenkasse
US	United States of America
VISAT	Vieillissement, Santé, Travail (Aging, Health and Work)
WOLF	Work, Lipids and Fibrinogen

1 Introduction

Within the young but well-established area of personnel economics, 'insider econometrics' has emerged as a fairly recent research field (Shaw 2009), and even as a new '*empirical research strategy*' (Ichniowski and Shaw 2013, p. 263).[1] Two seminal contributions to the literature can be described as the starting points of this new line of research.[2] Firstly, Ichniowski et al. (1997) analyzed the effects of innovative human resource management practices on productivity using 2,190 monthly observations on 36 US steel finishing lines of 17 different companies. They found innovative human resource management practices such as incentive pay, teamwork or job rotation to be associated with an increase in worker productivity. Secondly, Lazear (2000) investigated the sensitivity of the behavior of windshield installers in a large US company to the introduction of incentive pay. Information on over 3,000 employees from a US auto glass company over a time span of 19 months was used to identify the effects of an incremental replacement of hourly wages by a piece-rate remuneration scheme. He estimated the introduction of the piece-rate scheme to be associated with an increase in company productivity of about 44%. This was partly explained by the incentive effect of the new scheme and partly by a sorting effect through the attraction of more able new recruits.

The two studies clearly demonstrate the key characteristics of the insider econometrics approach:

- Micro-level panel data generated within one company, a few companies or an industry is gathered and employed to study the effect of management practices on the productivity of firms (Bartel et al. 2004).
- To do so, rigorous empirical analysis is complemented by corporate or industry expert's inside knowledge of the production processes of the company (Ichniowski and Shaw 2013).

1 Personnel economics evolved on the basis of work from Lazear (1993, 1995, and 1998) and emphazises the analysis of human resources and its management using microeconomic methodologies.

2 There are earlier studies, which display characteristics of insider econometric research (Ichniowski 1992). However, the studies of Ichniowski et al. (1997) and Lazear (2000) are the most influential early studies.

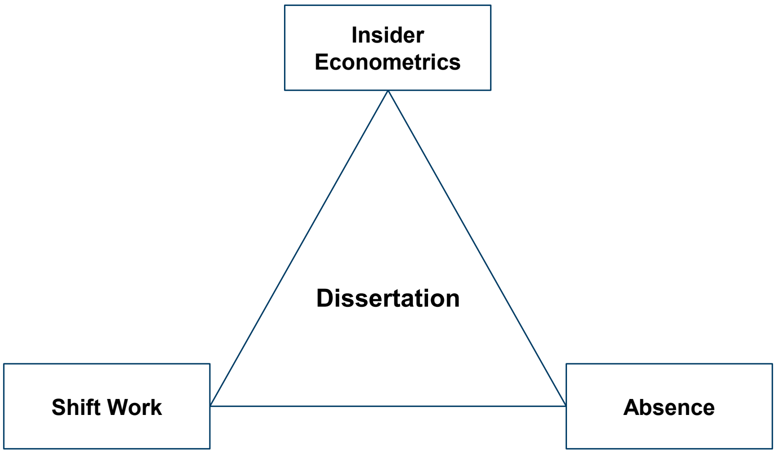
The studies of Ichniowski et al. (1997) and Lazear (2000) have been succeeded by a notable growth of empirical work on the productivity effects of various human resource management instruments and practices. Banker, Lee, Potter and Srinivasan (2000) looked at the changes in the behavior of sales employees in ten outlets of a large US retail firm following the implementation of a performance-based compensation plan. Gant et al. (2002) analyzed seven steel finishing lines in terms of differences in employee communication behavior between innovative and traditional human resource management systems. Bandiera et al. (2005, 2007, 2009, 2011) studied the response of fruit-pickers and managers at a farm in the UK to changes in incentives, e.g. in the remuneration system.

More recent examples include the work of Bloom et al. (2013) and Chan et al. (2014). A sample of 28 plants of 17 large Indian textile companies served as the basis for the quasi-experimental examination of productivity effects of management practices by Bloom et al. (2013). The innovative management practices in focus are diverse, including, for example, factory operations (e.g. regular machine maintenance), quality control (monitoring of defects) and human resources (performance-based incentive schemes). The results of the study indicate that company productivity increased on average by about 11% as a consequence of the introduction of these modern management practices. Chan et al. (2014) used daily information on sales from employees of cosmetic shops in a large metropolitan department store in China to examine potential peer effects of incentive schemes. Using detailed sets of information from the different shops, Chan et al. showed that compensation scheme designs may result in peer effects within a company, on the one hand, and strategic cross-company effects, on the other hand.[3]

The following work seeks to pursue an insider econometric approach by using novel, previously inaccessible data sets gathered from the human resources controlling department of a large multinational car manufacturer. The research goal of this work is to uncover effects of organizational practices (changes in shift schedules) on worker productivity (absence behavior) and, thereby, to extend the insider econometric literature.

[3] For a detailed review of the insider econometrics literature, see Lazear and Shaw (2007), Shaw (2009), Bloom and Van Reenen (2011), as well as Ichniowski and Shaw (2013).

The insider econometric approach can be understood as providing the methodological framework for the work at hand. Two further research fields define the context and structure: shift work research and research on absence. Both will be described in detail in the following sections. Together, these three research fields can be identified as constituting the triangular research framework in which this dissertation is situated (see figure 1.1.).



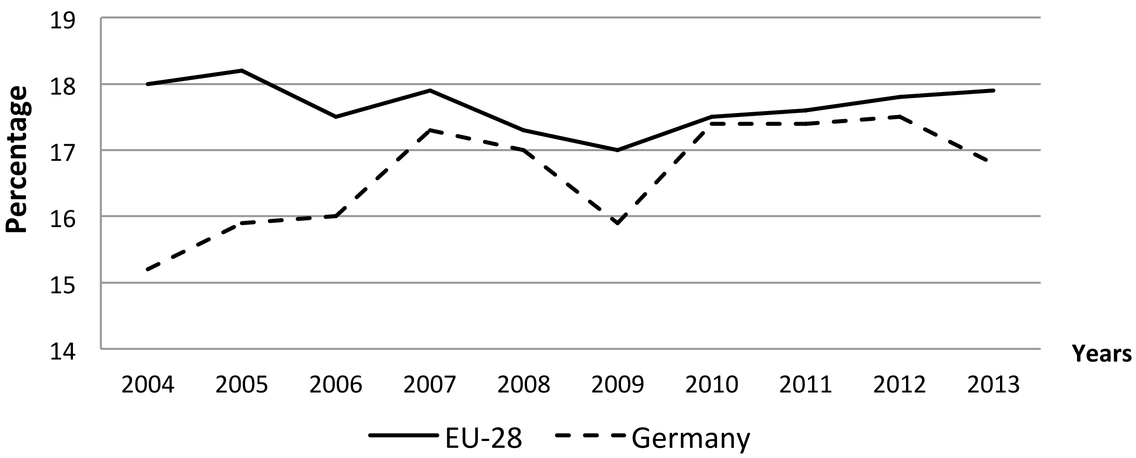
Source: Own illustration.

Figure 1.1: The Research Framework of the Underlying Work.

The second component of the research framework is shift work since a main goal of this work is to assess the effects of shift schedule changes on the absence behavior of workers. Therefore, an introduction to shift work and its components appears warranted. Today, shift work – defined as '*a method of organization of working time in which workers succeed one another at workplaces so that the establishment can operate longer than the hours of work of individual workers*' (International Labour Organization (ILO) 1990 as cited in International Agency on Research on Cancer (IARC) 2010, 563) – is prevalent in a wide array of industry sectors.[4] These include, for example, the catering and hotel industry,

[4] There are alternative definitions, such as the definition according to the EU Council Directive 93/104/EC, which states that '*shift work shall mean any method of organizing work in shifts whereby workers succeed each other at the same work stations according to a certain pattern, including a rotating pattern, and which may be continuous or discontinuous, entailing the need for workers to work at different times over a given period of days or weeks*' (Council of the European Union 1993) or the definition of Eurostat, which understands shift work as '*a regular work schedule, during which an enterprise is operational or provides services beyond the normal working hours (weekdays 8 am to 6 pm; evening closing hours might be later in the case of a longer noon break), and where different crews of workers*

health services (hospitals etc.) or the traditional manufacturing industries. The extension of operation hours due to the implementation of shift work has become an important factor for international competitiveness for firms in the capital-intensive manufacturing sector. For certain operations (e.g. nuclear plants or steel production) it is – due to economic as well as procedural reasons – even impossible to disrupt operating cycles (Monk and Folkard 1992). Additionally, certain services entail a societal imperative for 24/7 operations (e.g. police, fire department, health care) (Harrington 2001). Therefore, shift work plays an important role in industrialized economies. In Germany, for example, shift worker account for roughly 16.8 % of the working population. Furthermore, although the share of shift work has remained fairly stable within the European Union (EU) over the last decade (see figure 1.2), the share of 18 % of the working population being engaged in shift work in 2013 also serves as an account of its significance (Eurostat 2015b). This proves especially true for European countries like the Czech Republic, Poland, or Croatia, where shift workers account for 28.7 %, 30.6 %, and 35.1 % respectively (Eurostat 2015b).



Source: Own illustration, based on Eurostat 2015b.

Figure 1.2: Shift Workers (aged-16-64) as a Percentage of the Working Population.

However, as the definition of shift work by the ILO indicates, shift work is a rather generic term, which covers a wide array of different configurations of shift schedules (Knutsson 2004, Schlick et al. 2010). Therefore, a brief assessment of the main characteristics of the

succeed each other at the same work site to perform the same operations. Shift work usually involves work in the early morning, at night or at the weekend; the weekly rest days might not coincide with the normal rest days' (Eurostat 2015a). However, the definitions are very much identical.

design of shift work that are important for the present research is provided in the following.

To begin with, there is a fundamental difference between the time scopes of shift systems. In that regard, shift systems can be broadly categorized as either continuous or discontinuous. A continuous system implies that work is performed around-the-clock, including weekends since in some fields, such as hospitals or police departments, it is a necessity to work on weekends. Discontinuous systems are diverse and are all characterized by not performing around-the-clock work (Knauth and Hornberger 1997). This includes, for example, shift schedules with work from Monday to Friday with weekends off or schedules without night work (regardless of whether weekends are off).
A second important differentiation is that between permanent shift systems and systems that include alternating shifts. In a permanent shift system – the predominant system in the United States (US) – workers are constantly employed in one shift (Knauth and Hornberger 1997). Hence, one group of workers is employed in, for example, morning shifts while another group constantly works in evening shifts. In an alternating or rotating system, however, workers are engaged in different types of shifts since they switch – depending on the specific schedule – between different shifts (e.g. one week morning shift, one week evening shift). This alternative is more prevalent in Europe (Knauth and Hornberger 1997).

An important characteristic of the rotating shift systems is the direction of rotation. Shifts can either rotate in a forward or in a backward direction. A backward rotation implies a cycle of morning shift, night shift and evening shift, which may result in a minimum leisure time of 8 hours between shifts (between night and evening shifts) (Barton and Folkard 1993). In contrast, a forward rotating schedule follows a pattern of morning shift, evening shift and night shift. This results in a minimum leisure time of 24 hours between shifts (Hakola and Härmä 2001). Moreover, the forward rotation is found to correspond better to the 'body clock' of humans, facilitating the adjustment to the shift sequences (Aschoff 1965, Knauth and Rutenfranz 1976, Wever 1979). Therefore, from an occupational medicine point of view, forward rotation appears favorable over backward rotation (Barton and Folkard 1993).

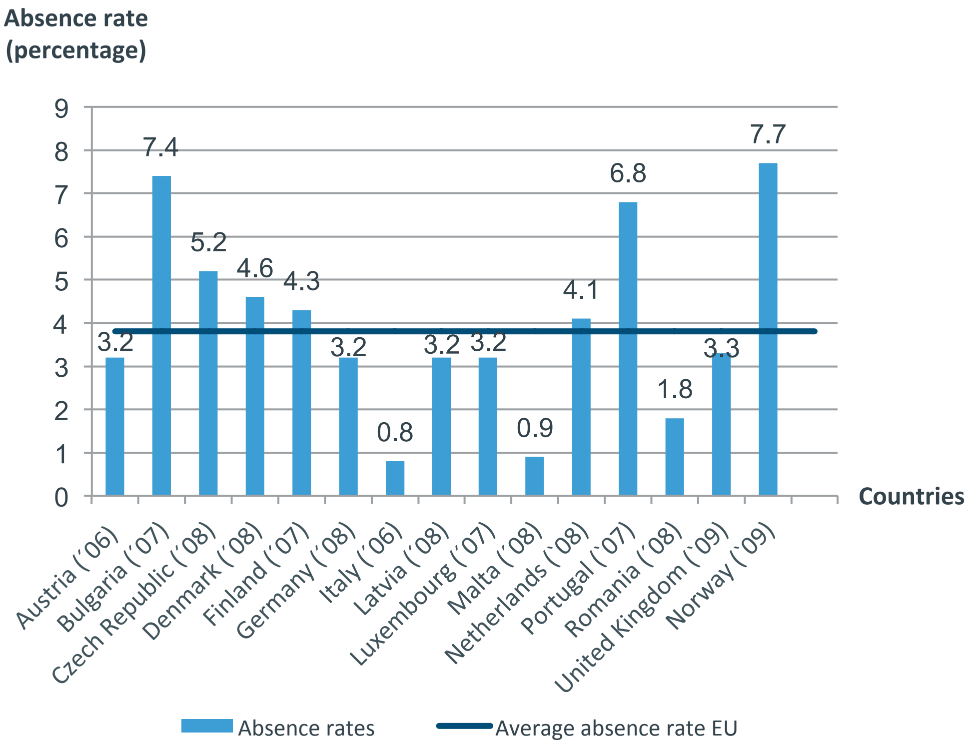
Another important feature of shift systems is the speed of rotation. Rotation speed is characterized as the frequency with which a group of workers changes shifts within their shift schedule. A slow rotation, for example, includes weekly rotating schedules. This means that workers might work for one week in morning shift, the next week in evening and the successive week in night shift. A fast rotation implies that the frequency of shift changes is higher (for example, two days morning, two days evening, two days night shift). In general, a fast rotation is considered preferable by occupational medicine experts due to less interference with human biological rhythms (Knauth 1997). In particular, the effects of these last two aspects (direction and speed of rotation) on worker absence will be emphasized during the course of this work. Further characteristics, which extend the scope of design mechanisms of shift work, include the length of shifts (e.g. 8h vs. 12h), the beginning and end times (e.g. morning shift from 6 am vs. 7 am) and the regularity of shift systems (e.g. weekly change vs. two day shifts, two evening shifts, one night shift) (Müller-Seitz 1991, Schlick 2010). However, these are not the focus of this work.

The final part of the present research strategy constitutes absence research. Absence – generally referred to as '*non-appearance for scheduled work*' (Kristensen et al. 2006, p. 1646) – is an economically important phenomenon. It addresses two important aspects. From an employer´s perspective, absence depicts a productivity measure (Ichniowski and Shaw 2013) since a rise in absence is associated with a decline in labor productivity and output (Chatterji and Tilley 2002). Moreover, absence also depicts an indicator for negative health outcomes for workers (Marmoth et al. 1995).

The overall absence rate in the European Union accrues to 3.8% (European Foundation for the Improvement of Living and Working Conditions 2010) and compares to 3.1% (for 2010) in the US (United States Bureau of Labor Statistics 2014).[5] However, comparable

[5] The estimate is based on reports from the respective EU countries. However, the years for which the estimates are reported vary between countries from 2000 to 2009 (European Foundation for the Improvement of Living and Working Conditions 2010). Hence, comparability appears limited.

absence rate figures between EU-countries are difficult to obtain since diverse definitions of absence (e.g. some countries include maternity leave while others do not) are applied. In an attempt to provide an overview on absence rates within the European Union (of 27 member states (EU27)) and Norway the European Foundation for the Improvement of Living and Working Conditions reported absence estimates to range from 0.8% in Italy to 7.7% in Norway (2010) (see figure 1.3).[6]



Note: Data for the remaining EU27 countries was either not reported (CY, EE, EL, ES, FR, IE, LT, PL, SE, SI, SK) or inconclusive (BE, HU). Years for which the measure was reported are in parenthesis.

Source: Own illustration, based on European Foundation for the Improvement of Living and Working Conditions (2010).

Figure 1.3: Overall Absence Rates of Selected EU27-Countries plus Norway for Different Years in the Period of 2000-2009.

The total costs associated with absence are substantial and are estimated to amount to roughly 2.5% of the European Gross Domestic Product (GDP) (European Foundation for the Improvement of Living and Working Conditions 2010). For Germany, the total costs of absence for the society in 2012 are estimated at €53 billion (BAuA 2014).

[6] Moreover, the differences may also be subject to influence from diverging institutional frameworks (e.g. sickness benefit systems) (Frick and Malo 2008).

Therefore, it is not surprising that research on the determinants of absenteeism is not a recent phenomenon – its origins date back to the late 1970s and early 1980s (e.g. Steers and Rhodes 1978, Allen 1981). Absence is a complex phenomenon and there is a wide variety of variables – examples include age (Barmby et al. 2004), gender (Voss et al. 2001), job motivation (Deery et al.1995), health (Leigh 1991), or monotonous work (Ose 2005) – which are understood to affect it. As a consequence, the field has been subject to extensive research across different disciplines such as, for example, psychology and economics (Kaiser 1998). Empirical evidence with regard to absence appears abundant, but a conclusive understanding of absence has not yet emerged.

An early attempt to provide a theoretical framework for absence research from a psychological perspective can be seen in a seminal work by Steers and Rhodes, who introduce a process model of employee attendance (1978). In the model being absent from work is understood as an individual decision based on two key elements:

- Motivation to come to work (attendance motivation)
- Ability to come to work

Both elements are influenced by personal characteristics (e.g. gender, age, education, family background). Additionally, the individual job situation (e.g. job scope, style of leadership) and attendance pressure aspects (e.g. market conditions, reward systems) affect the motivation to come to work. The ability to come to work (e.g. sickness, accidents) is understood to moderate the effect of attendance motivation on employee absence. Moreover, the decision to be absent can either be of voluntary (motivational) or involuntary (sickness, accidents) nature. In that regard, the Steers and Rhodes model (1978) opposes earlier arguments, which entirely focus on job satisfaction levels as the primary root for absence (see Kaiser 1998 for an overview). However, the model treats absence as a decision by employees only, not taking into account the role of employers. Moreover, economic as well as sociological (e.g., group norms) aspects are left out as well.[7]

[7] Another broad strand of the absence literature, which is not emphasized over the course of the present work, constitutes the 'social-psychological approach' (Kaiser, p. 82). This approach focuses on the relevance of group norms with regard to absence behavior of workers (Johns and Nicholson 1982, Rentsch and Steel 2003).

The economic view on absence differs from the psychological one and two main understandings of absence have emerged over the years.

- Neoclassical labor supply models, such as, for example, the work by Allen (1981) or Dunn and Youngblood (1986): Here, absence is seen as a result of individual labor-leisure choices, which are influenced by constraints from the employer side. Absence occurs as a consequence of differences in the individual labor supply and the organizational labor demand. Imperfect labor markets are assumed and, therefore, job search incurs costs. This induces that individuals may take a job even though contractual work hours exceed the work hours desired by the individual. In this case, the marginal rate of substitution between leisure and income deviates from the wage rate offered and the individual has an incentive to be absent from work (Allen 1981). Hence, the model expects individuals to be absent from work if the utility of being absent outweighs the associated costs (such as, for example, wage penalties). A decrease in utility – for example, lower wages or lower sick pay benefits – is expected to result in an increase of absence and vice versa. Additionally, Drago and Wooden also report a positive association of shift work – considered as a negative working condition – and absence.
- Absence models based on efficiency wage theory in the line of the work of Shapiro and Stiglitz (1984): Here, moral hazard and shirking are focused on and absence is assumed to be an indicator of individual effort levels. Being absent from work elevates the potential for dismissal and the loss of respective future earnings. Hence, the effort level of workers is correlated with wage levels since a worker identified as shirking may be confronted with dismissal, which impacts the respective wage level. Furthermore, different models emerged that focused on diverse means to reduce moral hazard and, therefore, absence rates. In that regard, for example, Arai and Thoursie (2005) showed that temporary contracts are negatively associated with absence rates. Other examples include the work of Henrekson and Persson (2004), Johansson and Palme (2005), or Ziebarth and Karlsson (2010) who show that a reduction of sickness benefit levels is associated with a reduction of worker absence.

Despite early assessment that '*shiftwork is an important variable in understanding absenteeism*' (Markham et al. 1982, p. 225), the different models, and the extensive empirical literature on the determinants of absence, the role of shift work and absence has only gained limited attention so far (Catano and Bissonnette 2014). Therefore, the underlying work seeks to contribute to the understanding of absence with regard to the influence of shift work. Evaluating the effects of shift work on worker absence in a labor-leisure context predicts absence to be increased under shift work since shift work is identified as a negative working condition. This holds also true for the context of moral hazard since the psychological costs associated with a dismissal are thought to decline as a consequence of exposure to shift work (Drago and Wooden 1992). Hence, theoretical considerations presume a positive association between shift work and worker absence.

However, the empirical projects carried out over the course of the present work do not focus on the absence effects of shift compared to day work. Rather, the work tries to identify the potential of ergonomically designed shift models – in contrast to traditional shift models – to reduce work stress and, therefore, result in lower rates of absence. Hence, the work at hand seeks to contribute to the literature by assessing the effects of shift model changes on worker absence within the production line of a large international automobile manufacturer. From a theoretical point of view the expected absence effects of ergonomically improved shift models in comparison to traditional shift models is presumed to be negative. Under labor-leisure choice models, the ergonomically improved shift systems are assumed to provide improved working conditions and, hence, a negative association with worker absence is expected. The same is expected with regard to the moral hazard approach since psychological costs of a potential job loss are elevated through ergonomically improved shift models. However, empirical evidence on the topic remains limited. In order to fill this gap in research, the following core model is used over the course of the present work:

$$(1)\quad \textit{Absence Rate} = \beta_0 + \beta_1 \textit{Ergo-Shift} + \chi\delta + \varepsilon_i$$

Absence Rate is measured as the proportion of the number of days absent divided by the scheduled number of working days (per month per team (organizational unit)).[8] The use of an objective absence measure – reported based on company records – depicts an important advantage over a substantial part of the absence literature, which relies on self-assessed survey reports on the prevalence of worker absence.[9] *Ergo-Shift* is an indicator for the introduction of an ergonomically improved shift model and takes on the form of a dummy variable. The notation $\chi\delta$ includes the influence of further variables such as, for example, the unit size – measured as the average number of employees in a team (organizational unit) per month – or the projected absence rate – measured as a proportion of number of expected days absent divided by the scheduled number of working days (per month per organizational unit).[10] For the different empirical projects of this work, the variables inserted for $\chi\delta$ differ.

Applying models of the abovementioned form, the work at hand seeks answers to the following three core questions:

(1) Do changes in the design of shift models influence worker absence?
(2) Do ergonomic improvements in the design of shift models reduce worker absence?
(3) Are there different patterns of worker absence between varying shifts (morning, evening, night) of the same shift schedule?

While the first two questions clearly address shift model changes (chapters five to seven), the third question zeroes in on a detailed evaluation of intra-shift model dynamics with regard to worker absence behavior and will be of particular interest in the fourth research article (chapter eight). To address the research questions, a variety of econometric mod-

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8 Vacation entitlements and holidays are excluded from absence rates. However, short as well as long term absence spells are included in the measure. Certified and uncertified sickness absence cases are included since the German Continued Remuneration Law requires employees to provide a certificate of illness only after three days (EntgFG 1994a).

9 The advantage can be seen in the fact that self-assessed absence is expected to significantly underreport actual absence levels (Johns 1994).

10 The human resources controlling department uses the projected absence rate as an instrument for the calculation of personnel requirements of the company. It is computed based on the gender composition and age structure of the units as well as on the job type (white/blue collar work). However, the exact algorithm behind it is proprietary information and unknown to the author.

els are estimated to account for the specific characteristics of the underlying data. The dependent variable – absence rate – is measured as a proportion and, therefore, fractional response models are warranted (Papke and Wooldridge 1996, 2008). Hence, generalized linear models (GLM) using logit link functions and binomial families are applied. Further models estimated in the course of the work at hand include, for example, fixed-effects, poisson, and negative binomial models.

In order to achieve the research objective, the underlying work is structured as follows: Chapter two seeks to elucidate the relationship between shift work and worker health. Therefore, empirical evidence on the association of shift work with varying negative health outcomes is presented. Worker absence as a consequence of shift work is evaluated in chapter three, where the surprisingly scarce empirical evidence on the topic is analyzed. Subsequently, chapter four seeks to illustrate how different shift work design mechanisms – speed and direction of rotation – potentially alleviate negative consequences associated with shift work. Chapter five to eight comprise four separate research projects, which are sought to be published in peer-reviewed academic journals in the area of health economics. The first three studies contribute to the literature on shift work and worker absence through the evaluation of absence effects of newly introduced shift schedules, which are expected to increase worker health, in similar organizational settings. The final study focusses on the effects of different positioning of shifts (morning, evening, night) on worker absence in an existing shift schedule.

Chapter five depicts joint work with Bernd Frick and Robert Simmons in which a balanced panel of some 400 production teams (organizational units) in a large automobile plant is used to analyze changes in absenteeism following an organizational innovation intended to improve worker health and well-being. During the period under consideration (January 2009 to December 2011) the firm replaced its traditional shift schedule that was associated with high health risks for workers by an ergonomically more advantageous system. The estimations show that this organizational 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 ergonomic perspective again associated with higher health risks than the second one. Absence figures quickly returned to their initial levels. This suggests that leisure preferences can override health concerns in worker responses to the implementation of different shift schedules.

At the core of chapter six lies the evaluation of the introduction of a different ergonomically advanced (rapidly forward rotating) shift model in the production line of the same automobile manufacturer. Again, the newly installed shift model is expected to alleviate health risks of workers. The analysis of monthly data on 86 organizational units over a timespan of two years reveals that absence rates are significantly reduced following the introduction of the new shift model. A control group, which is subject to only moderate shift model changes does not reveal significant changes in absence rates. However, it becomes apparent that the reduction effects of the ergonomically advanced model may mainly be driven by motivational rather than short-term health effects. Summarizing, the results indicate that ergonomic designs in shift models offer the potential to increase the supply of labor of the existing workforce through reduced worker absenteeism.

Using data on 43 organizational units from a component manufacturing plant of the aforementioned automobile company, the implementation of a different ergonomically advantageous shift model and its effects on worker absence builds the topic on chapter seven. In contrast to the earlier results, however, it becomes apparent that there is no significant effect of the new shift model on worker absence levels. The results can be explained by the fact that the adaptations conducted in the design of the shift model can be assessed as moderate. With regard to potential determinants of worker absence the results indicate a positive association of absence and age. Contradicting the majority of the academic literature, unit size is not found to be of influence on absence rates.

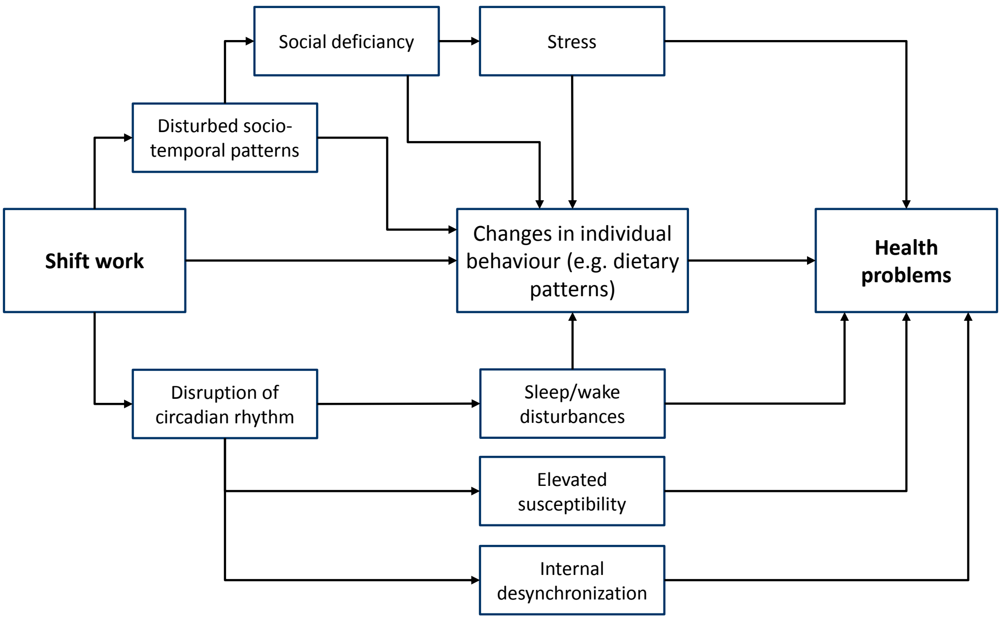
Instead of focusing on shift model changes, chapter eight emphasizes the evaluation of intra-shift model effects on absence. In this joint work with Bernd Frick, a balanced panel of some 150 organizational units in a large German automobile plant (with some 15,000 week-unit-observations from the year 2009 and 2010) is used to analyze the impact of the positioning of shifts (morning, evening, and night) on worker absence. It shows that during evening shifts absence rates are significantly higher than during either morning or night shifts and that absenteeism is particularly high during the evening shift immediately following the three weeks of consecutive night shifts. The first finding is contributed to 'social opportunity costs' of working (i.e. while friends and family are enjoying their leisure time) and the second finding to a 'tax evasion effect' (the night shift premium is subject to income tax if a worker calls in sick during the night shift but is exempt from taxation if the employee shows up at work).

Subsequently, the results of the studies and their implications are summarized and discussed in chapter nine.

2 Shift work: Health and Social Aspects

From an occupational medicine point of view, exposure to shift work – irrespective of the specific design – can be understood as a detrimental stress factor (Folkard and Lombardi 2006, Beermann 2010a, 2010b). Therefore, it is no surprise that the field of shift work and its potentially harmful effect on worker health has been studied in great detail by occupational medicine researchers (see e.g. Poissonnett and Veron 2000, Costa 2010 for an overview). The following section briefly explores the biological mechanisms behind different health effects associated with shift work and provides a concise overview of the relevant literature with respect to the health effects of shift work.

Shift work requires around-the-clock work and includes working at times that are normally reserved for leisure or sleep (evening, night). As a consequence, working evenings and nights creates circumstances in which workers oppose the natural sleep-wake patterns of diurnal life forms (Ohayon et al. 2002). This can be identified as the main source of health-related disorders in connection with shift work (Harrington 2001, Folkard and Tucker 2003) since the disruption of sleep-wake patterns and the associated patterns of activity and rest constitute substantial stress factors for the endogenous regulation of the human circadian rhythms (Costa 2010). This is critical because humans display circadian rhythms for body temperature, respiratory rate, hormone production etc., which operate on a 25-hour cycle basis (Harrington 2001). These rhythms can be described as inner body clocks, which regulate human bodily functions. Almost all body clocks are regulated by a main body clock, which is situated in in the suprachiasmatic nuclei in the human brain. Additionally, external environmental factors such as the light and dark cycle influence body functions (Reppert and Weaver 2002, Dibbert et al. 2010). Furthermore, these clocks cannot easily be reprogrammed since the respective time sequences are genetically predefined. For example, under traditional working and living conditions, the body temperature peaks in the late afternoon, while its lowest point occurs in the early hours of the morning (Rajaratnam and Arendt 2010). The secretion of melatonin is normally highest during the night. Melatonin is a hormone that reduces the bodily activity level and leads to increasing tiredness/reduced alertness in the evening because its level of secretion is dependent on light exposure (Akerstedt 2003). Exposure to shift work and the accompanying activities at unusual times results in exogenous disruptions to the above-mentioned endogenously regulated rhythms and exposes the human body to stress (Costa 2010). Examples include long wake phases during nights and sleep phases during the day – both requirements for working in night shifts – which require the adaptation of biological functions that are normally inactive at the specific time of day/night (e.g. level of alertness, digestion at night). This may result in negative health-related outcomes since the adjustment of body functions is a slow process, at about one hour per day (Czeisler et al. 1981). However, disruption of circadian rhythms is not the only pathway through which shift work may affect health. In particular, the interference of shift work schedules with time periods normally reserved for leisure and family activities (late afternoon, evenings, and weekends) may result in serious disturbances in socio-temporal patterns and stress which can result in negative health outcomes (Knutsson 1989). Moreover, working at unusual times also induces behavioral adaptations such as, for example, the adjustment of dietary patterns (e.g. eating at times, which are normally reserved for sleep during night shift hours (for an overview on potential mechanisms of shift work on worker health see figure 2.1)).



Note: Own illustration, based on Knutsson (1989).

Figure 2.1: Mechanisms behind Shift Work and Ill Health.

Notwithstanding the social influences of shift work on worker health, circadian disruption and its impact on various human biological rhythms as a consequence of shift work can be identified as a main reason for a potential increase in the risks for negative health consequences of workers (Knutsson 2004). The next section will present empirical evidence on the effects of working shifts and different disease outcomes.

2.1 Sleep Problems

The effects of shift work on sleep were the focus of a cross-sectional study by Härmä et al. (1998). The authors used questionnaire data on 3,020 male full-time employees (aged between 40 and 55 years) from two governmental institutions (Finnish Railways and Post and Telecommunications Agency) as well as five industrial firms (e.g. oil refinery plant, heavy engineering) in Finland. The questionnaire was completed in 1996/1997 and information on the type of shift model was gathered through a self-assessment of workers, who were asked whether they were employed in permanent day work, 2-shift-work, 3-shift-work, irregular shift work or permanent night shift. However, since the shift schedules between the institutions at hand differed substantially (e.g. forward as well as backward rotating and slow as well fast rotating shift schedules were included), the results need to be understood as aggregates over different shift schedules. The effect of the direction of rotation, for example, could not be assessed by means of the presented data. Analysis of variance as well as logistic regression analysis was applied in order to provide answers for the research question. Confounding factors such as the level of physical activity, the level of alcohol consumption or whether the individual was smoking were controlled for. The results indicate an increased prevalence of sleep irregularities and disturbances for 3-shift (odds ratio (OR): 1.51, confidence interval (CI), 95%: 1.15-1.99) and irregular shift workers (OR: 1.64, CI, 95%: 1.21-2.21) in comparison to day workers.

Drake et al. (2004) used data on 2,570 randomly sampled telephone interviews with participants (aged 18-65 years) from the metropolitan area of Detroit to assess the effects of shift work on self-reported quality and quantity of sleep. Using covariance analysis, the authors identified the prevalence of insomnia or excessive sleepiness to be substantially higher among both night shift workers (32% higher) and shift workers in rotating shift schedules (26% higher) compared to day workers. However, the fact that all information (e.g. on working shifts, on sleep quality etc.) are subjective individual assessments rather than objective evaluations constitutes a clear drawback of the study. Furthermore, different shift schedules are only categorized in day, evening, night and rotating schedules, which limits commensurability since, for example, the length of shifts and starting times may vary substantially between types of e.g. night shifts.

Data from a French prospective study on aging, health and work (VISAT) was employed by Tucker et al. (2011) to assess the prevalence of sleep problems among shift workers.[11] In a three-wave longitudinal set-up (1996, 2001, 2006) 1,246 participants provided information on their work status (e.g. shift work, former shift work, no shift work) and sleep quality (e.g. difficulty falling asleep, premature wakening). Using analysis of variance, the authors found evidence that shift workers displayed a higher prevalence of sleeping problems, especially premature wakening, in comparison to non-shift workers. A shortcoming of the study was its lack of information on the different shift systems in which the people were employed (e.g. forward or backward rotating models).

Finally, two seminal reviews on the effect of shift work on sleep quality and quantity by Akerstedt (1998, 2003) both provided evidence for an unambiguous effect. Working during the night significantly affected the length of sleep after a respective night shift by about two to four hours. Similar effects were identified for sleep periods after morning shifts (Akersted 2003). Although in general, empirical evidence in the field suffers some drawbacks (self-assessed data (e.g. Drake et al. 2004), limited differentiation between shift schedules (e.g. Härmä et al. 1998, Tucker et al. 2011)), the results nevertheless indicate a clear association between the prevalence of shift work and the risk of sleep disorders/disturbances. Hence, it appears that the distortion of sleep-wake patterns related to shift work depicts a serious negative influence on sleep quality and quantity.

[11] VISAT (Vieillissement, Santé, Travail) is a French research project on aging, health, and work. It aims at understanding how working conditions and age affect health resources of workers and recently retired people. For this purpose, information is collected on 3,237 participants - wage earners as well as recently retired people - on clinical factors such as weight, height and blood pressure through medical examinations by occupational physicians. Additionally, questionnaires on the work status were completed. The VISAT evaluation is of a longitudinal design including three waves (1996, 2001, and 2006).

2.2 Gastrointestinal Disease

The disruption of traditional sleep-wake patterns and the resulting circadian disruptions, however, appear not only to materialize in sleeping problems. Working in rotating and night shifts also entails changes in dietary patterns since meals are often consumed at unusual times (Costa 2010). These erratic patterns of dietary provision lead to an altered secretion of digestive enzymes as well as changes in the gastrointestinal activity. The consequence may be an increased risk for gastrointestinal complaints and disorders among shift workers (Vener et al. 1989). However, empirical evidence on the topic is not as extensive as for potential sleep disorders.

Caruso et al. (2004) made use of information on a total of 343 workers who were employed for at least five years at an auto factory in the Midwest (US) to assess the influence of shift work on the prevalence of different gastrointestinal diagnoses. All participants worked on either permanent day (6:00 to 14:30) or evening shift (14:30 to 23:00) from Monday to Friday with weekends off. Night workers were excluded since there were only a limited number of workers employed on permanent night shifts. At the outset, participants were asked to complete a questionnaire including demographic, psychosocial and health aspects. The relevant exogenous variables in the study were self-reported symptoms of gastrointestinal disorders or diagnosis of gastrointestinal diseases. Additionally, various control variables (e.g. demographics, lifestyle) were included. Cross-sectional logistic regression analysis revealed that working on permanent evening shifts increased the risk of gastrointestinal disorder diagnosis (OR: 3.29, CI, 95%: 1.34-8.06) compared to permanent day shift employment. However, in a multiple regression analysis no significant increase in the risk for gastrointestinal symptoms was found (0.406, F = 0.062). Clear shortcomings of the study are the cross-sectional design as well as the self-reported dependent variables, which may have substantially altered the results.

A more recent study by Van Mark et al. (2010) examined the effect of shift work on the risk of gastrointestinal disorders using a cross-sectional sample of 615 automobile plant workers. Participation was voluntary and a survey as well as a medical check-up was conducted over a time period of two years. A total of 384 individuals worked shifts (311 including night shifts, 73 excluding night shifts) while 231 were daytime workers (74 had shift work experience, 157 never engaged in shift work). The prevalence of gastrointestinal disorders was declared positive if certain related health outcomes (e.g. reflux, acute or former gastritis) were reported in the medical history or questionnaire. In contrast to Caruso et al. (2004), Van Mark et al. (2010) fail to provide significant evidence for an association between shift work and an increased prevalence of gastrointestinal disorder symptoms or complaints (OR: 0.72, CI, 95%: 0.34-1.49).[12] However, the drawbacks of the study are identical to those of the study by Caruso et al. (2004).

Using a cross-sectional research design, Nojkov et al. (2010) examined the prevalence of bowel disorders among 399 US nurses in relation to their exposure to shift work. Information was gathered through questionnaire participation, through which information regarding health and sleep was requested. Shift work exposure was self-assessed as day, night, or rotating shift engagement. A total of 214 nurses worked day, 110 night and 75 rotating shifts. Nojkov et al. used a multiple regression approach and controlled for potential confounding factors (e.g. age or gender). They found that working rotating shifts was associated with a significantly increased risk for the prevalence of irritable bowel disorder as well as an increased risk for other gastrointestinal problems such as, for example, abdominal pain. Again, the cross-sectional design and the self-assessed information constitute drawbacks of the analysis.

Finally, in a fairly recent literature review on the relation between shift work exposure and the prevalence of gastrointestinal disorders, Knutsson and Boggild (2010) predominantly presented support for a positive association between the exposure to shift work and the prevalence of gastrointestinal disturbances. In their review of 20 research papers, the majority revealed an increased risk for individuals engaged in shift work compared to day workers with regard to the risk for gastrointestinal diseases. Hence, empirical evidence thus far points in the direction of an increased health risk through gastrointestinal disorders as a consequence of shift work. However, methodological drawbacks such as the predominantly cross-sectional nature of the research designs (e.g. Caruso et al. 2004,

[12] The coefficients for all gastrointestinal symptoms included were not significant and included, for example, reflux symptoms (OR: 0.34, CI, 95%: 0.12-0.94) or gastritis (OR: 0.89, CI, 95%: 0.39-2.06).

Van Mark et al. 2010) provide room for further investigation, for example through longitudinal studies.

To summarize, the literature review on potential health effects of shift work points to negative health outcomes with regard to sleeping disorders and gastrointestinal diseases.

2.3 Metabolic Syndrome

A third field in which shift work is assumed to entail negative health outcomes is the prevalence of metabolic syndrome. The metabolic syndrome is a group of medical risk factors, which elevates the risk for negative health outcomes such as diabetes, cardiovascular disease or stroke). An individual is diagnosed with metabolic syndrome if central obesity and two out of four additional risk factors are prevalent.[13] These include raised triglyceride levels, reduced high density lipoprotein (HDL) cholesterol, raised blood pressure and raised fasting plasma glucose (International Diabetes Foundation 2006).[14]

Karlsson et al. (2001) deployed information on 27,485 people from the Västerbotten Intervention Programme (VIP) to assess whether there is a link between shift work and the risk for metabolic syndrome.[15] The data used in this specific context combines information on blood sampling and survey data form participants, who completed the survey/examination between 1992 and 1997. The information on shift work exposure was

13 Central obesity is defined as having a waist circumference of more than 94 cm for European men and more than 80 cm for European women. The values for other ethnic groups vary (e.g. 90 cm for Chinese men).

14 According to the International Diabetes Foundation (2006), the exact levels for each risk factor include: Elevated triglyceride level: ≥ 150 milligram/deciliter(mg/dL) (1.7 millimole per liter (mmol/L)); reduced HDL cholesterol: < 40 mg/dL (1.03 mmol/L*) in males and < 50 mg/dL (1.29 mmol/L*) in females; increased blood pressure (BP): systolic BP ≥ 130 or diastolic BP ≥ 85 millimeters of mercury (mm Hg); and elevated fasting plasma glucose (FPG): ≥ 100 mg/dL (5.6 mmol/L).

15 The Västerbotten Intervention Programme is situated in the county of Västerbotten (Sweden) and seeks to prevent cardiovascular disease and diabetes in the working population. It was introduced in 1985 since the county of Västerbotton was subject to the highest rates of mortality from cardiovascular disease in Sweden. Since the introduction of the community program, participants (male and female) were asked to complete surveys on working conditions, smoking habits and dietary information at the age of 30, 40, 50 and 60 years. Additionally, heath examinations were conducted to generate reliable information on health outcomes (such as blood pressure levels) of participants. So far, over 110,000 health examinations have been completed in the program to explore differences in metabolic risk factors (such as e.g. obesity, blood cholesterol levels) for cardiovascular disease between shift and day workers (Weinehall et al. 2001).

self-assessed by each individual by answering the question of whether participant´s work in shift or weekends. Hence, shift work was very broadly defined here and there is no possibility to differentiate between different types of shift work. Information on the health status (blood pressure levels, body mass index (obesity)) was gathered through medical examinations. The analysis was of cross-sectional nature since for each individual there is only one survey/examination over the respective timespan. Using logistic regression analysis, the authors found evidence that shift work was associated with an increased risk for metabolic syndrome. In particular, the risk for certain symptoms of metabolic syndrome such as e.g. obesity appeared elevated.

These findings were supported by Karlsson et al. (2003) in a cross-sectional study on shift workers in the Swedish paper industry. The underlying research goal was to evaluate the relationship between shift work and metabolic risk factors as well as type-2 diabetes. To do so, a 1996-1997 sub-sample from the WOLF survey on 1,314 male workers – 665 day workers and 659 three-shift workers – from two different paper plants in Sweden participated in a medical examination (e.g. information on height, body mass index, cholesterol levels).[16] Additionally, a complementary survey on working conditions, health and education was completed. The multiple logistic regression results indicated an increased risk for some risk factors for metabolic disturbances such as low HDL-cholesterol (the risk was doubled among shift workers, (odds ratio of 2.02, (95% CI: 1.24-3.28) and high levels of triglycerides (odds ratio: 1.40, 95% CI: 1.08–1.83).

De Bacquer et al. (2009) used information from a Belgian epidemiological cohort study (Belstress study) to investigate the relationship between exposure to shift work and the prevalence of metabolic syndrome.[17] The sample included a total of 1,529 male workers

[16] The WOLF (work, lipids and fibrinogen) study is a Swedish prospective cohort study. It aims at analyzing the role of occupational conditions and cardiovascular risk factors and disease development. Corporate occupational health units carried out baseline screenings for over 10,000 male and female employees from around 60 firms over the timespan from 1992 to 1998 in north Sweden and the Stockholm region. The screening included clinical examination and blood sampling (Whang 2013).

[17] The Belstress study is a prospective cohort study of different industries and sectors in Belgium, which was initiated in 1994. A total of 16,335 individuals (male and female) within the age-bracket of 35 to 59 years have participated voluntarily. The study follows two main goals: First, to evaluate the relationship between work stress and sick leave in the Belgian working population and second, to assess the relationship between work stress and coronary heart disease among male workers. All individuals are

from two public institutions, six private institutions and one bank in Belgium. Information for the longitudinal study was gathered in 1995-1998 for the first wave and in 2002-2003 for the second wave. Both included a self-administered survey (including e.g. socio-demographics, medical history, working conditions) and medical examinations through occupational health teams. There were a total of 309 workers classified as working rotating shift schedules (two- or three-shift schedules) but no differentiation between different schedules was made and the results were only aggregated for all shift workers. Moreover, due to the high number of companies included, it appears reasonable to assume that the shift schedules between the companies differ in terms of direction of rotation, length, breaks etc. So a generalization of the results appears difficult. Nevertheless, the results of the logistic regression estimations indicated an elevated risk for developing metabolic syndrome among rotating shift worker (OR: 1.46, CI, 95%: 1.04-2.07) compared to day workers.

Additionally, Pietroiusti et al. (2010) conducted research on Italian health workers over a period of five years. The study focused on the relationship between night shift work and the risk to develop metabolic syndrome. In the prospective cohort study, female as well as male nurses of three large hospitals were observed. Furthermore, the study was conducted over a five-year period (from January 2003 until December 2007) during which 738 health workers (402 night workers, 336 day workers) participated. However, the term night shift worker was rather loosely defined including all workers who work at least an average of four nights per month over the course of a year. More detailed information on the design of the different shift schedules falling in this category was not available. The information on the participants was gathered by occupational medics during annual health examinations that were part of a health surveillance initiative at the hospitals. Pietroiusti et al. (2010) applied multiple cox regression analysis and concluded that the risk of developing metabolic syndrome was significant and strongly related to the exposure of night shift work (hazard ratio: 5.10, CI, 95%: 2.15-12.11).

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employed in either public institutions or 24 companies from varying industries in Belgium. Information was gathered both, through questionnaires as well as complementary medical examinations (Kittel et al. 2002)).

At the core of a more recent cross-sectional study by Tucker et al. (2012) lay the question, whether there is an association between shift work experience and incidence of metabolic syndrome. Tucker et al. used information from the first wave (1996) of a French prospective study on aging, health and work (VISAT) on 1,757 wage earners or recently retired people, who self-assessed their exposure to shift work. The results of their logistic regression analysis indicated that current as well as past shift work exposure – controlled for confounding factors such as, for example, age or smoking – predicted the prevalence of metabolic syndrome. Furthermore, the results indicated an increased prevalence for metabolic syndrome for people with ten or more years of experience in rotating shift work compared to those with less or no shift work experience at all. However, as in the related study by Tucker et al. (2011) on the effects of shift work on sleep, the study lacked information on the different shift systems in which the people were employed (e.g. forward or backward rotating models).

In conclusion, empirical evidence clearly suggests an association between shift work and an increased risk for metabolic syndrome or symptoms thereof. However, more detailed information on shift schedules is desirable in order to assess whether certain shift schedule designs may assert a more profound influence than others.

2.4 Heart Disease

In an early study on the subject, Kawachi et al. (1995) used a sub-sample of the Nurses' Health Study comprising of information on 79,109 female nurses in the US to assess the potential link between shift work and the risk for cardiac infarction.[18] Over the timespan from 1988 to 1992, the participants were asked to complete a questionnaire every two years. The participating nurses were between 42-67 years old at the baseline of the study (1988). Self-assessed information by nurses provided the basis for the study and no objective measures (e.g. medical examinations, blood samples) were applied. Furthermore,

[18] The Nurses’ Health Study was initiated in 1976 with the aim to generate a deeper understanding of potential long-term risk factors for cancer and cardiovascular disease for women. Therefore, a total of 121,700 female nurses aged 30 to 55 years completed a questionnaire about individual risk factors for coronary heart disease and cancer. The information included e.g. smoking habits and questions on the personal history of diseases (e.g. heart infarction, angina, and cancer). Since the initial study in 1976 the questionnaire has been repeatedly handed out every two years to the entire sample group (Colditz et al. 1997). Today, a revised version of the health study still continues.

exposure to shift work was self-assessed as the number of years during which a person worked in rotating night shift. Here, rotating night shift was defined as any shift that included a minimum of three night shifts per month in combination with day and evening shifts in a month. In order to assess the risk for cardiac infection from shift working nurses, incident rates for cardiac infarction were recorded over a four-year follow-up period and amounted up to 292 cases. Kawachi et al. estimated the age-adjusted relative risk for cardiac infarction to be significantly higher (relative risk ratio (RR): 1.21, CI, 95%: 0.92-1.59) in women who had shift work experience compared to women with no shift work experience. Again, the self-assessed nature of the relevant information may have substantially distorted the results.

Two years later, Tenkanen et al. (1997) analyzed the association between shift work and the risk for coronary heart disease in a Finnish cohort. Therefore, a sub-sample of the Helsinki Heart study was used comprising 1,806 Finnish male workers (40-55 years old) from different industries (e.g. oil refinery, heavy engineering.[19] All participants were accessed to have no indication of a cardiovascular disease at the outset of the study period (1982). At the beginning of the trial period, all participants completed a psychosocial questionnaire also providing information regarding their current shift work status (options included: day work, part-time work, two-shift work, three-shift work, irregular work or night work). Hence, information on the shift schedules appears rather aggregated since they may differ in design aspects (such as, for example, rotation speed or starting times). The follow-up period lasted until 1993 and incidents of coronary heart disease were recorded from hospital discharge records and the death register. To estimate the relative risk of shift workers for coronary heart disease compared to non-shift workers, Tenkanen et al. used Cox proportional hazard models. The results supported the findings of Kawachi et al. (1995) and indicated that exposure to shift work is associated with an increased risk for the prevalence of coronary heart disease (for three-shift workers: RR: 1.7, CI, 95%: 1.0-2.7, for two-shift worker: RR: 1.9, CI, 95%: 1.0-3.3).

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[19] Helsinki Heart Study is a primary prevention trial and aims at analyzing the influence of cholesterol on morbidity and mortality regarding coronary heart disease in a Finnish male working population. The sample includes workers from companies of different industries as well as governmental institutions and the study consisted of a baseline at 1980 and a five year follow-up phase (Mänttäri et al. 1987).

Using data on 17,649 Japanese male workers, Fujino et al. (2006) also found support for a positive relationship between the exposure to shift work and the prevalence of coronary heart disease. The study was designed as a prospective cohort study and at the baseline (1988-1990) all participants answered a survey with questions about individual characteristics (e.g. smoking status, alcohol intake). The exposure to shift work was also self-assessed by the participants by answering which shift schedule they predominantly worked on during their career (day, night, alternate night and day). During the follow-up period (until 2003), the prevalence of coronary heart diseases was recorded through assessment of the vital status of each participant. This was checked on an annual basis through data held at regional research centers about death causes. For the purpose of the study, death through ischemic heart disease was focused on. Cox proportional hazard models were used to estimate the relative risk for coronary heart disease related to shift work. The results further strengthen the evidence on a positive link between shift work and the risk for coronary heart disease by providing evidence for an increased risk of mortality for shift workers due to heart disease (RR: 2.32, CI, 95%: 1.37-3.95).

A more recent cohort study by Hublin et al. (2010) used 22-year follow-up data on Finnish twins to assess the relationship between shift-work and the risk of mortality/disability retirement as a consequence of coronary heart disease. The sample included a total of 20,142 participants both male (48.8%) and female (51.2%) who received a first questionnaire in 1975 and a second in 1981. The questionnaires requested information on socio-demographics (e.g. marital status, education), health status, lifestyle, and work patterns. The shift work status was self-assessed in both questionnaires as either mainly daytime, nighttime or shift work. The Population Register Centre of Finland served as a source for the vital status of participants over the 22-year follow-up period (until December 2003). Statistics on cause-of-death for the respective causes were gathered from Statistics Finland while data on disability retirement due to coronary heart disease was gathered from the Finnish Social Insurance Institution and the Finnish Centre for Pensions. Hence, Cox proportional hazard models were estimated in order to assess the influence of shift work on the number of deaths/disability retirements due to coronary heart disease. In contrast to the studies presented above, no evidence was found to support an association between shift work and cardiovascular disease. This held true for both, men (hazard rate (HR): 1.06, CI, 95%: 0.75-1.50) and women (HR: 1.21, CI, 95%: 0.75-1.93). Furthermore, no increase in the risk for an early retirement due to cardiovascular disease for shift workers (women: HR: 0.79, CI, 95%: 0.43-1.43, men: HR: 0.70, CI, 95%: 0.48-1.03) compared to day workers was assessed.

Empirical evidence on an increased risk for coronary heart disease among shift workers appears rather conclusive. However, a recent review of the literature by Wang et al. (2011) found the evidence for the association to be rather moderate or suggestive, pointing to potential flaws in study designs (methodology) and to the need for further research.[20]

2.5 Cancer

In addition to the health outcomes related to shift work presented above, the risk for cancer became a growing concern in recent times. One reason for this can be seen in the activity of the International Agency on Research on Cancer (IARC), which – in 2007 – assessed shift work, which includes the disruption of circadian rhythms, to be presumably carcinogenic to human individuals (Straif et al. 2007, IARC 2010). The assessment was based both on '*limited evidence*' for research on carcinogenicity and shift work exposure (involving night shifts) and on '*sufficient evidence*' for research with experimental animals (IARC 2010).[21] The focus in the area is predominantly on the association between shift work exposure and the risk for breast cancer, which will be the focus of the following examples for empirical evidence. However, there is also a growing literature on other cancers (such as colorectal or prostate) (Wang et al. 2011).

In a prospective cohort study on US nurses, Schernhammer et al. (2006) assessed a potential association of shift work and the risk for breast cancer. As a data source, a baseline

[20] A recent study by Lee et al. (2015) on South Korean automobile manufacturing workers further supports the conclusion by pointing to potentially increased risks for night shift workers with regard to cardiovascular diseases.

[21] The IARC considers the evidence to be limited since credible evidence for an association between shift work and the risk for cancer exists. However, chance, bias (e.g. selection bias) or confounding factors cannot be ruled out as influencing the results (IARC 2010).

questionnaire (requesting information on, e.g., health status and potential risk factors for cancer) from the Nurses' Health Study in 1989 was used. A total of 115,022 female nurses (aged between 25 and 42 years at baseline) with no history of cancer participated and were followed for a period of twelve years. Information on shift exposure was self-assessed as the number of months that participants had worked on rotating night shifts (>= three nights per month) in addition to day or evening shifts in that month. Since the Nurses' Health Study survey is repeated on a biannual basis, information on shift work exposure was updated every two years. The number of breast cancer cases served as the dependent variable and was assessed by reports of the nurses as well as the National Death Index to identify deaths due to breast cancer. Over the entire period, a total of 1,352 cases of breast cancer were reported in the cohort. Cox proportional hazard models were applied and revealed an increased risk for nurses with rotating shift work experience of over 20 years (RR: 1.79, CI, 95%: 1.06-3.01) compared to women who never worked that schedule.[22] No increased risk was found for shift work exposure of less than 20 years (1-9 years: RR: 0.98, CI. 95%: 0.87-1.10, 10-19 years: RR: 0.91, CI, 95%: 0.72-1.16). A clear drawback of the study, however, was the small number of breast cancer cases for nurses with shift work experience of 20 or more years (n=15) since the number of nurses with such a long shift work history was rather limited. Furthermore, although various confounding factors were included, the authors were unable to rule out unobserved factors such as, for example, potential radiation exposure as a driving influence.

A similar study design was used by Pronk et al. (2010) who evaluated the risk for breast cancer as a consequence of shift work exposure in a cohort of 73,049 Chinese women. Data was gathered from the Shanghai Women's Health Study – a prospective cohort study being in Shanghai, China. At baseline (1996-2000), women (40-70 years old) from seven urban communities in Shanghai were asked to participate in a personal interview on topics such as demographic information, socioeconomic status and lifetime occupational history (which included information on all jobs a woman worked in). The assessment of shift work exposure was based on an evaluation of a Chinese industrial hygienist, who classified jobs in four groups (no night-shift work, incidental night-shift work, jobs

[22] Confounding factors such as, for example, age, number of children, smoking status etc. were controlled for.

likely to involve the night shift, but only part of the night or involving on call periods and all-night shift jobs). As an additional measure, the self-assessed night shift work experience of participants was gathered. During a follow-up period until 2007, breast cancer occurrences were identified in the course of follow-up interviews (every two years) or through annual data base (Shanghai Cancer Registry, Shanghai vital statistics database) evaluation. Cox proportional hazard models were estimated and revealed no association between night shift and the risk for breast cancer (night shift exposure assessed by expert: HR: 1.0, CI, 95%: 0.9-1.2, self-assessed night shift exposure: HR: 0.9, CI, 95%: 0.7-1.1) compared to workers, who never worked night shifts. A drawback of the study can be seen in the measurement for shift work exposure. The expert classification with only four categories appears rather broad and may distort effects. The self-assessment of shift work schedule also is prone to reporting errors. Nevertheless, the study contributes to the rather inconclusive evidence on the association between shift work and the risk for cancer.

Hansen and Stevens (2012) conducted an interview-based case-control study on the topic among Danish nurses. The authors used information of 58,091 members of the Danish Nurses Association who were – at baseline (2002-2005) – under the age of 70 and free of breast cancer. At baseline, a structured interview was conducted requiring information on, for example education, lifestyle factors and other potential confounders. From July 2001 until June 2003 a total of 301 cases of breast cancer were diagnosed in the cohort (310 including deaths) and 267 patients participated in the study. Cancer diagnosis was assessed via a national registry (Danish Cancer Registry). For each case of breast cancer four breast cancer-free control cases were identified, which resulted in a total of 1,035 control cases. This was accomplished by incidence density matching on year of birth (+/- one year) and timing of the interview. Shift work exposure was self-assessed for each job held longer than one year as permanent day, rotating day-evening, day-night, day-evening-night, other rotating or permanent night shift. The exposure was then calculated as the lifetime duration in each schedule weighted by the hours worked per week. Additionally, the number of shifts per midnight was assessed similarly. Multiple logistic regression analysis was used and various confounding factors (e.g. age, breast cancer history in the family) were controlled for. The results indicate a clear association of working rotating shifts including night shifts (OR: 1.8, CI, 95%: 1.2-2.8) as well as working in permanent night shifts (OR: 2.9, CI, 95%: 1.1-8.0) with the risk for breast cancer compared to day shift work. However, it needs to be mentioned, that the number of cases in the permanent night shift group was rather limited (n=18). Furthermore, the self-assessment of shift exposure over the entire career may bias the results.

The evidence presented mirrors the existing inconclusive evidence on a relationship between shift work and the risk for different forms of cancer. This is further supported by literature reviews on the topic by Kolstad (2008) and Wang et al. (2011) who assess a potential link to be rather moderate pointing in a similar direction as the IARC (2010).[23]

2.6 Social Aspects

The majority of shift work research is conducted with regard to negative health and physiological outcomes associated with working shifts. However, social desynchronization, as a consequence of working at times during which a majority of social and family activities takes place, also depicts a well-documented research area. In particular, shift workers may be subject to greater difficulties in aligning work and social/family life since the majority of social/family activities is oriented according to 'normal' (daytime) rhythms of society (Costa 2010). As a consequence, work life conflicts based on colliding schedules may arise since the working time substantially exacerbates participation in social and family roles (Carlson et al. 2000). The social aspects influenced by working in shift are diverse and a succinct selective overview on different aspects is presented below.

The issue of negative work-family spillovers, such as bad moods or low levels of energy, in relation to shift work exposure was analyzed by Grosswald (2003) in a representative population of U.S. workers. Results clearly indicated increased negative spillovers from work on family for people engaged in shift work. Similarly, in a cross-sectional study on 3,122 employees of the Dutch Military Police Force, Demerouti et al. (2004) focused,

[23] In a review on circadian disruption and breast cancer He et al. (2014) found a positive association for shift work and breast cancer risk (RR: 1.19, 95% CI: 1.08-1.32) but also pointed to the need for further research on the matter.

among other things, on the issue of work-home conflict levels in association with working in fixed or rotating shifts or during socially valuable hours (weekends and evenings). The results revealed a general negative effect of shift work – regardless of rotating or fixed – with work-family conflict and the effect was more pronounced for fixed evening or night shift work than for rotating shifts. This evidence was supported and extended to a different occupational group by a recent work of Kunst et al. (2014) who examined potential negative work-family spillover effects – assessed through questionnaire data – of shift work in a sample of Norwegian nurses. Again, all types of shift work were associated with higher levels of negative work-family spillover effects in comparison to day workers.

A more specific research focus was applied by White and Keith (1990) who evaluated the effect of working shift on self-assessed marital quality and divorce decisions of 1,748 individuals. The results indicated a clearly negative association of shift work – exposure to shift work was assessed as a yes or no question with no differentiation between different shift schedules – and marital quality. At the same time, divorce rates were reported to be elevated for shift workers. In a later study, Presser (2000) also evaluated divorces as a consequence of shift work and found evidence for an increased prevalence of divorces for married people with children in the early years (<five) of marriage.

Another aspect touched by the issue of shift work and its consequences for social and family life is parenting and child development. The effects of working shifts on parenting were evaluated in a qualitative study by Root and Wooten (2008) in a US automobile parts manufacturing plant. The interviews revealed that exposure to inflexible shift schedules reduced the opportunities / capabilities for fathers to partake in their children´s extracurricular activities such as, for example, team sports. This held true in particular for night and evening shifts.

Moreover, difficulties for parents to align shift work and family life were found to result in increased adverse child development outcomes. For instance, using data from a large US survey on youth and children, Han (2008) found the prevalence of behavioral problems (e.g. hyperactivity, immaturity, antisocial behavior) of children aged four to ten to be elevated for children whose mothers were engaged in shift work. Additionally, using data from the same survey, Han and Miller (2009) found evidence for increased depression incidents among adolescents (aged 13 to 14) whose mothers were engaged in night shifts and whose fathers were engaged in evening shifts.

In summary, a wide range of negative social consequences (such as negative work family spillover, marital instability and parenting) is found to be associated with working shifts. Alongside these social effects, the literature review on potential health effects of shift work pointed to negative health outcomes with regard to

- sleeping disorders (clear evidence),
- gastrointestinal diseases (clear evidence),
- metabolic syndrome (moderate evidence),
- cardiovascular disease (moderate evidence), and
- cancer (limited evidence).

3 Shift Work and Absence

The evidence for negative health outcomes as a consequence of shift work exposure suggests a potential relationship with worker absence. This is supported by the fact that sickness absence is generally accepted as a suitable proxy for general well-being and health (Marmoth et al. 1995, Hensing et al. 1998, Henderson et al. 2005). In the following, a selective review of the empirical evidence of the absence effects of shift work is provided.

Covering the years 1968 and 1969, Taylor et al. (1972) conducted one of the first studies on the relationship between shift work and worker absence. They used information on 1,930 male blue-collar workers (965 pairs, one shift / one day worker) from 29 British organizations from manufacturing (e.g. metal manufacturing) as well as service industry (e.g. transport). For pairs of workers to be included, they had to be manual workers at the same firm, perform a similar job and be employed in that job over the entire observation period. Additionally, pairs were matched by year of birth or, approximatively, by year of birth group (e.g. 1910-1914). Absence measurements were recorded from company records and included medically certified absence (> three days), short sickness absence spells (< three days) and other absence. Furthermore, shift work exposure was assessed by means of company records and a total of six main shift schedules were identified including, for example, a discontinuous three-shift, a continuous three-shift and a permanent night shift schedule. Hence, the data set of the analysis appeared rich on information. However, the analysis was wanting since only comparisons of means between the different groups were conducted. Therefore, the validity of the results must be regarded as limited from an empirical standpoint. Furthermore, the cross-sectional nature of the evaluation needs to be regarded as an additional drawback of the study. For the sake of completeness, results are reported and Taylor et al. (1972) found no evidence on a positive association between shift work and worker absence. In contrast, they reported reduced absence (certified (-13%), short spells (-17%) and other absence (-22%)) for shift workers compared to day workers. Moreover, the type of shift schedule was not found to influence absence behavior of workers.

Another early study on the topic, conducted by Markham et al. (1982), used data from manufacturing workers in a metal component plant of a large American conglomerate over the time span of two years (1977-1979) to examine absence effects of differences in the scheduling of the shifts (day, evening and night shifts). Information on about 1,325 blue-collar workers was gathered from the company records. The company operated a total of three different shift schedules including a permanent day, evening and night shift. Absence – vacation and holidays were excluded – was recorded from corporate records on a daily basis and assessed on an aggregated shift level (e.g. absence for the permanent day shift). Using analysis of variance, Markham et al. (1982) found no evidence for differences in absence between different shift schedules (F = 0.98, p = not significant). However, the advantages of a longitudinal study design were diminished by high turnover rates (average daily rates between 0.12 and 0.33 percent, depending on the shift) in the population. Therefore, the empirical relevance of the paper is to be considered as limited.

Kleiven et al. (1998) examined the effects of shift work on certified sickness absence in a Norwegian chemical plant between 1979 and 1989. Data on more than 3,500 workers was gathered through corporate records (e.g. worker characteristics (e.g. age, gender), shift system) as well as the Department of Occupational Health (absence, reasons for absence), which collected this data in Norway up to the year 1990. Hence, in contrast to most other studies, Kleiven et al. were able to resort to objective criteria in both shift work exposure and absence data, which provides a substantial data advantage. Worker absence was included in the study if it extended over the duration of three consecutive days. Only longer time periods were considered since absence spells of three days or less required no certification from a physician and therefore no reason for the absence spell could be identified. In the analysis, Kleiven et al. focused on specific disease groups (e.g. gastrointestinal disease or coronary heart disease). Using logistic regression estimations, no effect of shift work on absence due to any of the examined diseases was found for three-shift workers. However, two-shift workers were absent more often compared to day shift workers on aggregate (OR: 1.63, CI, 95%: 1.16-2.30). Nevertheless, excluding absence spells of three days or less may seriously influence a potential effect of shift work on worker absence. The results of Kleiven et al. (1998) point to the fact that the design of shift work may be of importance with regard to respective shift work health effects.

In a study on factory workers at a Japanese light metal goods manufacturer, Morikawa et al. (2001) evaluated the effect of shift work on long-term sickness absence. The measure for absence used here was the cases of absence that lasted more than seven days and that were certified by a medical physician. Additionally, participants (between 18 and 54 years of age) completed a questionnaire on factors such as work characteristics, behavioral risks (e.g. smoking) and status of health in 1990, the baseline of the research, in order to account for confounding factors in the analysis. The exposure to shift work was evaluated as the number of non-daytime working days within one year and clustered into three groups (< 82, 82-169, and > 170 days). The shift models at the plant included two and three-shift systems. Over a timespan of eight years (until 1998), long-term absence spells of workers were recorded based on first occurrences since a long-term absence may induce the risks of further related occurrences. Using Cox regression, the evaluation revealed that workers with the highest exposure to non-daytime working days (>170 days) displayed a significant increase in the risk for long-term absence spells (relative risk (RR): 1.34, CI, 95%: 1.07-1.67) compared to day workers. Results for shift workers with less exposure to non-daytime working days (< 82, 82-169 days) showed no significant differences compared to day workers (RR: 0.87, CI, 95%: 0.68-1.12 and RR: 0.95, CI, 95%: 0.74-1.21). These findings suggest that the exposure to non-daytime shifts is of relevance with regard to potential health effects of shift work.

Tüchsen et al. (2008a) conducted a prospective study in order to assess the relative risk of absence for shift workers (male and female) compared to day workers in a cohort of Danish workers. A telephone interview was completed at the beginning of the study in 2000 by a total of 5,017 individuals (1008 shift workers, 4009 day workers) aged between 18 to 64. Shift work status was self-assessed by participants between the categories irregular working hours, two-shift systems, fixed evening shifts, three-shift systems or fixed night system. Data on absence of workers was gathered through a national register (DREAM, a register on all public transfer payments to Danish citizens). All sickness absence spells longer than 14 days were recorded in DREAM since employers are entitled to governmental compensation if employees are absent 14 days or more. All 5,017 individuals were followed up during for 78 month. After an absence spell longer than 14 days, individuals were removed from the study. For the estimations, Tüchsen et al. differentiated between short- (> 2 weeks) and long-term (> 8 weeks) absence spells. Maternity leave, however, was excluded. Cox proportional hazard models were estimated and various confounders (e.g. health, age, education) were included. The authors found no evidence for a significant association between shift work and short-term (HR: 0.88, CI, 95%: 0.74-1.04) as well as long-term (HR: 1.13, CI, 95%: 0.88, 1.45) sickness absence. However, the study failed to include absence spells of less than 14 days, which may strongly affect the results.

In a methodically similar study, Tüchsen et al. (2008b) examined the effect of shift work on sickness absence in a sample of Danish female elderly care workers. In 2004/2005, a total of 5,627 shift and day elderly care workers were interviewed (information requests included e.g. family status, health status). Shift work was self-assessed as the usual work time of participants (optional answers included: fixed day, fixed evening, fixed night, irregular day or evening, irregular evening or night, irregular day or evening or night). Information on short- (>two weeks) and long-term (>eight weeks) absence spells was again gathered through access to a national register (DREAM). The follow-up period lasted for 52 weeks and only the first occurrence of absence was recorded since the rate of subsequent occurrences may be affected through the first occurrence. Using Poisson regression and controlling for various confounding variables (e.g. age, health status), Tüchsen et al. found evidence for an increased risk (risk ratio (RR): 1.29, CI, 95%: 1.10-1.52) of short-term absence as a consequence of evening shift work. However, no significant relation was found for long-term absence spells (RR: 1.24, CI, 95%: 0.99-1.56). Again, the study failed to include absence spells of less than 14 days, which may strongly affect the results.

Furthermore, Fekedulegn et al. (2013) evaluated the association between shift work and sickness absence using detailed information on 424 US police officers. Data on the participants of the study came from the Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) study for which 424 police officers from Buffalo (New York) were subject to a medical examination from June 2004 to October 2009.[24] The examination provided information on e.g. demographic factors and health status. Additionally, information on shift work exposure as well as sickness absence (any sick leave / any sick leave > 3 days) was gathered through an occupational history from the police payroll department on a daily basis for a time period of 15 years (since 1994). The historic database provided daily information on, for example, the type of work (regular work) or the type of absence (e.g. sickness absence) for each officer. All participants worked in permanent shift schedules (permanent night, day, or evening). However, since work schedules may differ over the 15-year time span, the predominant shift schedule of each police officer was identified by using the shift schedule in which an officer spent most of his working hours. Sickness absence was recorded when the officer was paid for regular work failed to attend work due to sickness. Only the first occurrences of sickness absence have been taken into account. Fekedulegn et al. (2013) used Poisson regression analysis and found a positive association of night shift work and sickness absence (>= 1 day of sickness absence spells) compared to day (incident risk ration (IRR): 2.04, CI, 95%: 1.56-2.68) and evening (IRR: 1.69, CI, 95%: 1.29-2.22) shift. Similar outcomes were reported for absence spells lasting three days or more. The study uses a rich set of data with objective criteria for absence occasions. Yet, a drawback can be seen in the fact that shift schedule exposure is a highly aggregated measure since only the schedule in which an officer was predominantly engaged was considered.

Another fairly recent study by Catano and Bissonnette (2014) evaluated whether shift work is linked to increased sickness absence in the Canadian workforce. The authors used previously accessible data from three waves (2001, 2003 and 2005) of a large Canadian workplace survey (Workplace and Employee Survey), which is carried out every two years.[25] The surveys were conducted as telephone interviews by Canada´s national statis-

[24] The Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) is a population-based study in which information on physiological as well as psychological status is pooled. It aims at investigating relationships between e.g. stress at work or lifestyle factors and metabolic or cardiovascular outcomes (Violanti et al. 2006).

[25] The Workplace and Employee Survey gathers information on a total of 20,000 employees drawn from roughly 6,000 private-sector companies which is iterated on a two-year basis. The companies included are the same in each wave. However, individuals participating are likely to be different between the waves.

tics agency and each wave included a total of more than 20,000 participants (2001: 20,377, 2003: 20,834, 2005: 24,197) from various industry fields (e.g. manufacturing, construction, education and health). The interview included questions on demographic variables, work arrangements and shift work. Participants were also asked to provide the number of days they were absent due to sickness over the previous 12-month period. The information was clustered into four groups: no, 1-3, 4-10 or 11 or more sickness absence days. Absence due to other reasons (e.g. disability, marriage, and education) was recorded separately. Shift work was assessed as working fixed shifts, rotating 2-shifts or rotating 3-shifts. In their empirical analysis (using chi-square tests and hierarchical regressions), Catano and Bissonnette failed to identify a general association of shift work with sickness absence. But, focusing only on shift workers, rotating shifts are associated with an increase in sickness absence (β: 0.008, $p<0.001$). However, the study by Catano and Bissonnette displays some clear weaknesses. First, although the sample resembles a longitudinal design (since the companies included are the same every two years), participants in the survey differ which results in three cross-sectional designs. Second, sickness absence is self- reported by participants, which may result in serious underestimation of the true level of absence (see Johns 1994). Finally, the methodology of the study appears questionable since no information on chi-square test results or exact specification of the regression model is provided.

Finally, Slany et al. (2014) studied the association of a wide range of psychosocial work factors, including shift work, on long sickness absences in a population of 32,708 participants (49.3 percent female, 50.7 percent male) from 34 countries. The cross-sectional information was gathered through the European Working Conditions Survey from 2010, which was completed in face-to-face interviews with participants. The questionnaire included information on various work-related fields, including a total of 25 psychosocial work factors such as job demands, working hours and work-life balance. Shift work exposure was self-assessed as working permanent shifts or alternating shifts – a total of 20.5 % of the population was subject to either form of shift work exposure. The absence variable was the result of a self-assessment of participants regarding the number of health-related absence periods within the last twelve months that exceeded a duration of seven days.

Using logistic regression analysis, Slany et al. (2014) found evidence of a positive association of exposure to rotating shift work and sickness absence (men: OR: 1.19, CI, 95%: 1.03-1.39, women: OR: 1.26, CI, 95%: 1.09-1.45). Nevertheless, the study displays some weaknesses such as the cross-sectional design, the self-assessed absence measure and the exclusion of absence occurrences of less than seven days.

In summary, it can be stated that a survey of the literature reveals surprising insights since no conclusive evidence of a positive association between shift work and worker absence can be identified so far. Although the topic is not a recent trend, as the work of, for example, Taylor et al. (1972) and Markham et al. (1982) demonstrate, research in the area remains rather limited. For instance, as far as the author is aware, there exists only one systematic literature review. This review was conducted by Merkus et al. (2012) and included a broad occupational scope with research papers from various backgrounds such as, for example, Japanese textile workers, Danish health care workers or samples of different working populations (e.g. French, Danish). Overall, the review of 24 studies, which met predefined inclusion-criteria, supports the finding of inconclusive evidence that results from the above survey of empirical research on the topic.[26] On the one hand, Merkus et al. (2012) presented persuasive evidence for a positive relationship between the exposure to fixed evening shifts and sickness absence. Four studies in the review examined the relationship of fixed evening work and sickness absence and results were univocal with regard to a positive effect on absence.[27] On the other hand, results for other shift work types (including, for example, rotating shifts and night shifts) and their effect on worker absence appeared to be spurious correlations at best. Furthermore, Merkus et al. identified a total of six studies, which analyzed absence effects with regard to rotating shift work. Of these, only half revealed a positive link and the remaining half indicated a negative or no association.[28] The authors also pointed out some of the difficulties in the

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26 The criteria included, for example, the language in which the papers were written (English, Norwegian, Danish, Swedish, German, French and Dutch) and transparency concerning the estimation methods (Merkus et al. 2012).

27 The studies included only evaluations of health care occupations, including Canadian nurses (Bourbonnais et al. 1992), French hospital staff (Ohayon et al. 2002), Danish elderly care workers (Tüchsen et al. 2008) and French occupational physicians (Niedhammer et al. 2008).

28 Evidence for a positive association of rotating shift work and absence was provided by Bourbonnais et al. (1992), Ohayon et al. (2002) and Niedhammer et al. (2008). However, no association was reported in

comparability of the studies evaluated since often there was no specific information about the exact shift schedule provided. The differences in the results of the various studies on the relationship between shift work and worker absence may appear surprising. However, a potential explanation for the ambiguous results may be attributable to the so called 'healthy worker effect' (Taylor et al. 1997, Knutsson 2004).[29] This effect delineates a potential selection bias within the workforce between shift and non-shift workers. This, in turn, may result in a healthier population of shift workers compared to day workers. The effect can be understood as twofold. First, those workers, who assess themselves as resilient to the stress related to shift work predominantly self-select into shift work. Hence, 'healthier' or more resilient workers self-select into shift work, leading to a healthier sample than the non-shift worker sample. Second, only the healthy workers are expected to remain in shift work while people with health problems are expected to switch to day work. This is expected to reinforce the abovementioned mechanism and contribute to a heathier shift worker sample compared to day workers (Knutsson 2004). The prevalence of a 'healthy worker effect' may lead to a substantial underestimation of the actual health effects related to shift work (Taylor et al. 1997). Additionally, this may also result in underestimations concerning the effects of shift work on worker absence.

Notwithstanding the first argument, another reasons for the ambiguous results may be due to national and cultural differences of the populations studied, differences in the study designs (cross-sectional vs. longitudinal), varying types of shift work included in the studies (e.g. rotating, permanent, two-shift, three-shift), or the quality of the absence measure (self-assessment vs. company records). This clearly represents a drawback of much of the literature on the topic so far. The empirical studies presented later in the course of this work (see chapters 5-8) address these shortcomings and seek to extend the existing knowledge on the relationship between shift work and worker absence. First, instead of using broad and generic differentiations between shift work schedules (such as,

Kleiven et al. (1998) and Tüchsen et al. (2008) while Higashi et al. (1988) indicated a negative association.

29 Research by Knutsson and Akerstedt (1992), however, suggests that shift and day workers do not differ per se with regard to their health status. Instead, they identify differences between day and shift workers with regard to sleep patterns. This indicates a selection of more sleep-problem resistant workers rather than healthier workers into shift work. The effect, albeit, appears identical.

for example, rotating vs. fixed shifts) as was done in the existing literature, a detailed description of the specific shift schedules is provided. Furthermore, the longitudinal study designs as well as rich sets of information on blue-collar worker absence – based on corporate records instead of self-assessment – depict substantial advantages over most of the existing literature and enable the empirical studies presented in the course of this work to substantially contribute to the matter of whether shift work is associated with worker absence. However, the focus of the work at hand is not on the comparison between shift work and day workers, but, instead, differences between diverging shift models are evaluated.

4 Ergonomic Shift Work Design

Notwithstanding the association of shift work with negative health outcomes and the inconclusive link with worker absence, the abolition of shift work – for the purpose of improving worker health – appears to be no viable option due to economic and social necessities for shift work. Therefore, other ways need to be explored in order to mitigate negative health effects of shift work. In that regard, the design of shift models appears as a potential measure (Knauth 1993, 1997). In particular, the application of ergonomic guidelines for the design of shift work may enable the reduction of negative health consequences associated with working in shifts (Beermann 2011, Engel et al. 2014)).[30] Knauth even concludes that the ergonomic design of shift models is '*one of the most effective countermeasures*' (Knauth 1997, p. 159) against negative shift work effects. The ergonomic recommendations for shift work design include (Knauth 1996, Knauth and Hornberger 1997, Costa 2010):[31]

- **Avoiding early starts for morning shifts:** early starts in morning shifts decrease the number of sleeping hours before the morning shift since most workers follow their usual sleeping patterns and go to bed at the usual time (Folkard and Barton 1993). This is likely to result in increased fatigue in morning shifts.
- **Limitation of night work (no more than three consecutive night shifts):** night work is associated with the prevalence of sleeping problems (Akerstedt 2003). Hence, longer night work periods are expected to induce an accumulation of sleep deficits.
- **Compressed free time on weekends:** weekends depict the time of the week with the highest social value since a lot of leisure and family activities are centered on weekends (Knauth and Hornberger 1997). Therefore, free time on weekends is an important issue for shift workers. In particular, since weekday evenings – the second most important socially valuable time – is often occupied by shift work.

30 In Germany, for example, ergonomic guidelines are a mandatory legal requirement (Arbeitszeitgesetz (ArbZG, Working Time Act) 1994).

31 However, despite the different recommendations, there is no univocal solution for the design of shift models since worker´s individual tolerance to shift work varies (for an overview see Saksvik et al. 2011) and different contextual settings require tailored solutions (Folkard 1992, Knauth 1993, Costa 2010).

- **At least one free evening during the week:** Weekly rotating shift schedules result in weeks without free evenings at weekends. This puts a burden on social and family life (Knauth 1997) since weekday evenings are highly valuable with regard to 'socially-usable' leisure time. This can be eased by rotating schedules that allow for at least one free evening per week.
- **Avoiding sudden changes to shift schedules (regular shift system):** some shift systems require additional shifts in order to reach the contractual working hours (Knauth and Hornberger 1997). In order to reduce the impact on social and family life the predictability of the work schedule appears relevant.
- **Flexible working time arrangements (considering worker preferences):** flexible schedules with options for workers (e.g. to reduce evening shifts in some weeks) and, for example, flexitime are a means to increase the compatibility of private and work life.[32]
- **Forward rotation of shifts (MEN) instead of backward rotation (MNE)**: a clockwise or forward rotating shift schedule coincides more closely with the endogenous circadian rhythm of humans. (Knauth 1993).
- **Fast rotation of shifts (one to three days)**: fast (three or less consecutive shifts of the same type) instead of slow rotation appears preferable for different reasons. Firstly, work in morning and night shifts is associated with reduced quantities of sleep (Akerstedt 2003), which may accumulate in longer rotating schemes. Secondly, a large number of consecutive evening shifts obstruct social and family life (Knauth 1997).

Most of the research as well as the underlying work focus on the aspects of the direction of rotation and the speed of rotation. Therefore, a concise overview of the literature with regard to the above-mentioned two design mechanisms is presented in the following section.

[32] Flexitime is a form of working time organization that requires the worker to be at the work place for a specific period of time (core time) each day but offers workers flexibility concerning starting and ending times of the working day (Schlick et al. 2010).

A controlled longitudinal study by Knauth and Hornberger (1995) investigated health and social consequences of shift system changes in the chemical sector. A total of 399 chemical workers participated in two surveys. The first survey was conducted one month prior to the shift model change and the second one seven to nine months after the change. The 339 workers formed a total of five experimental groups (n=260) and respective control groups (n=139). Each experimental group was subject to a similar but slightly different shift system change. At the outset, all groups worked in one of three different slow backward rotating systems (a discontinuous three-shift system, a continuous four-shift system or a continuous five-shift system). After the shift model change, all experimental groups worked in one of three different continuous fast rotating five-shift systems with a reduced number of successive night shifts. The questionnaires requested information on, for example, socio-demographics, worker well-being and social aspects. Using analysis of variance, Knauth and Hornberger (1995) found evidence for improved worker well-being and reduced sleep disturbances and fatigue in some of the experimental groups. Other health effects were not identified, which may be explained by the rather short period of only seven to nine month that was covered after the shift model changes. However, enhancements in social and family life were also identified as a consequence of two of the shift model changes that took place.

In another controlled intervention study, Knauth and Hornberger (1998) assessed the impact of the introduction of ergonomically advanced (fast forward rotating) shift schedules on the subjective health and social status of shift workers in a German steel company. A total of 179 steel workers were asked to participate in two surveys, which requested information on demographics, social aspects, and health (e.g. information on sleeping or gastrointestinal problems) – first, before a change in the shift schedule and second, ten months after the introduction of the new shift system. The study evaluated two different types of shift schedule changes. Therefore, the population was divided in four groups. One group (n=40) changed from a weekly (six-day) backward rotating shift schedule (with Sundays off) to a quickly forward rotating shift schedule. A control group remained in the backward rotating schedule (n=34). Another group (n=51) changed from weekly (seven-days followed by two day off) backward rotating schedule to a (n=54) fast forward (only two successive days in one shift) rotating shift schedule. Again, there was a control group, which remained in the backward rotating schedule. Using analysis of variance, no significant changes in the subjective health of participants were identified. However, social aspects (reduction of social problems, increased leisure time with friends) enhanced as a consequence of the new shift schedules.

Hakola and Härmä (2001) explored the impact of a change in the speed and the direction of shift schedules on sleep and wakefulness of workers in a Finnish steel manufacturing plant. At the plant, the shift model was altered from a continuous slowly backward rotating system (EEE-MMMNNN-----; evening (E), morning (M), night (N), and day off (-)) to a quickly forward rotating system (MMEENN----). For their analysis, Hakola and Härmä used information on 16 workers who were all subject to the aforementioned change in the shift model. To gather information, questionnaires on sleep and alertness in the different shifts were issued before and after the change in the shift schedule. Additionally, sleep of all participants was monitored via an actigraph as well as sleep diaries for the period of one shift cycle before (15 days) and after (10 days) the shift model change. In contrast to Knauth and Hornberger (1998), who also used analysis of variance, Hakola and Härmä (2001) found evidence that a change from the slowly backward rotating shift schedule to the faster forward rotating schedule results in a positive effect on sleep and wakefulness. However, the study results need to be treated with care since no control group is included and, therefore, results may be biased.

These results are supported by Härmä et al. (2006), who conducted a controlled intervention study with male technicians at a line maintenance unit at the Helsinki–Vantaa airport, Finland to evaluate the effect of a change in the shift schedule from a backward rotating three-shift model to a fast forward rotating three shift model on self-reported sleep and health. At the outset of the study, all workers were employed in a continuous backward rotating three-shift system (EEE--MMM--NNN--). In November 2002, 40 workers volunteered to participate in a new fast-forward rotating shift schedule (MEN--) while the remaining workers stayed on the original backward rotating schedule. Data was generated through questionnaires (topics included sleep problems, general health issues) and the voluntary participation in field studies (e.g. including the use of an actigraph and sleep/social life diaries) at two points in time: 1.5 years before (May/April 2001) and 6 months after (May/April 2003) the introduction of the new shift model. Questionnaires were answered by 273 workers at the beginning of the study in 2001 and by 154 (38 fast forward rotation, 116 backward rotation) in 2003. Additionally, participation in the field studies included 49 workers at the outset and 40 (31 fast forward rotation, 9 backward rotation) in 2003. Using a linear mixed model approach the authors concluded that the introduction of a quickly forward rotating shift schedule improved the perceived effects of the current shift schedule on sleep, general well-being and social life. However, since the selection in the new shift model as well as the participation in the surveys and field studies was voluntary, the study may have suffered from potential selection bias.

Additional evidence for the advantageousness of forward rotating shift schedules was provided by Van Amelsvoort et al. (2004). In their study, longitudinal data on Dutch three-shift workers – mainly from the automobile and paper industry – was used to assess differences in health, well-being and social aspects between workers in forward (n=95) and backward rotating (n=681) shift schedules. At baseline and every four months for the 32-month follow-up period, participants were asked to respond to questionnaires on, for example, demographics, work schedules, health aspects (general health, fatigue) and work-home interaction. Hence, all information, including shift schedule data, was self-assessed by participants. Cox regression analysis was used to assess the differences between forward and backward rotating shift schedules. Backward rotating schedules were found to be associated with limited general health (RR: 3.21, CI, 95%: 1.32-7.83) compared to forward rotating schedules. Additionally, backward rotation was also assessed to be inferior with regard to work family conflict (RR: 7.36, CI, 95%: 1.05-52.7). Hence, the results of Van Amelsvoort et al. (2004) also point to the potential of decreasing negative health outcomes associated with shift work through shift work design mechanisms (forward rotation).

Viitasalo et al. (2008) conducted a controlled intervention study on 84 line maintenance workers of a Finnish airline company to assess health effects of newly introduced shift schedules. At baseline, all 84 participants worked in a backward rotating shift schedule (EEE--MMM--NNN--). 22 workers remained in the backward rotating system over the entire observation period. However, 40 workers changed to a rapidly forward rotating shift schedule (MEN--) while a further 22 changed to a flexible shift system (shift schedules were issued only four weeks in advance but were similar to the initial system, except the three days off instead of the two). However, not only the design of the shift models changed but also the start and finishing times as well as the length of shifts. All participants were subject to an occupational health examination at the beginning of the study, during which objective health measures were assessed (e.g. heart rate, blood pressure, cholesterol levels). Additionally, surveys on, for example, disease history, lifestyle, and dietary factors were conducted twice (at baseline and after the introduction). Using analysis of variance, Viitasalo et al. (2008) found evidence indicating that a faster rotation speed in combination with a change to a forward direction helped to ease daytime sleepiness of workers. A limitation of the study can be seen in the fact that the duration of the shifts was extended in the fast forward rotating schedule (from 8 hours (on all shifts) to 9 (night) or 10 hours (morning and evening)), which may counteract the ergonomic improvements (fast forward rotation) of the new shift system.

In a more recent study, Hakola et al. (2010) evaluated shift model changes with regard to healthcare-worker well-being using information on 75 Finnish nurses from different municipal hospitals. At baseline, all nurses worked in backward rotating two- or three-shift systems. The ergonomic advancements of the new shift systems that were introduced focused on the forward direction of shift schedules. For all changes, the aggregated amount of working hours in each shift remained stable. The participants filled out two questionnaires – one before and one after the shift model change. The questionnaires gathered information on demographics, work ability and well-being. Hakola et al. (2010) used a linear mixed-model approach and provided evidence for positive health effects as a consequence of ergonomic shift schedule design in Finnish health care workers. Not only well-being at work and general health improved as a consequence of a change in the shift schedule, but social and family life improved as well.[33]

[33] The precise coefficients were not reported in the study and are, therefore, not included here.

In conclusion, evidence on the positive effects of shift schedule design – with regard to direction as well as speed of rotation – on health appears fairly univocal. However, whether these effects lead to reduced rates of worker absence has not been studied so far. The following empirical studies seek to address this gap in research.

5 The Costs of Shift Work: Absenteeism in a Large German Automobile Plant

5.1 Introduction

Shift Work is common in many industries around the world. Capital-intensive production in e.g. automobile and steel plants on the one hand and the uno actu provision of services in e.g. hospitals, emergency rescue services, police and fire departments require around the clock presence of workers. In Germany, around 6.3 million employees (that is 15.6 % of the workforce) have recently been reported to work in shifts (German Federal Statistical Office 2013). Furthermore, 42% of all manufacturing firms use some sort of shift work and about 15% of the workforce in that sector work on rotating shifts (see Jirjahn 2008). 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 Krings et al. 1999 and Brachet et al. 2012). The topic has until recently remained a domain for occupational medicine (see section 5.2 below).

One potential side effect of shift work is absenteeism, both real in terms of genuine sickness, and opportunistic behavior. Absenteeism is disruptive to manufacturing production and may have long-term health consequences for workers if health disruptions persist. In this paper we use monthly data on absenteeism in some 400 organizational units in a large German automobile plant over a period of 36 months to analyze the impact of changes in the shift schedule on workers' absenteeism. Our study design has a number of advantages: First, we have complete information for all the units over an extended period of time and, second, we have a quasi-experimental design allowing us to identify the positive effects of a move towards a shift schedule that is considered as beneficial especially by (outside and in-house) medical experts. The new 'forward rotating' shift schedule was regarded by experts as causing fewer health risks for workers. We show that absence rates fell when this system was introduced, a response that can be attributed to better health conditions of the workforce. 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 on night shift. 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 48 hours only for recovery over the weekend. Since the schedule was modified again after a few months (see below), the company failed to secure the health benefits from the initial change in regime. They also faced the same costs of absenteeism with the third regime as with the initial shift plan. Had the workforce not resisted the shift regime that was apparently advantageous with respect to worker health, the company would have incurred lower costs of absence.[34]

The remainder of the paper is structured as follows: Section 5.2 provides a review of the relevant literature while section 5.3 describes the three different shift systems used in the respective plant of the automobile company. In section 5.4 we present the data and some descriptive evidence while section 5.5 includes our econometric evidence documenting the changes in worker behavior following the implementation of a new shift system that specialists from occupational medicine strongly favor above its predecessor as it is considered to foster worker health and well-being. Section 5.6 concludes.

5.2 Literature Review

A broad consensus seems to exist on the negative consequences of (rotating) shift work: First, 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, Akerstedt 2003, Nakata et al. 2004). Second, shift work has been found to be detrimental to family and social life (e.g. Gray et al. 2007, 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 night hours (e.g.

[34] Among occupational medicine specialists the second shift regime is considered ergonomically advantageous in that it aims to reduce the detrimental health effects associated with shift work. In this paper we refer to shift systems as ergonomically advantageous if empirical evidence documents that they are associated with fewer health problems than the systems that had been used before.

Hänecke et al. 1998) and the retiring 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).

An important issue that has not yet been convincingly addressed in the literature is the impact of shift work in general and different shift systems/schedules in particular on worker behavior such as, for example absenteeism. Due to differences in the data and the estimation techniques used, the available studies fail to reach consensus: A number of 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 the number of absence spells per year (e.g. Böckerman and Ilmakunnas 2008).

The design of shift work schedules has been found to be particularly important for employee health and well-being. Peters et al. (2015) find the sustainable employability of nurses to be influenced by the type of work schedules with fixed morning shifts having a positive effect on sustainable employment while rotating three-shift systems depicting a negative influence. Oexman et al. (2002), for example, find that rotating hours changing once a week and backward rotating hours can cause considerable shift work coping problems. Moreover, Bambra et al. (2008) document that switching from backward to forward shift rotation and from slow to fast rotation can have positive effects on a number of health outcomes. At the same time, however, Merkus et al. (2012) in their systematic review of the empirical literature – looking at the relationship between rotating shift work and sickness absence – fail to find unanimous results. This points to the complex nature of absenteeism (Eriksen et al. 2003) being contingent on various factors (this, in turn, suggests that changes in shift rotation and/or shift schedules may not necessarily lead to lower absenteeism).[35] Thus, irrespective of its widespread use, the empirical evidence on the influence of the structure of shift work (e.g. type of rotation and length of cycles) on various measures of worker performance remains limited and inconclusive (examples documenting the lack of consensus are, for example, Brachet et al. (2012) and Krings et al. (1999)).

Our paper fits within the genre of nano-econometrics or 'insider' econometrics, which emphasizes rigorous econometric analysis of panel data generated within one company or a few companies (for surveys of the literature see e.g. Ichniowski and Shaw 2013, Bloom and Van Reenen 2011, Lazear and Shaw 2007).

5.3 Shift Systems

All the organizational units in our study are located in the body shop, the paint shop or the assembly in the same plant of a large German vehicle manufacturer. Irrespective of the shift system in use, work for the different shift teams starts at 6:30 am, 2:30 pm and 10:30 pm. At the beginning of our observation period, all units worked under a shift system that required 6 weeks of weekly rotation from evening shift (E) to morning shift (M) followed by three weeks on night shift (N). Thus, the shift system is discontinuous with working days ranging from Monday to Friday with weekends off (see figure 5.1).

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

Source: Own illustration, based on company records.

Figure 5.1: Initial Shift System (Regime 1: Jan 2009 until Dec 2010).

This system was criticized by employee representatives because of the 3 weeks of consecutive night shifts and because of its 'violation' of generally accepted health-related

35 The most prominent factor determining absence, however, is sick leave (Henrekson and Persson 2004).

guidelines for the design of shift systems.[36] It was replaced by a system presumably associated with lower health risks for workers. Moreover, this change was considered beneficial from the standpoint of occupational medicine experts expecting the disappearance of the shift-coping problems coming along with the original backward-rotating pattern. The new system started on Jan. 1st, 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 five day week starting in the morning, then switch to the evening shift for week two before working 5 days on the night shift in the third week. In the week following the night shift, the cycle starts again (see figure 5.2; note that Friday night shifts finish Saturday morning).

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

Source: Own illustration, based on company records.

Figure 5.2: New Forward Rotating Shift System (Regime 2: Jan 2011 until Aug 2011).

A few months later, the decision was repealed following worker complaints to the works council and the shift plan was modified again. This time the rotation direction of the system was changed. The new shift system was implemented following the company's summer break on Aug. 15th, 2011 and included a weekly backward rotating long cycle (5 days) system (see figure 5.3). The system remained in practice beyond 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) backward rotation was preferred by workers and their representatives because of its impact on the rather long break on weekends. However, over a complete 3-week shift cycle, both systems (forward vs. back-

[36] 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 work on weekends is to be avoided (ArbZG 1994).

ward) provide the same total amount of leisure time at weekends.[37] What is different, however, is the distribution of the leisure periods, resulting in one rather short weekend during the forward rotating cycle.

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

Source: Own illustration, based on company records.

Figure 5.3: Backward Rotating Shift System (Regime 3: Sept 2011 until Dec 2011).

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 changeover in the third weekend with a night to evening adjustment on the second weekend. This gives 56 hours of leisure time. So, although, the total available time is the same in both systems over a four-week period, workers placed a premium on the extra recovery/leisure time derived from the night to evening 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 in the weekend break following a night shift when moving back to an evening 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 the main reason for the second adjustment of the shift system. 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.

[37] Both changes in the shift system had no effect on worker remuneration, because the number of night shift, for which a 30-50 percent premium is paid, remained the same under the three different regimes. Thus, from a purely financial point of view workers should be indifferent between the three regimes.

Although the available evidence (see section 2 above) is inconclusive, we expect absenteeism to be lower in regime 2 (a forward rotating continuous cycle) compared to regime 1 (a discontinuous system with six weeks of weekly rotation from morning to evening shift followed by three weeks of night shift). Moreover, we expect absence rates for regime 3 to be lower than for regime 1, but higher than for regime 2. Finally, we expect absence rates for regime 1 to be higher than for regime 3.

5.4 Data and Descriptive Evidence

In order to analyze 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 to December 2011) during which no other changes in e.g. the production process occurred that could have affected worker absenteeism (such as e.g. the start of production of a new car). Our study design has a number of advantages: First, the required information is completely available for all units over a period of 36 consecutive months and, second, 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 analyze the impact of different shift systems on worker absenteeism with a precision that would be lacking in broader establishment-based surveys.

However, 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 (such as in 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 like 'laboratory rats'.[38]

[38] The difficulties of implementing field experiments in firms are discussed in Bandiera et al. (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, Bruhn et al. (2013) as well as Calderon et al. (2013) in Mexico, Giné and Mansuri (2011) in Pakistan; for an extensive review of the literature see Karlan et al. (2012). Some of the most widely cited studies in this tradition

Our initial data set included monthly information on 1,031 organizational units performing a variety of different tasks in the production process (body shop, paint shop, assembly, quality management as well as supporting activities). Construction of a balanced panel resulted in a data set including 451 organizational units (information on the remaining 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 absence rate, the monthly projected absence rate and the number of employees. In total, the units in the sample employ some 7,500 workers.[39]

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.

(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.

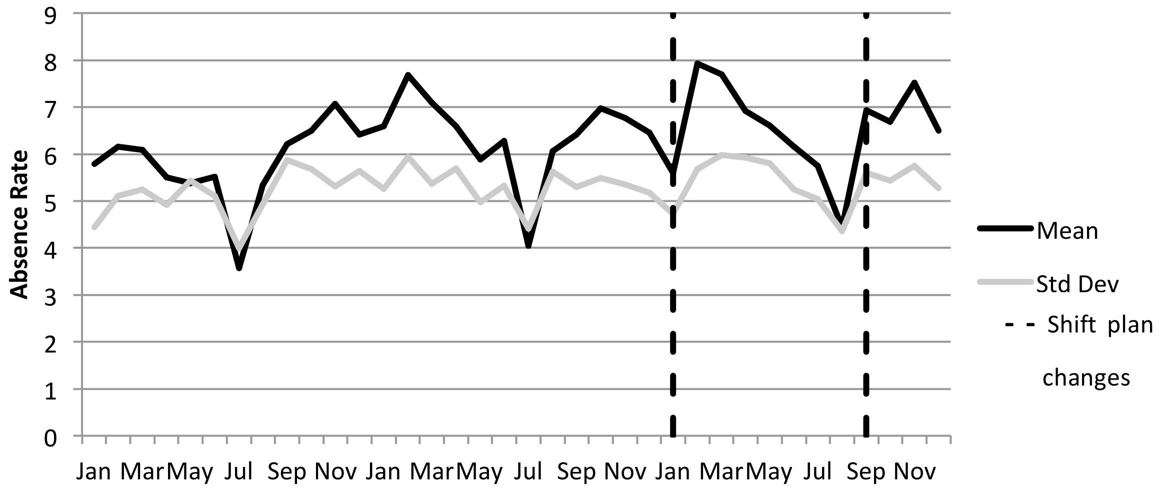
39 The projection is based on the gender composition and the age structure of the units. A 35 year-old female production worker for example is expected to be absent from work 5.2% while a 25 year-old male white-collar employee is expected to be absent from work only 1.0%. Thus, due to the low turnover rate, the projected absence rate increases over time as the company's workforce gets older.

Table 5.1: Summary Statistics.

Variable	Mean	Std. Dev.	Min.	Max.
Employees	17.99	7.69	5.00	49.00
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
Shift Regime 1	0.67	-	0	1
Shift Regime 2	0.22	-	0	1
Shift Regime 3	0.11	-	0	1
Number of organizational units: 409 Number of unit-month-observations: 14,724				

Source: Own calculation.

Furthermore, the reduction of the data set through 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 was obtained from the firm's central human resource reporting system. Monthly absenteeism is measured in percent of regular hours of work. 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 et al. 2013) and the most recent aggregate figures for the German manufacturing sector (see Badura et al. 2012).



Source: Own illustration, based on company records.

Figure 5.4: Absence Rates by Month over the Observation Period (2009-2011).

Figure 5.4 displays the development of the average absence rate over the observation period. As expected, average absenteeism is higher during the winter months. Furthermore, the dips in absenteeism during the summer months and especially in July are not surprising since the plant shuts down production for three weeks during the summer.[40]

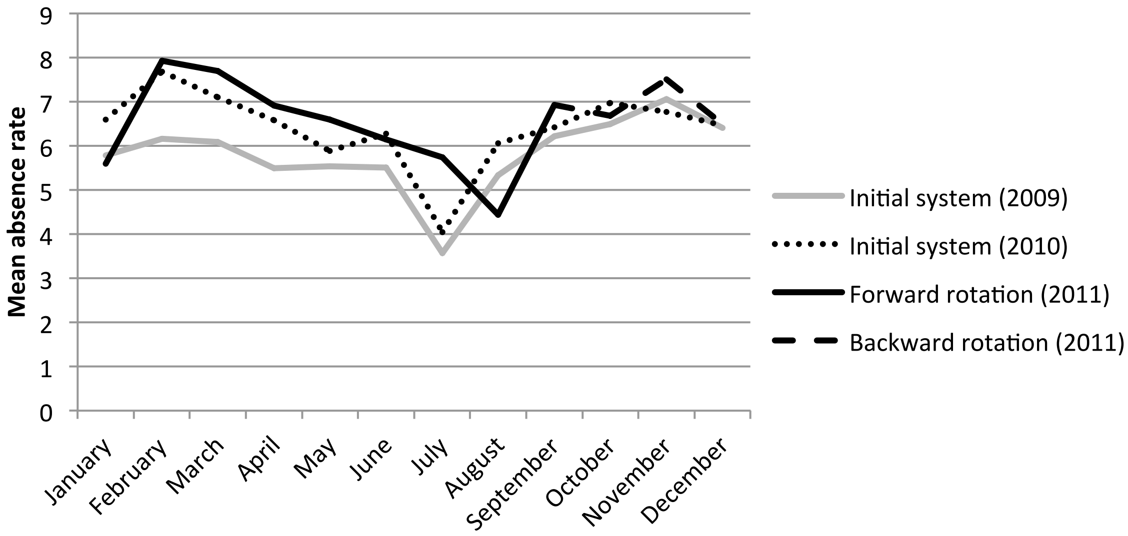
A comparison of average absence rates under the three different shift systems (see figure 5.5) reveals a particularly low level of absenteeism for 2009 and a high level for 2011.[41] This is most likely due to the uncertainty resulting from the aftermath of the economic crisis. In general, absence rates are lower during economic downturns because a tight labor market (due to high unemployment) offers limited alternatives to workers losing their jobs (i.e. the opportunity costs of losing the job increase).[42] Another explanation is that during the economic crisis capacity utilization was lower and, therefore, workers

40 Due to the working time arrangements of the company a worker on a holiday leave is by definition not 'absent', because during his holiday leave he 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.

41 Data on the initial system was available for two years (2009-2010) and the shift schedule was not altered over this period of time. Therefore, two lines (the grey and the dotted) represent the initial system in figure 5.5.

42 In a recent paper, Lazear et al. (2013) demonstrate that during economic downturns workers tend to work harder, i.e. to produce more output, to avoid being laid off.

were exposed to less stress.[43] Unfortunately, we cannot empirically distinguish between these two equally plausible hypotheses. However, we control for seasonal and business cycle effects by estimating our models with 36 month dummies.



Source: Own illustration, based on company records.

Figure 5.5: Monthly Absence Rates by Shift System.

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 5.4).[44]

A final observation that warrants some discussion 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

43 Table 5.3 in the appendix documents considerable changes in the levels of production and employment as well as profitability over the five-year period 2007-2011: First, employment and production have increased considerably and, second, return on sales has reached record levels, resulting in bonus payments of 7,500 Euros per worker and year. Equally important, however, is the massive increase in productivity as measured by cars produced per worker and year.

44 Kernel density estimates of the observed and the projected absence rate by regime are provided in Figures 5.6 and 5.7 in the appendix.

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.[45]

5.5 Model, Estimation and Results

In order to analyze the effects of shift model changes on worker absenteeism, the following general model is used:

$$(5.1)\quad \textit{Absence Rate} = \beta_0 + \beta_1 \textit{Shift} + \beta_2 \textit{Projected Rate} + \beta_3 \textit{Unit Size} + \beta_4 \textit{White Collar} + \beta_5 \textit{Month} + \varepsilon$$

where

Absence Rate is the proportion of number of days absent divided by the scheduled number of working days per month per organizational unit;

Shift is a vector of three shift dummies;

Projected Rate is the expected rate of absence per month per organizational unit;

Unit Size is the average number of employees in an organizational unit (per month);

White Collar is the average absence rates of white collar workers at the plant per month;

Month is a vector of month dummies; and

ε denotes the random error term.

Our dependent variable – absence rate – is measured as a proportion. Thus, our estimations need to account for this proportional or fractional nature. Applying linear probability models would lead to predictions that are situated outside the regressor's range for extreme values (Baum 2008). A potential solution appears in the logit transformation of the regressor and the subsequent application of linear regression models. However, this would neglect the potential for the regressor to take on the values zero and one. Hence, in order test for the impact of the two changes in the shift system on absence rates we estimate a generalized linear model (GLM) using a logit link function and binomial family to account for the proportional nature of our dependent variable, which is bounded be-

45 The starting date of the summer holidays (which last in general for six weeks) varies by federal state. They start between middle of June (in the Northern states) and end of July (in the Southern states) and end between end of July and middle of September.

tween 0 and 1.[46] Thus, a fractional response model along the lines proposed by Papke and Wooldridge (1996, 2008) and used by e.g. Frick et al. (2013) who analyze the impact of semi-autonomous teams and team bonuses on absence rates in a large German steel plant is applied.[47]

Table 5.2: GLM Regression of Shift Systems on Absence Rate.

Variable	Coefficient	Clustered Robust Standard Errors (Units)	t statistic
Shift Regime 2	**-0.127*** **	0.047	-2.67
Shift Regime 3	-0.077	0.046	-1.60
Projected Absence Rate	**0.378*** **	0.028	13.57
Unit Size	**0.005* **	0.003	1.95
White-Collar Absence Rate	0.003	0.032	0.10
Month-Year Dummies		included	
Constant	**-4.216*** **	0.132	-31.81
*** p< 0.01; ** p < 0.05; * p < 0.10			
N = 14,724			

Source: Own calculations.

It appears from table 5.2 that the majority of the variables included in the estimation are statistically significant. The size of the effects can be evaluated by evaluating marginal effects, using the margin command in STATA.[48] First, absenteeism is slightly higher in larger units (a finding that is in line with the literature, e.g. Dionne and Dostie 2007) and, second, a one percentage point increase in the projected absence rate is associated with a 2.2 percentage point increase in the observed absence rate (suggesting that health

46 Baum states that using the binomial distribution family may serve as an appropriate choice although the dependent variable is continuous in nature (2008).

47 Papke and Wooldridge apply fractional response model estimation to employee participation rates in pension plans (1996) and school test pass rates (2008). Our dependent variable is similar. Oberhofer and Pfaffermayr (2012) 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.

48 Running OLS regression with clustered standard errors as robustness check provided identical results with regard to the sign of coefficients (see table 5.4 in the appendix). However, the magnitude of the coefficients is not directly comparable (therefore, margins are calculated, see table 5.5 in the appendix for the results).

problems of female and older workers are underestimated by the firm's human resource management department). Most important, however, 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 0.73 percentage points.[49] 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 to the initial level. However, the latter coefficient failed to reach statistical significance. Summarizing, our findings seem to suggest that workers care more about the distribution of their recovery/leisure time than about the health effects of alternative shift systems, which, in turn, indicates that workers may discount future health problems. Moreover, absenteeism may be considered an attempt to avoid potential future health problems of workers.

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 rates of full-time white-collar workers performing regular daytime hours. 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 production worker shift pattern.

As a further robustness check we split our sample at the median of the projected absence rate and repeated the estimations with the two 50% subsamples. Moreover, we also divided the dataset in two equally large samples at the median of the size of the units (see tables 5.6 and 5.7 in the appendix). The results reveal interesting differences in the basic

[49] 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.

pattern. The change from regime 1 to regime 2 was associated with a significant decrease in monthly absenteeism only in those units where the absence rate was low. However, no differences for shift regime shifts between unit size subsamples were detected.

Moreover, the (inter-)quantile regression results also reveal interesting differences (see tables 5.8 and 5.9 in the appendix). The decrease in monthly absenteeism from regime 1 to regime 2 is more pronounced in the higher quantiles of the distribution. Also, absenteeism turns out to be significantly lower in regime 3 (compared to regime 1) in the highest quantiles of the distribution.

5.6 Summary and Conclusions

Our main result is that in a large German automobile plant the change from a shift system considered as ergonomically unfavorable (as it is characterized by three continuous weeks 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 is completely offset by a second modification of the shift system. Changing the direction of rotation (from forward to backward, i.e. from a system considered as advantageous from a health perspective to one that is associated with higher health risks for workers by medical experts) is associated with an increase in monthly absence rates back to original levels. This is worrying for the company. Both the initial and 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 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 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 to the second was due to minor sickness, major sickness or shirking behavior.

According to our estimations, the introduction of an ergonomically advantageous shift system is associated with a 0.73 percentage point decrease in monthly absenteeism (a decline of more than 11%). Evaluated at the mean of the two coefficients we estimate the benefits due to the initial decrease in absenteeism at about €2.5 million (about €330,000 per month). Since the organizational units included in our sample comprise only 30% of workforce the total returns are more than three times as high (nearly €8.3 million).[50] However, these benefits were forfeited by changing the shift system again after a rather short period of time in response to (specific groups of) workers expressing their discontent with the continuous forward rotating shift system.[51] Moreover, the company is since 2011 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.

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50 Calculated as hours lost due to additional absenteeism times gross hourly wage costs per workers.

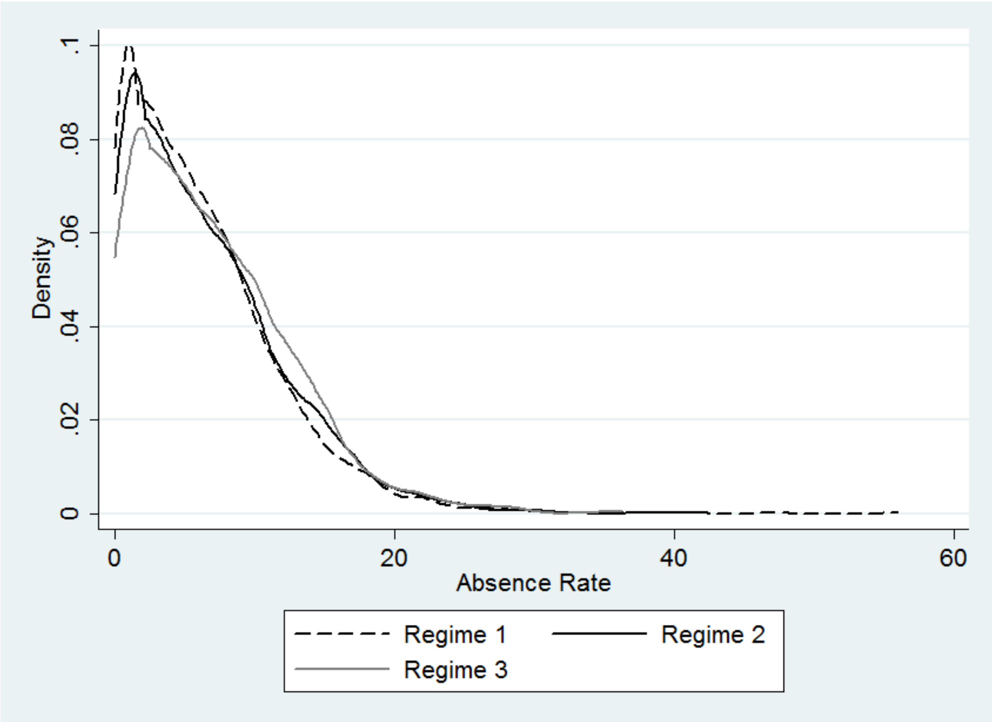
51 We have also investigated in more detail the possibility of a 'Hawthorne effect' (e.g. Bloombaum 1983, Franke and Kaul 1978, Jones 1992, Levitt and List 2011). It has until recently been taken for granted that any organizational change will eventually lead to a short-term change in employee behavior independent of the nature of the change and that this change will decrease over time. In our estimations – which are available on request – we fail to find any such effect.

5.7 Appendix

Table 5.3: Employment, Production, and Profitability of Automobile Company.

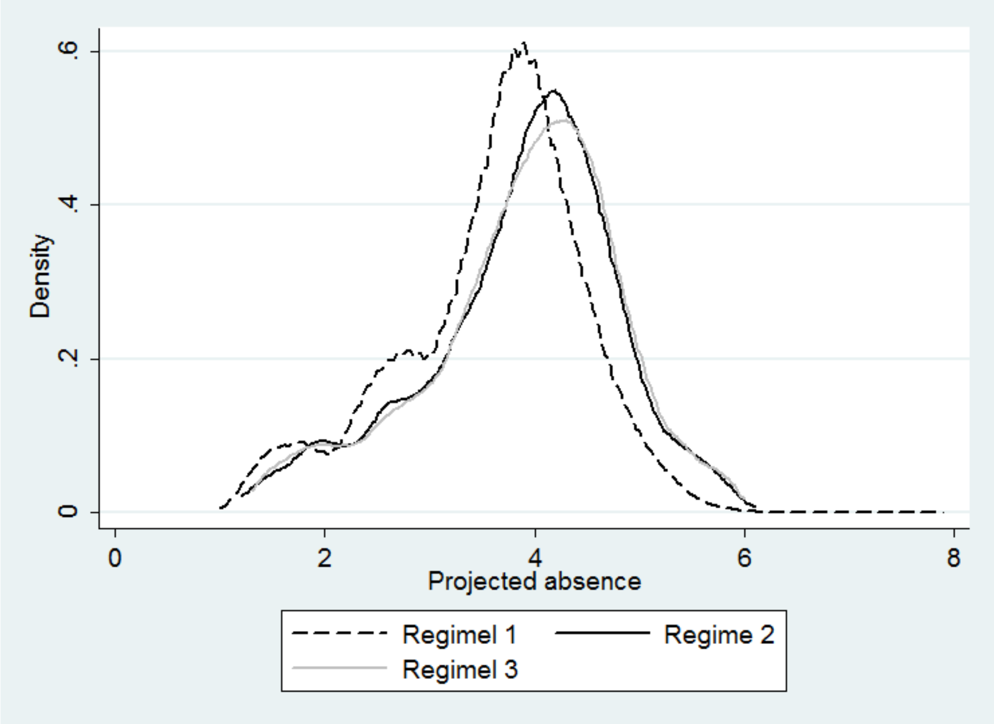
Year	Employment (Germany, in 1,000)	Production (Germany, in 1,000)	Cars per Employee	Return on Sales
2007	175	2,086	11.9	6.0
2008	178	2,146	12.1	5.8
2009	173	1,938	11.2	1.2
2010	178	2,115	11.9	7.1
2011	196	2,640	13.5	11.9

Source: Own illustration, based on company records.



Source: Own illustration, based on company records.

Figure 5.6: Kernel Density Plot of Absence Rate by Shift Regime.



Source: Own illustration, based on company records.

Figure 5.7: Kernel Density Plot of Projected Absence Rate by Shift Regime.

Table 5.4: Robustness Check of Absence Rate – Ordinary least square regression.

Variable	Coefficient	Clustered Robust Standard Error (Units)	t statistic
Shift Regime 2	**-0.0066****	0.0027	-2.43
Shift Regime 3	-0.0037	0.0028	-1.32
Projected Absence Rate	**0.0201*****	0.0016	12.82
Unit Size	**0.0003***	0.0002	1.66
White-Collar Absence Rate	0.0000	0.0019	0.04
Month-Year Dummies		Included	
Constant	**-0.0151****	0.0067	-2.25

*** p< 0.01; ** p < 0.05; * p < 0.10
n = 14,724

Source: Own illustration, based on company records.

Table 5.5: GLM Estimation: Marginal Effects (Dependent Variable: Absence Rate).

Variable	Marginal Effects	t
Shift Regime 2	**-0.0073***	2.64
Shift Regime 3	-0.0045	1.64
Projected Absence Rate	**0.0220**	12.22
Unit Size	**0.0003**	1.97
White-Collar Absence Rate	0.0002	0.10
*** p< 0.01; ** p < 0.05; * p < 0.10;		
N = 14,724		

Source: Own calculations.

Table 5.6: GLM Estimation – Robustness Check on Absence Rate (I)
Median Split Projected Absence Rate.

Variable	Projected Absence Rate Low (n=191 units)	Projected Absence Rate High (n=218 units)	Full Sample (n=409 units)
Shift Regime 2	**-0.141**	-0.104	**-0.127***
Shift Regime 3	-0.046	-0.087	-0.077
Projected Absence Rate	**0.427***	0.301***	**0.377***
Unit Size	0.005	0.005	**0.005***
White Collar Absence Rate	0.059	-0.042	0.003
Month-Year Dummies		Included	
Constant	**-4.516***	**-3.758***	**-4.216***
*** p< 0.01; ** p < 0.05; * p < 0.10			

Source: Own calculations.

Table 5.7: GLM Estimation – Robustness Check on Absence Rate (II) Median Split Unit Size.

Variable	Unit Size Small (n=191 units)	Unit Size Large (n=218 units)	Full Sample (n=409 units)
Shift Regime 2	**-0.128***	**-0.119****	**-0.127*****
Shift Regime 3	-0.084	-0.062	-0.077
Projected Absence Rate	**0.414*****	**0.347*****	**0.377*****
Unit Size	**0.021***	**0.010*****	**0.005***
White Collar Absence Rate	0.003	-0.004	0.003
Month-Year Dummies		Included	
Constant	**-4.529*****	**-4.195*****	**-4.216*****

*** p< 0.01; ** p < 0.05; * p < 0.10

Source: Own calculations.

Table 5.8: Quantile Regression on Absence Rates.

Variable	10%	25%	50%	75%	90%
Shift Regime 2	-0.0023	**-0.0045****	-0.0030	**-0.0083****	**-0.0081***
Shift Regime 3	-0.0013	-0.0012	-0.0031	-0.0042	**-0.0102***
Projected Absence Rate	**0.0041*****	**0.0094*****	**0.0185*****	**0.0271*****	**0.0332*****
Unit Size	**0.0008*****	**0.0009*****	**0.0006*****	**-0.000*****	**-0.0008*****
White Collar Absence Rate	-0.0004	0.0010	0.0039	-0.0009	0.0004
Month-Year Dummies			Included		
Constant	**-0.0198*****	**-0.0284*****	**-0.0345*****	-0.0064	**0.0220***
Pseudo R2 (overall) * 100	6.09	8.31	9.34	9.82	11.5

*** p< 0.01; ** p < 0.05; * p < 0.10

n = 14,724

Source: Own calculations.

Table 5.9: Interquantile Regression on Absence Rates.

Variable	10/25	25/50	50/75	75/90
Shift Regime 2	-0.0021	0.0015	-0.0054	0.0003
Shift Regime 3	0.0001	-0.0019	-0.0011	-0.0060
Projected Absence Rate	**0.0053*** **	**0.0090*** **	**0.0086*** **	**0.0060*** **
Unit Size	**0.0001*** **	**-0.0003*** **	**-0.0006*** **	**-0.0008*** **
White Collar Absence Rate	0.0015	0.0029	**-0.0047***	0.0012
Month-Year Dummies		Included		
Constant	**-0.0086****	-0.0061	**0.0281*** **	0.0285
Pseudo R2 (overall) * 100 (lower)	6.09	8.31	9.34	9.82
Pseudo R2 (overall) * 100 (upper)	8.31	9.34	9.82	11.50

*** p< 0.01; ** p < 0.05; * p < 0.10

n = 14,724

Source: Own calculations.

6 The Impact of Ergonomic Shift Work Design on Absenteeism

6.1 Introduction

The study of absenteeism and its determinants has been a prominent field of research over the past decades. One reason for this can be seen in its high costs to economies and companies. In the US for example, the consequences of absenteeism materialize through an estimated total financial burden of around $117 billion per year (Forbes 2012).[52] However, overall, absence rates for the US have been moderate and fairly stable over the recent years amounting up to 3.1% for 2013 (United States Bureau of Labor Statistics 2014).[53] The study of absenteeism provides an interesting field for management as well as research since the identification of its drivers and the levers to influence absenteeism may generate profound cost savings.

There are some determinants of absenteeism, which have been subject to extensive research. These include for example the influences of wage rates (e.g. Youngblood 1984, Chaudhury and Ng 1992), gender (e.g. Allen 1981, Drago and Wooden 1992) or age (Martocchio 1989, Barmby et al. 2004). However, there are further potential determinants, which have not been studied as thoroughly. Among these shift work plays a prominent role due to its relevance for the manufacturing and service sector in developed economies.[54] In the US for example, the most recent estimates on the overall number of people working in shift stem from the Current Population Survey. It was conducted in May 2004 and reports 21 million employees (18% of the US workforce) to be engaged in shift work (McMenamin 2007).[55] Shift work is widely accepted to represent a risk factor for various kinds of health disorders such as sleep disturbances (Costa 1996, 1997, Akerstedt 2003) or gastrointestinal problems (Knutsson and Boggild 2010). However, its relationship with absence has so far only been subject to fragmentary evaluation and the evi-

[52] These estimates exclude costs arising as a consequence of lost productivity. Hence, actual costs of absenteeism are likely to be significantly higher.

[53] Overall absence rates are 3.1% for 2010, 3.0% for 2011 and 3.1% for 2012 respectively (United States Bureau of Labor Statistics 2014).

[54] In the US for example, 36% of service workers and 18% of manufacturing workers are employed in shift work (McMenamin 2007).

[55] The numbers for the EU – 17% of the workforce are engaged in shift work – are similar to those reported for the US (European Foundation for the Improvement of Living and Working Conditions 2012).

dence indicates no clear relationship (Merkus et al. 2012, Catano and Bissonnette 2014). Further research is required in order to clarify a potential association. From a management standpoint, the topic draws special interest since it lies in the scope of decision makers to influence the use and form of shift work within an organization.[56] Therefore, it potentially depicts a cost sensitive means to increase the supply of labor of the existing workforce due to an increase in attendance rather than an addition of staff (Rajbhandary and Basu 2010). The paper aims to contribute insights on of how the design of shift models – in particular the design of shift models along the line of ergonomic guidelines – can influence absenteeism of blue collar workers in the manufacturing industry. Hence, information on shift model changes as well as information on absence rates of production teams (organizational units (OU)) from the manufacturing line of a large international automobile company is examined.

The paper is structured as follows: First, a literature review will provide a deeper understanding on the shift work and its relation to worker absenteeism. Subsequently, information on the company as well as the studied shift models will be introduced. As a next step, the data set is presented and descriptive analysis is provided. The estimations as well as the discussion of the results are the focus of the following chapter. Finally, a conclusion and outlook will be provided.

6.2 Literature Review

The International Labour Organization (ILO) (1990) (as cited in IARC 2010, 563) defines shift work as '*a method of organization of working time in which workers succeed one another at workplaces so that the establishment can operate longer than the hours of work of individual workers*'. However, the definition demonstrates that shift work is a rather generic term, which covers a broad array of specific configurations of shift schedules, such as permanent/alternating or continuous/discontinuous schedules.[57] On a global

[56] And, as Knauth (1988) pointed out, from a management perspective, shift work design may serve, among others, as a means to reduce weekly hours of work and facilitate the adaptation of operating hours to fluctuating work volumes.

[57] Permanent shift models require employees to work constantly in one shift, e.g. night shift. This may include workers being constantly employed at night. In contrast, alternating shift models require the worker to switch between shifts, for example to work night shifts for one week and morning shifts in

scale, a considerable variety of shift schedules exists (Knauth 1993). Nevertheless, the focus that all schemes are likely to share is the goal of achieving longer operational hours. In order to extend operational hours workers are required to be present at times that are not normally associated with working hours (such as night and early morning). The resulting interference with/and possible disruption of traditional sleep/wake patterns induces discrepancies in the biorhythm of workers and increases risks for health disorders (Costa 2010).

Among negative health consequences associated with shift work there is unequivocal evidence for sleeping problems and fatigue (e.g. Härmä et al. 1998, Akerstedt 2003, Folkard et al. 2005). Furthermore, it is widely accepted to induce the risk for gastrointestinal disorders (Scott et al. 1994, Knutsson 2003) as well as for diabetes and obesity (Karlsson et al. 2001, Scheer et al. 2009, Sathanathan 2010). Additionally, there is evidence for a potential relation between shift work and the risk for heart diseases (Knutsson and Boggild 2000, Ha and Park 2005). However, a more recent review on the topic by Wang et al. (2011) states that the evidence for an association between shift work and cardiovascular diseases is moderate. Nevertheless, in general, the evidence of an association of shift work and higher risks for certain negative health outcomes indicates a potential relation to absenteeism. This is underscored by the fact that sickness absence is generally accepted as a suitable proxy for general well-being (Marmoth et al. 1995).

However, potential negative consequences of shift work go beyond pure physical health aspects. Social and family life is also affected substantially since shift work requires working at times, which are usually reserved for family/leisure activities (e.g. evening hours) (Costa 2010). Reducing the available socially usable time negatively influences social and family life (Perry-Jenkins et al. 2007, Shen und Dicker 2008).

The relationship between shift work and absenteeism has been examined since the 1970s (Taylor et al. 1972, Nicholson et al. 1976). However, in the recent past the subject has

the subsequent week. The term continuous characterizes shift models which operate 24/7 while work in discontinuous models stops, for example, at weekends.

drawn rather sparse attention.[58] Surprisingly, though, the scarce research results on the issue appear ambiguous and provide no clear picture on the relationship between shift work and absenteeism (Merkus et al. 2012). The available studies predominantly analyze differences in absence of shift workers compared to non-shift workers. Explicit differences between diverging shift systems and worker absence have so far only been subject to evaluation in two recent working papers, which are presented in chapters five and seven. This appears to be surprising since the design of shift work is complex and its actual organization or design can take manifold forms.

So far, only occupational medicine research has focused on potential health effects of different shift model designs. Knauth (1997) states the design of shift models to be a powerful tool in mitigating negative health consequences of shift work. Focusing on ergonomic aspects such as the sequence of shifts (forward vs. backward rotation) and the speed of rotation worker health can be positively influenced (Knauth 1997). In an earlier work Knauth (1993) identifies eight crucial aspects concerning the ergonomic design of shift models such as the number of consecutive days in one shift or the direction of rotation.[59] These are assessed to alleviate health risks for workers (Knauth 1993). In particular the two crucial shift design characteristics mentioned (speed and direction of rotation) have been subject to a more detailed analysis. In a review of the existing literature Bambra et al. (2008) find a consistent reduction in negative health indicators (e.g. sleep problems) for fast rotating shift models compared to slow rotating as well as for forward compared to backward rotation. These findings are further supported by evidence from Härmä et al. (2006) who conducted a controlled intervention study in the line maintenance unit of a large airline company and found a rapidly forward rotating shift model to be superior in terms of worker health compared to a slowly backward rotating model. Applying a more narrow focus on the direction of rotation Barton and Folkard (1993) provide evidence for the relative advantage of forward compared to backward rotating mod-

[58] In general, the research area of shift work has, by and large, remained a field of occupational medicine and psychology. Economic analyses such as, for example, the work of Shen and Dicker (2008), or the empirical studies presented in the present work are rare.

[59] The remaining six aspects include length of shifts, start and finishing times of shifts, distribution of leisure time, regularity of the shift system, flexibility of the shift system and part-time or full-time work (Knauth 1993).

els using a sample of 261 industrial and service shift workers in the UK. Moreover, in comparison to non-ergonomic shift models the design and implementation of shift work according to ergonomic guidelines is generally associated with a reduction in health risks for workers (Costa 2010, Engel et al. 2014).

The study at hand seeks to further enhance the understanding of the effects of different shift schedules on worker health (absence rates). It does so by addressing the question whether a change in shift models, which follows occupational medicine expertise and ergonomic guidelines, leads to reduced health burdens for workers, consequently translating into lower rates of absence.

6.3 Company Background and Data

The shift model changes that are evaluated in this paper were implemented in a German production site of a large international automobile company. Thereby, the focus of the study is on manufacturing – blue-collar – work. The sector of manufacturing in the plant that we focus on is concerned with the body making part in the automobile production process. Work in the specific plant is exclusively organized in shift models of different types – the specific shift models considered here will be outlined shortly. For a timeframe of 21 months – from April 2010 to December 2011 – we have complete information on absence rates for all organizational units. Absence information prior to April 2010 is not available since the production sector was only then integrated into the company. Before, the sector constituted a wholly owned subsidiary of the company. The integration into the company was associated with modifications of employment contracts providing workers with higher wages and extended employment protection rights. However, we consider this not to influence the validity of our analysis since all OUs in this study were affected equally. In the analysis we refer to OUs, which can be thought of as production teams performing similar production steps since data privacy regulation at the company strictly prohibits the analysis of individual absence data. The data set includes a total of 86 organizational units with 1,200 employees of whom the majority is member of a large worker union. Working time is fixed and amounts to 35 hours per week for the majority of workers. All information is provided on a monthly basis (21 months) by the department of human resources controlling and observation numbers sum up to 1,806 unit-months observations. Using company records to access the relevant information serves as an important advantage of our study since it constitutes an objective measure of absence behavior in comparison to self-reported information (Deery et al. 1995). At the beginning of the observation period all 86 organizational units work in the same shift model. It is characterized by a total of 16 shift blocks per week – three blocks per day plus one morning shift block on Saturday (see figure 6.1).

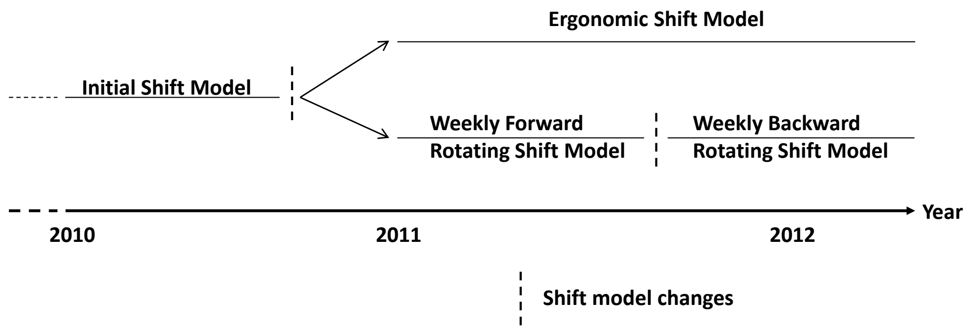
Hence, it becomes obvious that the model is of a discontinuous nature with weekends (apart from the morning shift week) being off. Furthermore, the model can be described as slowly rotating due to its 5-day sequences within one shift. After one week of morning shifts, which includes 6 shifts, the subsequent week is night shift while the third week evening shift. Due to this succession of shifts (M-N-E) the model is classified as backward rotating. Within this shift model the daily work schedule for the different shift teams starts at 6:30 am, 2:30 pm and 10:30 pm. This is true for all shift models, which will be evaluated in the course of this paper.

Day	**Mo**	**Tu**	**We**	**Th**	**Fr**	**Sa**	**Su**
Shift 1	**M**	**M**	**M**	**M**	**M**	**M**	
Shift 2	**N**	**N**	**N**	**N**	**N**		
Shift 3	**E**	**E**	**E**	**E**	**E**		

Source: Own illustration, based on company records.

Figure 6.1: Initial Shift Model (Apr2010 – Dec 2010).

From January 2011 onwards, different shift models are established for two sub-groups of our data set. For a schematic overview of the shift model changes see figure 6.2.



Source: Own illustration.

Figure 6.2: Overview of Shift Model Changes.

In January 2011, a sub-sample of the 86 OUs switched to an ergonomically improved shift model which was designed according to ergonomic guidelines aiming at reducing health burdens for workers while at the same time satisfying capacity requirements. In our sample 21 OUs, accounting for approximately 300 workers, were affected by this shift model change. The new ergonomically improved shift model (see figure 6.3) can be characterized as a short rotation scheme with a maximum of three consecutive shifts in one shift block (morning evening or night). Moreover, the shift model is strictly forward rotating with morning shifts being followed by evening and then by night shifts. Another profound distinction from the previous shift model is that days off occur not only on the weekends but also on weekdays. Finally, the new shift system is associated with a reduced number of shifts per shift cycle (17 compared to 21/22 over four weeks in the previous shift model), which is expected to further contribute to a reduction of stress and strain among workers.[60]

[60] However, it is noteworthy that contractual working time is not influenced by the type of shift model since it is bound by collective bargaining agreements the company has signed with IG Metall, the largest metal worker union in the world. Hence, if the number of shifts in a cycle is reduced and working time falls short of contractual work hours there will be e.g. extra shifts over the course of a specific timeframe (e.g. a year) to account for the differences in working time.

Day	Mo	Tu	We	Th	Fr	Sa	Su
Shift 1	M	M	E	E	N		
Shift 2			M	M	E		N
Shift 3	N	N			M	M	
Shift 4	E	E	N	N			

Source: Own illustration, based on company records.

Figure 6.3: Ergonomically Improved Shift Model (Jan 2011 – Dec 2011).

Simultaneously, a second sub-sample of 65 OUs with approximately 900 employees were subject to a different change in shift models and can be interpreted as our control group. The new shift model for this cohort is displayed in figure 6.4 and can be described as a slowly forward rotating shift model. In comparison to the initial model, two main attributes differ. On the one hand it is the rotation direction (forward instead of backward) and on the other hand it is the discontinuation of the Saturday shift. Hence, from a health-related point of view, this shift model can be assessed as a moderate improvement compared to the initial shift system.

Day	Mo	Tu	We	Th	Fr	Sa	Su
Shift 1	M	M	M	M	M		
Shift 2	E	E	E	E	E		
Shift 3	N	N	N	N	N		

Source: Own illustration, based on company records.

Figure 6.4: Forward Shift Model (Jan 2011 – Aug 2011).

However, only a few months later this model was modified again due to worker complaints to the works council. The new shift model was implemented following the company's summer break in the third week of August 2011. This time the adaptation of the shift model was less pronounced than the previous shift model change with the direction of rotation being the only feature that was adjusted – from forward (M-E-N) to backward rotation (M-N-E) (see figure 6.5). Generally, forward rotating models are considered to provide more recovery time between different shift spells (e.g. Härmä et al. 2006).

Day	Mo	Tu	We	Th	Fr	Sa	Su
Shift 1	**M**	**M**	**M**	**M**	**M**		
Shift 2	**N**	**N**	**N**	**N**	**N**		
Shift 3	**E**	**E**	**E**	**E**	**E**		

Source: Own illustration, based on company records.

Figure 6.5: Backward Shift Model (Sept 2011 – Dec 2011).

However, backward rotation was preferred by workers and their representatives due to its influence on leisure time on weekends. The distribution of the leisure periods resulted in one rather short weekend during the forward rotating cycle while switching from night shift to morning shift. This weekend only provided a total of 48 hours for recovery (sleep), leisure and social activities. The new backward rotating system replaced the night to morning change in the third weekend with a night to evening adjustment on the second weekend resulting in 56 hours of leisure time. Although the total available time on weekends was identical in both systems over a four-week period, workers preferred the extra leisure time derived from the night to evening adjustment over night to morning. Workers gained time for recovery and leisure when coming off a night shift. Hence, workers were provided with more time for sleep, home production and leisure during the weekend break following a night shift when moving back to an evening shift compared to the morning shift. Summarizing, the difference in the distribution in recovery time at weekends – in particular after night shifts – appeared as the main reason for this re-adjustment of the shift model. Hence, lack of acceptance by workers and the resulting pressure from the works council induced management to return to a backward rotating system. This weekly-backward rotating system remained in practice beyond the end of the observation period (December 2011).

6.4 Measures and Descriptive Analysis

The data comprises of only a limited number of 'internal' explanatory variables (e.g. projected absence rate per unit and the number of employees per unit). Fortunately, the limited number of explanatory variables and the resulting lack of controls is not a serious problem because personnel turnover is usually less than 4% per year at this company.

Hence, it appears reasonable to assume a stable team composition in the units over the observation period.

Table 6.1: Descriptive Statistics: Non-Ergo vs. Ergo (Over the Entire Observation Period).

Group	**Group 1 (Non-Ergo, n = 1364)**				**Group 2 (Ergo, n = 442)**			
Variable	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
Employees	12.84	2.25	5.00	27.00	15.70	5.82	8.00	34.00
Observed Absence Rate	5.98	4.78	0.00	24.00	5.03	4.09	0.00	20.60
Projected Absence Rate	3.48	0.38	2.80	5.00	3.56	0.34	3.00	4.70

Source: Own calculations.

Our endogenous variable absenteeism is measured by the number of days absent divided by the scheduled number of workdays (per month per organizational unit). Vacation entitlements as well as holidays are not included in the calculation of absence rates. Both, short as well as long-term absence spells are included in our measure. Furthermore, certified as well as uncertified sickness absence cases are included since the German Continued Remuneration Law (Entgeltfortzahlungsgesetz (EntgFG) 1994a) requires employees to provide a certificate of illness only after three days.[61] Hence, uncertified sick leaves with less than three days are also accounted for in the absence measure. For our two groups of OUs overall absence rates differ profoundly. While the group that switches to an ergonomically optimized shift model on average displays 5% absence, the group of OUs that is subject to less ergonomically advanced models records absence rates of about 6% over the course of the observation period (see table 6.1).[62] The values are in the range suggested by similar studies, which state absence rates for blue collar workers in the automobile industry to be in the range of 5.75 % to 6.25 % (see chapters five and eight). Projected absence rates also confirm previous estimates with overall levels for group one

61 With regard to the financial coverage of workers taking sick leave, the German law (Continued Remuneration Law (EntgFG 1994b)) requires employers to cover paid sick leave for a period of up to six weeks.

62 The difference between the two groups is statistically significant (F = 14.3). However, before the shift model changes were implemented (Jan 2010 - Dec 2010) there were no statistically significant differences between the two groups in terms of overall absence rates (non-ergo: 5.9 percent, ergo 2: 5.4 percent, F = 1.75).

being 3.5 % while for group two being 3.6 % (previous estimates of 3.65 % (see chapter 5) and 3.69 % (see chapter 8)).[63] The projected absence rate serves as an instrument for the human resources controlling department in calculating personnel requirements of the company. It is computed based on the gender composition and age structure of the units as well as on the job type (white/blue collar work). To illustrate this take the example of a 35 year-old female production worker who is expected to be absent from work 5.2 % while a 25 year-old female production worker is expected to be absent from work only 3.5 %.[64] In the analysis it serves as a proxy for age and gender. Information on these variables was inaccessible due to data security concerns of the data privacy department at the company.

Another variable included in our data set is the size of the OU measured by its number of workers. The two groups in our study display considerable variation in average OU size with roughly 13 workers per OU for group one while 16 for group two.[65] However, the minimum number of employees per unit over all groups is five. This can be explained by data privacy regulations, which required the human resources controlling to only provide information on OEs with five or more employees over the entire observation period.[66]

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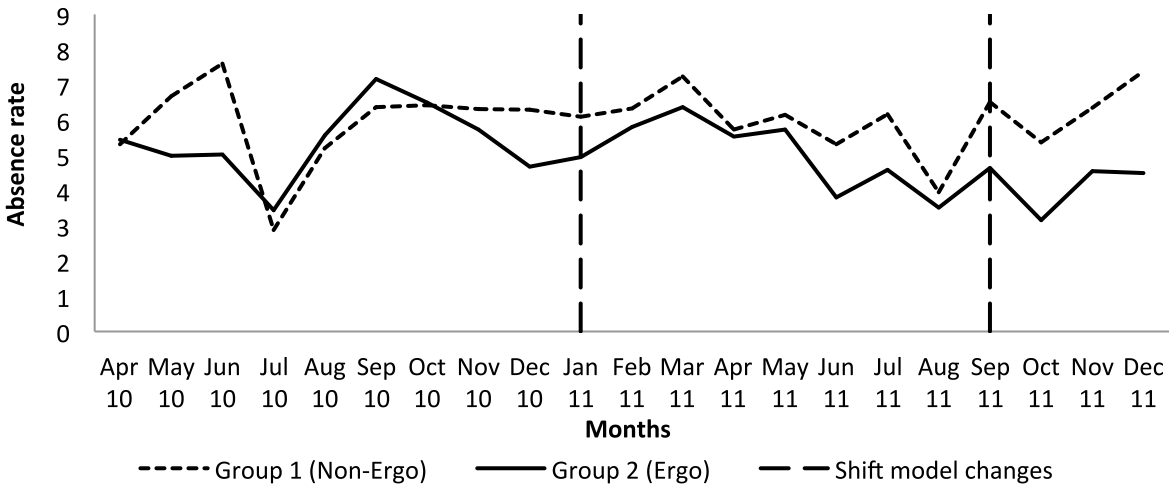
63 Again, the difference between the two groups is statistically significant (F = 13.4) for the entire observation period but no statistically significant difference emerges for the beginning of the observed timeframe (Jan 2010 - Dec 2010) (F = 2.05).

64 Due to low turnover rates, the projected absence rate is expected to increase over time as team composition remains fairly stable in composition while at the same time the workforce gets older.

65 Both, OU size at the outset as well as over the entire observation period differs significantly over the two groups (Jan 10 - Dec 10: F = 173.8; entire observation period: F = 162.5). The differences in OU size could affect the results since group size is generally assumed to be positively related to absenteeism (e.g. Steers and Rhodes 1978, Lokke Nielsen 2008).

66 Since the focus lies on teams (OUs) in automobile manufacturing it appears, however, reasonable to assume that there are only few units with less than five workers.



Source: Own illustration, based on company records.

Figure 6.6: Absence Rates By Month – Non-Ergo vs. Ergo (Apr 2010 - Dec 2011).

Looking at the development of absenteeism over time, in July 2010 a drop appears for both groups (see figure 6.6). The drop in absence rates can be explained by the company's three-week summer break during which large parts of the production processes are shut down and workers are expected to take holiday leave. In 2011 the summer break effect is not as distinct but a slight decline appears in August 2011. Furthermore, considerable differences in absence rates for the two groups over time become apparent. Prior to the first shift model change the patterns allow for no clear statement of differences in absenteeism between the two groups. However, subsequent to the shift model changes in January 2011 (first dashed vertical line) it becomes apparent that absence levels for the group that switched to an ergonomic shift model appear reduced compared to the group that is subject to minor shift model adjustments (group 1). Moreover, the graph indicates that following the second shift model adjustment in September 2011 (second dashed vertical line) – which only affected the 65 OEs not employed in the ergonomic shift model (group 1) – the difference between the two groups in terms of absence rates become even more pronounced. So far, the descriptive results provide a first indication in support of our underlying hypothesis that the design of shift models according to ergonomic guidelines can serve as a way to increase worker health and reduce absenteeism.

6.5 Methods and Results

We estimate a generalized linear model (GLM) in order to investigate the effects of shift model changes on worker absence rates. We do so to account for the proportional nature of our dependent variable (absence rate). The effects of shift model changes on absenteeism are analyzed by treating absence rate as a continuous variable. Thus, since our dependent variable is a rate that is bound 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 e.g. Frick et al. (2013) who analyzed the impact of semi-autonomous teams and team bonuses on absence rates in a large German steel plant.[67]

The underlying model takes on the following general form of:

$$(6.1)\quad \textit{Absence Rate} = \beta_0 + \beta_1 \textit{Shift} + \beta_2 \textit{Projected Rate} + \beta_3 \textit{Unit Size} + \beta_4 \textit{Month} + \varepsilon$$

where

Absence Rate is the proportion of number of days absent divided by the scheduled number of working days per month per organizational unit;

Shift is a vector of four shift dummies;

Projected Rate is the expected rate of absence per month per organizational unit;

Unit Size is the average number of employees in an organizational unit (per month);

Month is a vector of month dummies; and

ε denotes the random error term.

In the analysis the focus is on the coefficients of the dummies representing the different shift models. Nevertheless, month dummies to control for capacity, seasonal and business cycle effects are also included. The initial shift model (16 shifts, M-N-E) serves as our reference category. Table 6.2 provides an overview of the different models. It becomes obvious that the ergonomically improved model is associated with a significant decrease

67 Papke and Wooldridge apply fractional response model estimation to employee participation rates in pension plans (1996) and school test pass rates (2008). Our dependent variable is similar. 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.

in absence rates compared to the initial model – only the second model specification fails to reach statistical significance. Computing the average marginal effects using STATA reveals this effect of the full model (model 4) to amount to a 1.5 percentage point decrease in absence rates (see table 6.6 in the appendix for the margin results).[68]

Table 6.2: GLM Regression of Shift Systems on Absence Rate.[69]

Variables	GLM			
	(1)	(2)	(3)	(4)
Ergonomically Improved Model	**-0.203***	-0.218	**-0.279***	**-0.286****
	(0.114)	(0.149)	(0.143)	(0.142)
Forward Rotating Model	0.0185	-0.0547	-0.0932	-0.0949
	(0.0789)	(0.157)	(0.160)	(0.160)
Backward Rotating Model	**0.111***	**0.225****	**0.191***	**0.190***
	(0.0669)	(0.108)	(0.109)	(0.109)
Projected Absence Rate			**0.245*****	**0.241*****
			(0.0834)	(0.0811)
Unit Size				0.00263
				(0.00907)
Constant	**-2.793*****	**-2.769*****	**-3.615*****	**-3.636*****
	(0.0450)	(0.0718)	(0.302)	(0.325)
Observations	1,806	1,806	1,806	1,806
Month-Year Dummies	YES	YES	YES	YES

Clustered robust standard errors (units) in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Own calculations.

Moreover, it appears from the results that changing from the initial towards a slowly forward rotating model (M-E-N) has no statistically significant effect on worker absence rates – a robust finding over all model specifications. However, abolishing the forward rotating model and simultaneously introducing the backward rotating model, results in a

68 Similar results were obtained from OLS estimations – the effect is estimated to be 1.25 percentage points – which were computed as a robustness check (see table 6.5 in the appendix).

69 Throughout all tables in the work at hand, coefficients in bold indicate statistical significance.

positive link with absence rates. This holds true for model three and four. These results are rather surprising since the model differs from the initial model only in the absence of a morning shift on Saturdays. Additionally, the estimation results reveal the projected absence rates of workers to be positively linked to absence rates. This result is in line with earlier findings from studies in similar settings – presented in chapters five and eight – and indicates that projected absence rates underestimate health and age consequences of the workforce for worker absence. Finally, the number of employees per organizational unit (OU) is found to have no statistically significant effect on absence rates. This finding contradicts the majority of the available literature on absenteeism, which expects a positive association between group or firm size and absence rates (e.g. Barmby and Stephan 2000, Lokke Nielsen 2008).

In general it can be stated that the estimation results support the notions of our descriptive analysis and favor our underlying hypothesis that the design of shift models according to ergonomic guidelines can serve as a way to increase worker health and reduce absenteeism.

A noteworthy finding is that absence rates by itself cannot yield convincing information with respect to the nature of absence occurrences. Causes for absenteeism are widely acknowledged to be of either voluntary or involuntary nature (Steers and Rhodes 1978, Brown and Sessions 1996, Ose 2005). On the one hand, these authors understand voluntary absence to include shirking behavior and to be subject to individual motivation and decision-making. In that regard, Sagie (1998), for example, states that voluntary absence is based on individual goals and can be influenced through motivational factors. On the other hand, absence caused by factors outside an individual´s scope of influence is termed involuntary (this includes e.g. diseases or accidents). On the basis of our absence rate metric it is impossible to single out the nature of absence occurrences. Therefore, our underlying absence measure provides no means for separating the effects of the shift model changes on absence to either of the two.

However, there are other absence measures, which are understood to serve as more suitable approximations for the two different categories of absenteeism. First, there is the frequency of absence, which is measured as the number of absence spells over a specific period of time (here: months). It is frequently used as a proxy for voluntary absence since it is more probable to appear with short duration than involuntary absence cases (Chadwick-Jones et al. 1971, Kristensen et al. 2006, Lokke Nielsen 2008).

Table 6.3: Overview on Average Absence Frequency and Duration (per Employee per Month) Over the Entire Period of Observation.

Variable	N	Mean	Std.	Min.	Max.
Absence duration	1,707	1.42	1.55	0.00	16.00
Absence frequency	1,709	0.17	0.14	0.00	1.07

Source: Own calculations.

Second, the duration of sickness spells is a proxy for involuntary absence (Kristensen et al. 2006, Lokke Nielsen 2008). In our data set both variables are accessible on an aggregated level (per month, per OU). Since the spells per month are clearly related to the size of an OU we transform the variables to a more appropriate format by dividing the spells/duration (per OU and month) by the number of employees in the OU. As a result we end up with measures that provide us with the average frequency or duration of absence spells (per worker, OU and month) (see table 6.3).[70]

In order to assess these two outcome variables, the following models are used:

(6.2) Absence Duration

(6.2) Absence Frequency $= \beta_0 + \beta_1 Shift + \beta_2 Projected\ Rate + \beta_3 Unit\ Size + \beta_4 Month + \varepsilon$

where

70 There are missing values for the two newly introduced variables (absence frequency: 99, absence duration: 97).

Absence Duration is the average duration of an absence period per worker, OU and month; and *Absence Frequency* is the average number of absence spells per worker, OU and month. All other variables have already been introduced.

Absence duration takes the form of count data – a discrete variable with only a finite number of non-negative integer values – and therefore, the econometric methods require adaptation. However, it deviates from normal distribution and displays a right-skewed distribution (see figure 6.7 in the appendix). Therefore, negative binomial regression analysis is used since its distribution substantially deviates from Poisson distribution and overdispersion is an issue (see table 6.7 in the appendix).[71] For the absence duration OLS with clustered standard errors is estimated.[72]

Estimation results indicate that the introduction of the ergonomically improved shift model leads to a substantial decrease in absenteeism with a voluntary connotation (-0.5 percentage points, see table 6.4 for the results of the OLS as well as negative binomial estimations). However, it is important to keep in mind that absence frequency is only a proxy for voluntary absence and also includes non-voluntary absences. In order to reach a deeper understanding of the nature of absenteeism causes interviews with affected shift workers are necessary but go beyond the scope of the work at hand.

In contrast to earlier results (see table 2) the size of the OU reveals a negative association with absence frequency (-0.3 percentage points). This result is surprising since most scholars predict a reverse relationship since group cohesiveness declines with group size, which provides room for shirking behavior (Gibson 1966, Steers and Rhodes 1978). Focusing on the results from the negative binomial estimation it appears that the introduction of the ergonomically improved model does not reveal a significant effect on involuntary absences (in the form of absence duration). This may be explained by the relatively short timeframe (21 months, 12 months subsequent to the shift model changes) used in the

[71] The goodness-of-fit estimation for the Poisson regression provides further support for the use of negative binomial over Poisson regression (see figure 6.9 in the appendix).

[72] The distribution of absence duration is also skewed to the right, see table 6.8 in the appendix. OLS estimation results are reported for simplicity reasons since GLM estimations provided almost identical results (estimation results are available from the authors on request).

study since health consequences of shift work may emerge only after rather long periods of time (Hornberger and Knauth 1995).

Table 6.4: OLS (Absence Frequency) and Negative Binomial Regression (Absence Duration).

Variables	(OLS) Absence Frequency	(Neg. Bin.) Absence Duration
Ergonomically Improved Model	**-0.005****	0.741
	(0.025)	(0.177)
Forward Rotating Model	-0.019	0.954
	(0.026)	(0.237)
Backward Rotating Model	-0.012	0.993
	(0.021)	(0.150)
Projected Absence Rate	-0.005	**1.172****
	(0.010)	(0.086)
Unit Size	**-0.003*****	0.994
	(0.001)	(0.009)
Constant	**0.248*****	0.997
	(0.036)	(0.292)
Alpha		0.212
		0.041
Observations	1,709	1,707
Month-Year Dummies	YES	YES

Clustered robust standard errors (OU) in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Own calculations.

Overall, the econometric analysis reveals that the introduction of an ergonomically designed shift model serves as a means for reducing workers absence rates. Moreover, on the basis of the results presented here it appears evident that the reduction in absence rates is predominantly an effect of the reduction of motivational / voluntary absence rather than a health effect.

6.6 Conclusion

The empirical evidence provided here strongly indicates that shift model design is a means for the reduction of absenteeism of blue-collar production workers. The introduction of a rapidly forward rotating shift model is assessed to be associated with a substantial decrease in absence rates. A control group in a similar work environment, which is subject to shift model changes which do not follow ergonomic guidelines, does not show significant improvements in absence rates. The results support occupational medicine research which assesses ergonomic shift model design to be an important means for reducing health burdens of workers (Knauth 1997, Engel et al. 2014). Especially the direction as well as the speed of rotation is important measures to mitigate the health burdens associated with shift work in general (Hakola and Härmä 2001, Härmä et al. 2006). However, additional estimations indicate that the reduction in absenteeism following the shift model changes appear to originate from motivational rather than from health reasons.

Admittedly, due to the unique case-study design of this research project and the focus on company-internal data the general validity of the results appear restricted. Nevertheless, the paper contributes to the scarce literature on the link between shift work and absenteeism with a special focus on shift model changes rather than a comparison of shift versus non-shift workers. Hence, this field of research is of growing economic relevance, as shift work today appears to be indispensable with regard to international competitiveness. For human resource managers the results provide evidence that shift model adaptions in terms of ergonomic improvements may yield a return in the form of reduced worker absenteeism.

Finally, it is important to consider that the results here only reflect short-term effects of shift model changes. Long-term effects of changes in shift plans are an interesting topic for future research.

6.7 Appendix

Table 6.5: Robustness Check: OLS Estimation (Dependent Variable: Absence Rate)

Variables	OLS (1)	(2)	(3)	(4)
Ergonomically Improved Model	**-0.0101***	-0.0088	**-0.0123***	**-0.0125***
	(0.0052)	(0.0070)	(0.0067)	(0.0067)
Forward Rotating Model	0.0010	-0.00044	-0.0026	-0.0026
	(0.0044)	(0.0082)	(0.0084)	(0.0084)
Backward Rotating Model	0.0063	**0.0131****	**0.0112***	**0.0112***
	(0.0039)	(0.0065)	(0.0065)	(0.0065)
Projected Absence Rate			**0.0139*****	**0.0137*****
			(0.0051)	(0.0049)
Unit Size				0.0001
				(0.0005)
Constant	**0.0577*****	**0.0590*****	0.0111	0.0104
	(0.0025)	(0.0040)	(0.0180)	(0.0189)
Month-Year Dummies	NO	YES	YES	YES

Clustered robust standard errors (units) in parentheses

*** p<0.01, ** p<0.05, * p<0.1

n = 1,806

Source: Own calculations.

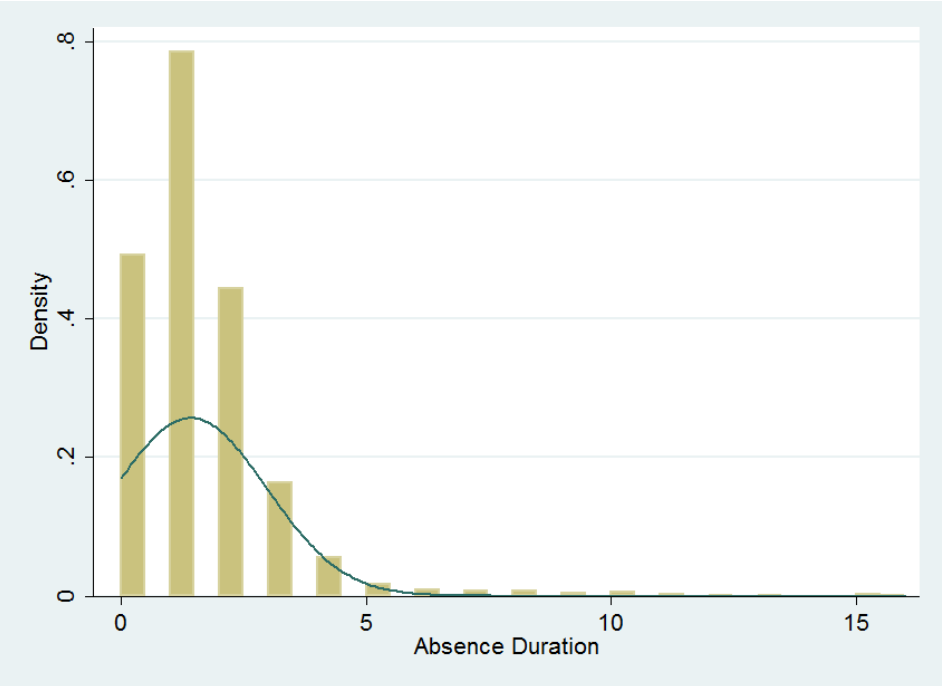
Table 6.6: GLM Estimation – Full Model (Model 4): Marginal Effects.

Variables	Marginal Effects	t
Ergonomically Improved Model	**-0.015****	2.03
Forward Rotating Model	-0.005	0.59
Backward Rotating Model	**0.010***	1.74
Projected Absence Rate	**0.013*****	2.92
Unit Size	0.000	0.29

*** p<0.01, ** p<0.05, * p<0.1

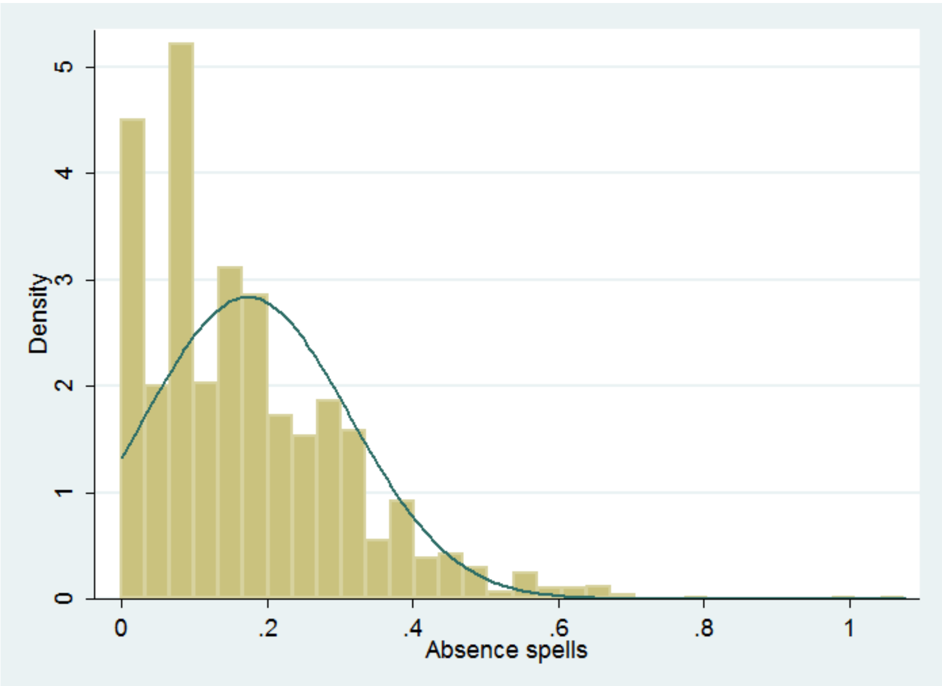
n = 1,806

Source: Own calculations.



Source: Own illustration, based on company records.

Figure 6.7: Histogram – Absence Duration (per Worker, per Month).



Source: Own illustration, based on company records.

Figure 6.8: Histogram – Absence Frequency (per Worker, per Month).

Table 6.7: Descriptive Information – Absence Spells.

	Percentiles	Smallest		
1%	0	0		
5%	0	0		
10%	0	0	Obs	1709
25%	.0714286	0	Sum of Wgt.	1709
50%	.1538462		Mean	.1734619
		Largest	Std. Dev.	.1407133
75%	.25	.6923077		
90%	.3636364	.7777778	Variance	.0198002
95%	.4285714	1	Skewness	1.152069
99%	.6111111	1.076923	Kurtosis	5.239393

Source: Own calculations.

```
. poisgof

         Deviance goodness-of-fit =  1897.582
         Prob > chi2(1682)        =    0.0002

         Pearson goodness-of-fit  =  2426.008
         Prob > chi2(1682)        =    0.0000
```

Source: Own calculations.

Figure 6.9: Poisson Goodness of Fit Estimation (Dep. Variable: Absence Duration).

7 Belastungsreduzierende Schichtmodelle und Fehlzeiten

7.1 Einführung

Hohe Fehlzeiten haben sich in den entwickelten Industrienationen zu einem volkswirtschaftlichen Kostenfaktor entwickelt. So betrug die Fehlzeitenquote im Jahr 2012 in Deutschland 3,88% (Techniker Krankenkasse 2013). Die Summe der Kosten, die der deutschen Volkswirtschaft durch die Abwesenheit von Erwerbspersonen entstanden, belief sich im Jahr 2012 auf 53 Mrd. Euro, ein Anstieg um knapp 36% seit 2010 (BAuA 2012, 2014).[73] Aus diesem Grund ist das Thema Fehlzeiten von Relevanz; zum einen aus Sicht der Praxis, da hohe Fehlzeiten hohe Kosten generieren, zum anderen aus Sicht der Forschung, da trotz zahlreicher Studien zum Thema Determinanten von Fehlzeiten weiterhin Forschungsbedarf besteht (Dionne und Dostie 2007). Sowohl Unternehmen, insbesondere das Personalmanagement, als auch die akademische Forschung sind daher bestrebt, weitere Einflussfaktoren von Fehlzeiten zu identifizieren.

Auf der Ebene der Arbeitsorganisation sind die Gestaltung von Schichtarbeit sowie die Auswirkungen von Schichtmodellveränderungen Faktoren, die in der Fehlzeiten-Forschung bisher wenig untersucht worden sind (Catano und Bissonnette 2014).[74] Die Verbreitung von Schichtarbeit unterstreicht jedoch die ökonomische Relevanz des Themas. So waren im Jahr 2012 in Deutschland ca. 6,3 Millionen Erwerbstätige, d.h. 15,6% der Erwerbsbevölkerung, in Schichtarbeit beschäftigt (Statistisches Bundesamt 2013). Die vorliegende Studie verfolgt daher das Ziel, mit Hilfe von Unternehmensdaten neue Erkenntnisse über den potentiellen kausalen Zusammenhang von Schichtarbeit und Fehlzeiten zu produzieren.

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73 Werden die Kosten, die durch Präsentismus entstehen, hinzugerechnet, so verdreifacht sich die Gesamtbelastung der Unternehmen (Booz and Company Inc. 2011).

74 Zur Definition von Schichtarbeit wird die Erläuterung der Internationalen Arbeitsorganisation (ILO) herangezogen, die Schichtarbeit als eine Organisationsform der Arbeitszeit versteht, in der Arbeiter einander an Arbeitsplätzen ablösen, so dass die Betriebsdauer über der Dauer der individuellen Arbeitszeit liegen kann (ILO 1990, zitiert IARC 2010, 563). Die Erläuterung der Arbeitsmedizinischen Leitlinie der Deutschen Gesellschaft für Arbeitsmedizin und Umweltmedizin e.V. definiert Schichtarbeit in ähnlicher Weise als *„[…] eine Form der Tätigkeit mit Arbeit zu wechselnden Zeiten (Wechselschicht) oder konstant ungewöhnlicher Zeit (z.B. Dauerspätschicht, Dauernachtschicht)“* (Griefahn et al. 2006, 390).

Die vorliegende Studie verwendet dazu Daten aus der Produktion in einem Komponentenwerk eines internationalen Automobilherstellers. Die Analyse fokussiert dabei die Auswirkungen der Einführung eines aus arbeitsmedizinischer Sicht vorteilhaften Schichtmodells auf die Fehlzeiten der Beschäftigten, aggregiert auf die Ebene von Produktionsteams (im Weiteren als Organisationseinheiten (OE) bezeichnet). Unterschiedliche OE-Spezifika wie z. B. Durchschnittsalter oder Anzahl der Beschäftigten finden ebenfalls in der Untersuchung Berücksichtigung.

Die Ergebnisse dieser Studie zeigen, dass die Einführung eines aus arbeitsmedizinischer Sicht vorteilhaften Schichtmodells nicht zu einer kurzfristigen Senkung von Fehlzeiten in den betroffenen OE führt. Die darüber hinausgehende Untersuchung OE-spezifischer Determinanten von Fehlzeiten resultiert in unterschiedlichen Befunden: Für die Auswirkungen der Größe einer OE auf die Fehlzeiten sind die Ergebnisse nicht eindeutig. In Bezug auf das Durchschnittsalter, den Frauenanteil sowie den Anteil der Beschäftigten mit Tätigkeitseinschränkung ist der Zusammenhang mit den Fehlzeiten positiv.

Im weiteren Verlauf ist die Studie wie folgt aufgebaut. Zunächst wird ein umfassender Überblick über existierende Forschungsergebnisse präsentiert. Hierbei stehen die gesundheitlichen Risiken von Schichtarbeit, der Zusammenhang von Schichtarbeit und Fehlzeiten sowie die Gestaltung von Schichtarbeit im Vordergrund. Anschließend erfolgt eine Beschreibung des spezifischen Studiensetups (Unternehmenshintergrund etc.) und eine erste deskriptive Erläuterung der Daten. Im weiteren Verlauf werden anhand der verwendeten Methodik die Ergebnisse der Modellschätzungen erläutert und diskutiert. Zur finalen Abrundung schließt sich ein kurzes Fazit an.

7.2 Literaturhintergrund

Schichtarbeit bildet heute einen integralen Bestandteil unterschiedlicher Wirtschaftszweige. Neben Bereichen wie Krankenhäusern, Polizei oder Feuerwehr ist vor allem in der produzierenden Industrie die Ausdehnung der Betriebszeiten, die durch Schichtarbeit erzielt werden kann, aus Gründen der Wettbewerbsfähigkeit weitestgehend unverzichtbar geworden (Jirjahn 2008).[75] Allerdings ist hierbei zu berücksichtigen, dass Schichtarbeit als ein bedeutsamer Risikofaktor für die Gesundheit der Beschäftigten anerkannt ist (Costa 1996, Esquirol et al. 2010). So weisen Schichtarbeiter im Vergleich zu Tag-Arbeitern bspw. für physische und psychische Leiden ein deutlich höheres Risiko auf (Folkard 1992). Dies wird vor allem auf die durch Schichtarbeit bedingte Desynchronisation des biologischen Rhythmus zurückgeführt (Folkard 1996, Parkes 2002). Im Bereich der Arbeitswissenschaft/-medizin ist die Assoziation von Schichtarbeit mit unterschiedlichen gesundheitlichen Risiken daher ein umfängliches Thema der Forschung. Die Arbeit in Schicht erweist sich dabei für Arbeitnehmer als ein erheblicher Risikofaktor, sowohl kurz- als auch langfristig (Kantermann et al. 2010). Als empirisch gesicherte Befunde sind hierbei vor allem die Verbindung von Schichtarbeit mit Schlafstörungen (Costa 1996, Akerstedt 1998, 2003) sowie Verdauungsstörungen (Harrington 1994, Drake et al. 2004, Knutsson und Boggild 2010) zu nennen. In Bezug auf das metabolische Syndrom bzw. Herzkreislaufstörungen (Boggild und Knutsson 1999, Karlsson et al. 2001, De Bacquer et al. 2009) ist die Befundlage als moderat einzustufen.[76] Die vorliegenden empirischen Untersuchungsergebnisse zum Zusammenhang von Schichtarbeit und dem Risiko an Krebs zu erkranken, legen bisher keinen eindeutigen Zusammenhang nahe (Kolstad 2008, Wang et al. 2011).[77] Die möglichen negativen Konsequenzen von Schichtarbeit gehen jedoch über die rein physische Gesundheit hinaus. So wird das Sozial-/Familienleben der Schichtarbeiter in erheblichem Maße beeinflusst, da Schichtarbeit häufig in Zeiträume (z.B. Abendstunden) fällt, die im normalen Tagesverlauf für soziale Aktivitäten genutzt werden (Costa 1997, Demerouti et al. 2004, Perry-Jenkins et al. 2007, Shen und Dicker 2008).

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[75] Schon früh bezeichnete Marris die „*high rates of capital utilization through shift-work*“ (1964, S. 3) als einen bedeutsamen Vorteil für Unternehmen.

[76] Wang et al. (2011) beurteilen die positive Verbindung zwischen Schichtarbeit und Herzkreislauferkrankungen aufgrund methodischer Bedenken an einigen Studien als moderat, generell spricht aber eine Vielzahl von Befunden für einen solchen Zusammenhang.

[77] Die Einstufung von Schichtarbeit als ein wahrscheinlicher Risikofaktor für Krebserkrankungen durch die Internationale Agentur für Krebsforschung (IARC) erfolgte im Jahr 2007 auf Basis von Tierversuchen. Diese stellten einen Zusammenhang zwischen schichtarbeitsähnlichen Faktoren (z.B. Änderung des Tag-Nachtrythmus) und dem Auftreten von Krebsleiden bei Versuchstieren fest (Straif et al. 2007, International Agency for Research on Cancer 2010). Konsistente Nachweise für eine Übertragbarkeit der Befunde auf den Menschen liegen bislang jedoch nicht vor (Deutsche Gesetzliche Unfallversicherung 2012).

Trotz der Identifikation von Schichtarbeit als Risikofaktor für verschiedene Krankheitsbilder kann zum jetzigen Zeitpunkt kein eindeutiger Zusammenhang zwischen Schichtarbeit und Fehlzeiten konstatiert werden (Catano und Bissonnette 2014). Merkus et al. (2012) finden in der einzigen Meta-Studie, die sich mit dieser Thematik beschäftigt, keine konsistente Evidenz. Lediglich in Bezug auf dauerhafte Arbeit am Abend (Tüchsen et al. 2008) kann ein eindeutig positiver Zusammenhang zwischen Schichtarbeit und Fehlzeiten konstatiert werden, nicht aber für rotierende Schichtarbeit bzw. Nachtschicht. In Bezug auf Fehlzeiten ist es wichtig zu bedenken, dass diese nicht ausschließlich durch gesundheitliche Ursachen bedingt sind. Neben gesundheitsbedingten Fehlzeiten wird daher in der Literatur auch auf die motivationalen Ursachen von Fehlzeiten verwiesen (vgl. Lokke Nielsen 2008).[78]

Schichtarbeit ist allerdings ein komplexer Begriff und beinhaltet viele unterschiedliche Formen der Arbeit in Schicht (Monk und Folkard 1992, Kantermann et al. 2010, Schlick et al. 2010) und die Ausgestaltung der einzelnen Schichtmodelle stellt einen bedeutsamen Faktor in Bezug auf die Gesundheitsrisiken von Schichtarbeit dar. Durch die spezielle Konzeption von Schichtmodellen unter Berücksichtigung von ergonomischen und arbeitsmedizinischen Kriterien können die negativen gesundheitlichen Folgen von Schichtarbeit nachhaltig reduziert werden (Karlsson et al. 2009, Costa 2010, Engel et al. 2014). Dabei gibt es allerdings keine allgemeingültige beste Lösung bezüglich des Designs eines Schichtmodells (Folkard 1992, Knauth 1993). Arbeitswissenschaftliche Empfehlungen zur Gestaltung von Schichtarbeit zielen jedoch darauf ab, die Modelle möglichst belastungsarm für die Beschäftigten zu gestalten (Beermann 2011).[79] Hierbei stehen, neben anderen Gestaltungskriterien, die Bedeutung der Rotationsrichtung und -geschwindigkeit eines Schichtmodells im Fokus der Betrachtung (Knauth 1996, Knauth und Hornberger 1997, Costa 2010). So ist bei der Wahl der Rotationsrichtung eines Schichtmodells aus arbeitsmedizinischer Sicht die Vorwärtsrotation zu bevorzugen (Viitasalo et al. 2008). Diese soll zu mehr Erholungszeit zwischen den einzelnen Schichten/Schichtblöcken führen (Härmä

[78] Brown und Sessions (1996) unterteilen dazu die Ursachen für Absentismus in „valid“ (z.B. Krankheit) und „invalid“ (z.B. shirking).

[79] In Deutschland haben die Gestaltungsempfehlungen für die Nacht-und Schichtarbeit sogar einen rechtsverbindlichen Charakter, da sie Bestandteil des deutschen Arbeitsrechts sind (vgl. §6 Abs. 1 ArbZG).

et al. 2006) bzw. günstiger für den circadianen, ca. 25-stündigen Rhythmus des menschlichen Metabolismus sein (Aschoff 1965, Wever 1979).[80] Zusätzlich präsentieren Bambra et al. (2008) Nachweise dafür, dass die Rotation möglichst kurzfristig erfolgen sollte, d.h. maximal drei identische aufeinander folgende Schichtblöcke. Hakola und Härmä (2001) sowie Härmä et al. (2006) liefern empirische Evidenz für die Reduktion von Schlafstörungen sowie die Verbesserung der allgemeinen Gesundheit durch die Einführung kurzzyklischvorwärtsrotierender Schichtmodelle im Vergleich zu langzyklischrückwärtsrotierenden Modellen. Knauth und Hornberger (1997) begründen dies damit, dass es in kurzzyklisch-rotierenden Modellen zu einer geringeren „Deformierung“ des biologischen Rhythmus kommt. Zusätzlich eröffnen diese Modelle die Möglichkeit einer erleichterten sozialen Teilhabe, da hierfür in kürzeren Abständen als in langzyklischrotierenden Modellen Möglichkeiten bestehen.

Die Wirkung der Umstellung eines Schichtmodells auf die Fehlzeiten von Beschäftigten ist bisher wenig erforscht. Ausnahmen bilden hierbei die Studien aus den beiden vorangegangenen Kapiteln, die eine Verringerung der Fehlzeiten von Produktionsmitarbeitern als Folge der Einführung belastungsreduzierender Schichtmodelle konstatieren. Die vorliegende Studie hat daher zum Ziel, weitere Einblicke in die Fehlzeitenwirkung belastungsreduzierender Schichtmodelle zu erhalten.

7.3 Unternehmenshintergrund, Daten und Analyse

In der Analyse werden Daten ausgewertet, die aus 43 OE in der Produktion eines Komponentenwerks eines großen internationalen Automobilherstellers stammen. Bei der Analyse dieser Daten wird untersucht, wie sich die Einführung eines nach arbeitswissenschaftlichen Empfehlungen gestalteten Schichtmodells auf das Fehlzeitenniveau ausgewirkt hat. Die 43 OE umfassen dabei ca. 750 Beschäftigte. Die betrachteten Daten liegen auf monatlicher Basis und annähernd vollständig über einen Zeitraum von zwei Jahren (24 Monate) vor.[81] Das genaue Beobachtungsintervall liegt dabei zwischen Januar 2011 und Dezember

[80] Die Vorwärtsrotation wirkt dabei wie eine sukzessive Ausdehnung des Tages und passt daher besser zum endogenen Biorhythmus der Arbeitnehmer (Aschoff 1965, Wever 1979).

[81] Für die verwendeten Variablen „Abwesenheitsfälle“ und „Abwesenheitsdauer“ beinhaltet der Datensatz einige fehlende Werte. Die Werte für die übrigen Variablen liegen hingegen vollständig vor.

2012. Die Bereitstellung der Information erfolgte durch die Personalabteilung des Werkes. Aufgrund betrieblicher datenschutzrechtlicher Bestimmungen wurden nur OE in den Datensatz aufgenommen, die über den gesamten Beobachtungszeitraum mindestens fünf Beschäftigte aufwiesen. Ein weiteres Kriterium für die Aufnahme in den Datensatz bestand darin, dass die jeweilige OE über den vollständigen Beobachtungszeitraum hinweg Bestand hatte. OE, die im Laufe dieses Zeitraumes neuinstalliert bzw. aufgelöst wurden, fanden keine Berücksichtigung.

Die OE können dahingehend als homogen eingestuft werden, als dass es sich ausschließlich um Einheiten in der Produktion handelt. Bezüglich der ausgeübten Tätigkeiten (z.B. Fertigung von Achsen, Lenkungen, Fahrzeugkomponenten) unterscheiden sich die OE untereinander. Zu Beginn des Beobachtungszeitraumes, von Januar 2011 bis Dezember 2011, arbeiteten alle 43 OE in einem überwiegend rückwärtsrotierenden Schichtmodell mit relativ langen Schichtblöcken (siehe Abbildung 7.1). Die wöchentliche Betriebszeit wurde durch vier Schichtteams in insgesamt 18 Schichten pro Woche ausgefüllt. Hierbei ist zusätzlich zu beachten, dass es sich um ein nicht-kontinuierliches Schichtmodell handelte.[82] Dieses Ausgangsmodell folgt überwiegend einer rückwärtsgerichteten Rotation, bei der auf einen Frühschichtblock ein Nachtschichtblock folgt und sich anschließend die Spätschicht anreiht (F-N-S).[83] Weiterhin ist das Modell als ein relativ langzyklisch rotierendes Modell zu klassifizieren, da bspw. sechs aufeinander folgende Frühschichten geleistet werden müssen, bevor ein Wechsel in die Spätschicht erfolgt. Die Einschränkung der relativ langfristigen Rotation kommt daher, dass zwischen den Phasen der Spät- und Nachtschicht vermehrt kurzzyklische Rotationen erfolgen mit einzelnen Schichtphasen von zwei bis vier Schichten.

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82 Kontinuierliche Schichtmodelle beinhalten einen durchgehenden Betrieb von Montag bis Sonntag. Das vorliegende Modell beinhaltet einzelne Schichten auch an Wochenendtagen, allerdings keinen durchgehenden Betrieb. Daher ist das Modell als nicht-kontinuierlich zu bezeichnen.

83 Es handelt sich jedoch nicht um eine rückwärtsgerichtete Rotation im strengeren Sinne (F-N-S), da im Anschluss an die Nachtschicht ein weiterer Spätschichtblock mit anschließender Nachtschicht folgt. (F-N-S-N-S).

Laufzeit	Woche 1							Woche 2						
Tag	Mo	Di	Mi	Do	Fr	Sa	So	Mo	Di	Mi	Do	Fr	Sa	So
Schicht 1	F	F	F	F	F	F				N	N	N		
Schicht 2	N	N			S	S		F	F	F	F	F	F	
Schicht 3	S	S	S	S			N	N	N			S	S	
Schicht 4			N	N	N			S	S	S	S			N

Laufzeit	Woche 3							Woche 4						
Tag	Mo	Di	Mi	Do	Fr	Sa	So	Mo	Di	Mi	Do	Fr	Sa	So
Schicht 1	S	S	S	S			N	N	N			S	S	
Schicht 2			N	N	N			S	S	S	S			N
Schicht 3	F	F	F	F	F	F				N	N	N		
Schicht 4	N	N			S	S		F	F	F	F	F	F	

Quelle: Eigene Darstellung, basierend auf Unternehmensdaten.

Figure 7.1: Ausgangsschichtmodell (Jan 2011- Dez 2011).

Zum ersten Januar 2012 wechselten alle betrachteten OE in ein verändertes Schichtmodell, wobei die Betriebszeit weiterhin von 4 Schichtteams in 18 Schichten abgedeckt wurde. Das neue Schichtmodell ist anhand arbeitsmedizinischer Empfehlungen gestaltet worden und ist durch eine streng kurzfristige sowie vorwärts gerichtete Rotation charakterisiert (siehe Abbildung 7.2). So schließt im neuen Modell an die Früh- die Spätschicht an, gefolgt von der Nachtschicht (F-S-N). Die strikte kurzzyklische Ausrichtung zeigt sich darin, dass ein Wechsel der Schichten spätestens nach zwei aufeinanderfolgenden Schichten erfolgt, so dass maximal zwei Tage in einem Schichtblock (Früh/Spät/Nacht) gearbeitet wird. Eine zusätzliche Neuerung ist die Verschiebung der Nachtschicht am Sonntag (Nacht von Sonntag auf Montag), die im Ausgangsmodell einmal monatlich je Schichtteam terminiert war, auf den Samstag (Nacht von Samstag auf Sonntag).

Laufzeit	Woche 1							Woche 2						
Tag	Mo	Di	Mi	Do	Fr	Sa	So	Mo	Di	Mi	Do	Fr	Sa	So
Schicht 1	F	F	S	S	N	N				F	F	S	S	
Schicht 2			F	F	S	S		N	N			F	F	
Schicht 3	N	N			F	F		S	S	N	N			
Schicht 4	S	S	N	N				F	F	S	S	N	N	

Laufzeit	Woche 3							Woche 4						
Tag	Mo	Di	Mi	Do	Fr	Sa	So	Mo	Di	Mi	Do	Fr	Sa	So
Schicht 1	N	N			F	F		S	S	N	N			
Schicht 2	S	S	N	N				F	F	S	S	N	N	
Schicht 3	F	F	S	S	N	N				F	F	S	S	
Schicht 4			F	F	S	S		N	N			F	F	

Quelle: Eigene Darstellung, basierend auf Unternehmensdaten.

Figure 7.2: Neues Schichtmodell (Jan 2012- Dez 2012).

Nach der Beschreibung der unterschiedlichen Schichtmodelle werden im Folgenden die in der Analyse verwendeten Variablen vorgestellt. Insgesamt enthält das verwendete Längsschnitt-Panel 1.032 OE-Monats-Beobachtungen (43 OE x 24 Monate). Ein Vorteil des vorliegenden Datensatzes besteht darin, dass die Daten direkt aus dem Personalcontrolling stammen und es sich daher nicht um subjektive Einschätzungen der Beschäftigten handelt (Deery et al. 1995). Dies ist gerade in Bezug auf Fehlzeiten ein bedeutsamer Punkt, da bereits Johns (1994) darauf hinwies, dass durch Beschäftigten-Befragungen erhobene Fehlzeiteninformationen deutlich hinter den tatsächlich von Unternehmen erhobenen Fehlzeiten zurückbleiben. Es bleibt allerdings anzumerken, dass über die Gründe für die Abwesenheiten/Fehlzeiten keine Informationen vorliegen.

Die Fehlzeiten im betrachteten Unternehmen werden auf Basis der geschuldeten Arbeitsleistung erhoben und als Prozentwert ausgegeben und vom ersten Tag an erfasst.[84] Dies ist ein weiterer Vorteil der Daten, da sich ein Teil der Studien zu Schichtarbeit und Fehlzeiten lediglich auf Ausfälle konzentriert, die länger als drei Tage andauern und damit kurzfristige Fehlzeiten ignoriert (siehe Merkus et al. 2012). Chadwick-Jones et al. (1971)

[84] Diese ergibt sich aus den Arbeitstagen pro Jahr reduziert um Feier- sowie Urlaubstage.

zufolge stehen gerade diese jedoch tendenziell mit motivationalen Gründen in Verbindung.

Neben den auf OE-Ebene aggregierten Informationen zu den Fehlzeiten finden weitere Variablen Eingang in das Modell (siehe Tabelle 7.1). OE-spezifische Variablen wie die Anzahl der Beschäftigten, der Frauenanteil, der Anteil an Beschäftigten mit einer Tätigkeitseinschränkung sowie das Durchschnittsalter der Beschäftigten wurden als Kontrollvariablen aufgenommen.[85]

Table 7.1: Übersicht der deskriptiven Statistiken.[86]

Variablen	MW	SD	Min.	Max.
Fehlzeiten (je OE, in%*100)	6,31	4,79	0,00	25,00
Anzahl der Beschäftigten (je OE)	16,85	4,71	7,00	31,00
Frauenanteil (je OE in%*100)	8,68	10,37	0,00	58,30
Anteil Beschäftigter mit Tätigkeitseinschränkungen (je OE in%*100)	1,89	3,15	0,00	12,50
Durchschnittsalter (je OE)	40,08	4,06	29,70	49,30
Abwesenheitsfälle (je MA)	0,15	0,12	0,00	0,64
Abwesenheitsdauer (Tage je MA)	1,36	1,13	0,00	8,00
n = 1.032				

Quelle: Eigene Berechnungen.

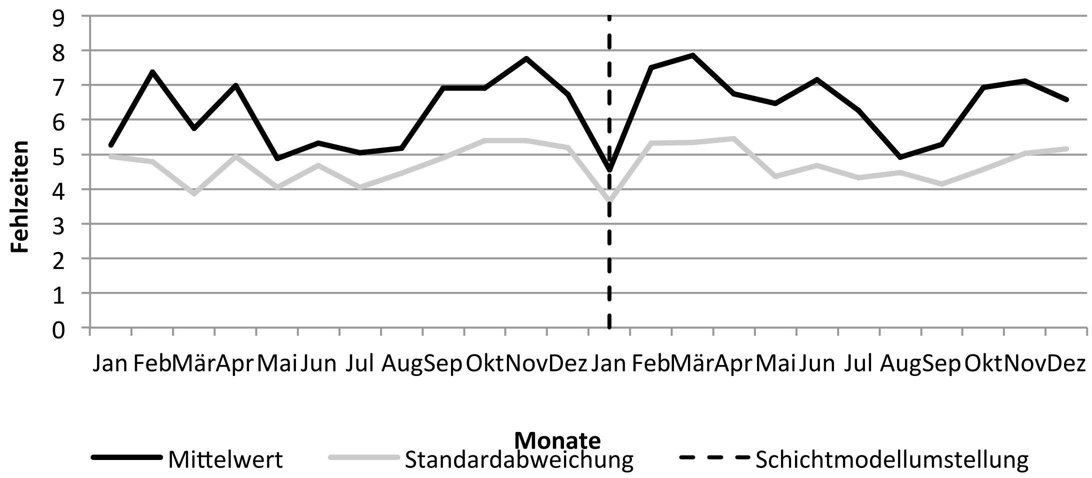
Zusätzlich wurden ebenfalls die monatliche Anzahl der Abwesenheiten (je Mitarbeiter und OE) sowie die monatliche Abwesenheitsdauer (monatliche Summe der Tage, die ein Mitarbeiter abwesend war, je OE) aufgenommen. Sie dienen im Verlauf der Auswertung dazu, mögliche motivationale Fehlzeitenwirkungen, die aus der Einführung eines aus arbeitsmedizinischer Sicht vorteilhaften Schichtmodells resultieren, zu identifizieren.

Die OE weisen im Mittel Fehlzeiten von 6,3% aus, wobei die Streuung (0 - 25%) sehr ausgeprägt ist. Etwa 6,2% der Beobachtungen weisen monatlichen Fehlzeiten von 0% aus.

[85] Die Variablen sind jeweils als Mittelwert der OE je Monat erhoben worden.

[86] Für die beiden Variablen Abwesenheitsfälle bzw. Abwesenheitsdauer sind einige Werte als fehlende Werte codiert (48 bzw. 50), da sich durch Abgänge in der OE für die jeweiligen Monate bei den Variablen negative Werte ergeben hätten. Bei der Abwesenheitsdauer handelt es sich um ganzzahlig gerundete Werte. Für die übrigen Variablen ist der Beobachtungssatz vollständig.

Die Anzahl der Beschäftigten pro OE liegt bei knapp 17, das Durchschnittsalter bei über 40 Jahren je OE. Der geringe Frauenanteil von 8,7% ist durch den Fokus der Studie auf den Bereich der Produktion zu erklären, wo der Anteil der weiblichen Beschäftigten im Unternehmen generell geringer ist.[87] Der Anteil der Beschäftigten mit Tätigkeitseinschränkungen umfasst diejenigen, die aus physischen oder psychischen Gründen nicht mehr alle Tätigkeiten in dem jeweiligen Bereich ausüben können. Mit einem Durchschnittswert von 1,9% ist der Anteil in den betrachteten OE gering, bei über 70% der Beobachtungen liegt der Anteil bei null.[88]



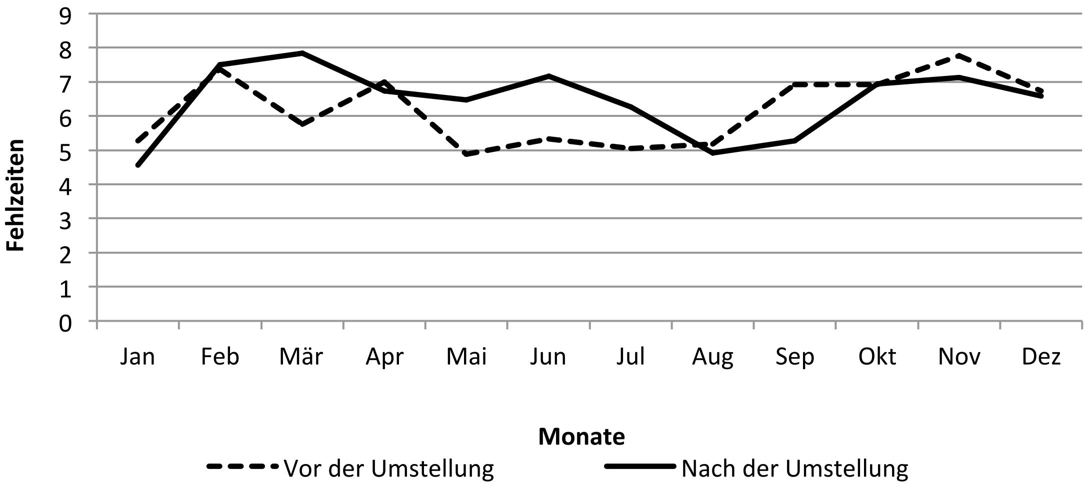
Quelle: Eigene Darstellung, basierend auf Unternehmensdaten.

Figure 7.3: Verlauf der Fehlzeiten (2011-2012).

Aus der Betrachtung des Verlaufs der Fehlzeiten über den gesamten Beobachtungszeitraum (siehe Abbildung 7.3) werden bereits einige Befunde ersichtlich. So liegen die Fehlzeiten in den Sommermonaten erkennbar unter den Werten in den Wintermonaten. Dies ist eine aufgrund der Zunahme von Erkältungskrankheiten in den Wintermonaten sowie der Urlaubszeit im Sommer erwartete Entwicklung.

87 Über 30% der Beobachtungen weisen einen Frauenanteil von null Prozent aus.

88 Eine Erklärung für diesen niedrigen Wert besteht darin, dass Beschäftigte mit stärkeren Einschränkungen häufig in Bereiche außerhalb der Produktion (z.B. Fahrdienst etc.) wechseln und daher nicht in dem Datensatz enthalten sind.



Quelle: Eigene Darstellung, basierend auf Unternehmensdaten.

Figure 7.4: Verlauf der Fehlzeiten (in den Unterschiedlichen Schichtmodellen).

Eine Besonderheit im zeitlichen Verlauf ist der Tiefpunkt des Fehlzeitenstandes im Januar 2012, dem ersten Monat der Schichtmodellumstellung. Im Vergleich der Monatsdurchschnitte wird dieser Eindruck nochmals verstärkt, da deutlich wird, dass die Fehlzeiten im Januar 2012 unter denen des Januars 2011 liegen (siehe Abbildung 7.4). Zusätzlich wird ersichtlich, dass die Fehlzeiten im Januar generell eher gering sind. Ein Erklärungsansatz hierfür kann darin gesehen werden, dass dieser Zeitraum einen beliebten Urlaubskorridor umfasst. Aufgrund des Verlaufes der Graphen ist auf den ersten Blick keine uniforme Wirkung der Schichtmodellumstellung auf die Fehlzeiten zu vermuten (Vergleich der durchgezogenen und der gestrichelten Linie). Im Folgenden werden die Zusammenhänge allerdings tiefgehend untersucht, um ein exakteres Bild zu erhalten.

7.4 Modell, Schätzungen und Ergebnisse

Es ist Ziel dieser Studie, die Wirkung der Einführung eines nach arbeitsmedizinischen Richtlinien gestalteten Schichtmodells auf die Fehlzeiten der Beschäftigten zu untersuchen. Das zugrunde liegende Modell lautet:

$$(7.1)\quad \text{Fehlzeiten} = \beta_0 + \beta_1\text{Schicht} + \beta_2\text{OE-Größe} + \beta_3\text{Alter} + \beta_4\,\text{Frauenanteil} + \beta_5\,\text{Einschränkungen} + \beta_6\,\text{Monate} + \varepsilon$$

Dabei ist *Fehlzeiten* die Quote der Fehltage durch die Anzahl an Arbeitstagen je Monat und OE. *Schicht* stellt einen Vektor aus zwei Schicht-Dummies dar. *OE-Größe* gibt die durchschnittliche Anzahl an Beschäftigten in einer OE je Monat an. *Alter* erfasst das Durchschnittsalter der Beschäftigten einer OE je Monat. *Frauenanteil* beschreibt den Anteil weiblicher Beschäftigter in einer OE je Monat. *Einschränkungen* stehen für den Anteil an Mitarbeitern mit Tätigkeitseinschränkungen je OE und Monat und ε gibt den Fehlerterm an.

Zu Prüfung des Modells finden GLM (Generalisierte Lineare Modelle) Regressionen Anwendung, um die Skalierung der abhängigen Variable zu berücksichtigen. Hierbei handelt es sich um eine Fractional Response Variable, da die Fehlzeiten in Prozentwerten vorliegen, mit den Grenzen Null und Eins (vgl. Papke und Wooldridge 1996, 2008).[89] Das vorrangige Interesse dieser Studie liegt in der Untersuchung der Fehlzeiten-Wirkung der Einführung eines neuen Schichtmodells. Diese wird über eine Dummy-Variable modelliert, die für alle Beobachtungen zum neuen Schichtmodell den Wert 1 annimmt und den Wert 0 für die Beobachtungen zum alten Schichtmodell. Da die Einführung kurzyklischvorwärts-rotierender Schichtmodelle nachweislich mit einer Verbesserung des allgemeinen Gesundheitszustandes sowie einer Reduktion von z. B. Schlafstörungen einhergeht (vgl. Hakola und Härmä 2001, Härmä et al. 2006), wird angenommen, dass sich dies auch in den Fehlzeiten der Beschäftigten widerspiegelt.

Hypothese 1: *Die Umstellung eines langzyklischrückwärtsrotierenden 18-Schichtsystems auf ein kurzzyklischvorwärtsrotierendes 18-Schichtsystem ist mit einer Reduktion der Fehlzeiten verbunden.*

Als Kontrollvariablen fließen Spezifika der OE in das Modell ein. Diese beinhalten neben der Anzahl der Beschäftigten das Durchschnittsalter, den Frauenanteil sowie den Anteil der Beschäftigten mit Tätigkeitseinschränkungen. In der Literatur findet sich generell ein positiver Zusammenhang zwischen der Größe einer OE/Abteilung und ihren Fehlzeiten

[89] Die Anwendung eines einfachen OLS-Schätzers würde dazu führen, dass die Outcome-Variable Werte enthält, die außerhalb der Grenzen von Null und Eins liegen. OLS fand lediglich als Robustheitscheck Anwendung (vgl. Tabelle 7.5 im Anhang) und bestätigt die Befunde aus der GLM-Schätzung weitestgehend.

(Gibson 1966, Steers und Rhodes 1978). Dies wird z. B. durch die größere Anonymität der Arbeitnehmer in größeren Einheiten und dem damit verbundenen geringeren Verantwortungsgefühl gegenüber Kollegen erklärt (Barmby und Stephan 2000). Eine steigende Gruppengröße führt weiterhin zu einem geringeren Gruppenzugehörigkeitsgefühl, wodurch die Anwesenheit am Arbeitsplatz weniger reizvoll erscheint (Porter und Lawler 1965). Diesen Erklärungsansätzen folgend wird auch in dieser Studie ein positiver Zusammenhang zwischen den Fehlzeiten und der Größe der OE vermutet:[90]

Hypothese 2: *Je höher die Anzahl der Beschäftigten in einer OE, desto höher sind die Fehlzeiten.*

Der Zusammenhang zwischen Alter und Fehlzeiten hingegen ist in der Literatur weniger eindeutig.[91] Auf der einen Seite weist die Mehrheit der Studien auf einen negativen Zusammenhang zwischen Alter und Fehlzeiten hin (z.B. Martocchino 1989, Hackett 1990, Kristensen et al. 2006, Markussen et al. 2011). Markussen et al. (2011) erklären ihre Befunde damit, dass jüngere Arbeitnehmer eine geringere Hemmschwelle haben, sich krank zu melden. Ein weiterer Argumentationsstrang verweist darauf, dass die defizitäre Passung zwischen einer Person und ihrer Job-Situation Fehlzeiten erhöhen kann. In diesem Ansatz werden Fehlzeiten als ein Indikator für die mangelnde Passung zwischen einer Job-Situation und einer Person verstanden. Mit steigendem Alter und Verbleib auf einer Stelle wird davon ausgegangen, dass die Passung zwischen Job-Situation und Person ansteigt und so die Fehlzeiten sinken (Schneider 1993). Auf der anderen Seite existiert jedoch auch empirische Evidenz, die einen positiven Zusammenhang von Alter und Fehlzeiten konstatiert (vgl. Barmby et al. 2004).[92] Diesen Ergebnissen liegt die Annahme zu Grunde, dass die Gesundheit mit zunehmendem Alter abnimmt (Yolles 1984). Aufgrund der umfangreicheren Studienergebnisse wird für diese Studie ein negativer Zusammenhang zwischen Alter und Fehlzeiten der Beschäftigten erwartet.

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[90] Einige aktuellere Studien (Frick et al. 2013 sowie die empirischen Studien der Kapitel 6 und 8) finden jedoch keinen Zusammenhang zwischen der OE-Größe und den Fehlzeiten.

[91] Das Durchschnittsalter ist erhoben als Mittelwert der Beschäftigten in einer OE.

[92] Barmby et al. (2004) finden auf Basis des UK Labour Force Surveys einen positiven Zusammenhang zwischen Alter und Fehlzeiten für die britische Erwerbsbevölkerung (Zeitraum 1984 - 2002).

Hypothese 3: *Je höher das Durchschnittsalter in einer OE, desto niedriger sind die Fehlzeiten.*

Die Wirkung des Anteils der weiblichen Beschäftigten auf die Fehlzeiten, erhoben als Mittelwert einer OE, wird als positiv vermutet, da diese Verbindung aufgrund der vorliegenden empirischen Befunde als gesichert angesehen werden kann (Voss et al. 2001, Kristensen et al. 2006, Lokke Nielsen 2008, Bekker et al. 2009). In ihrem Erklärungsansatz führen Fried et al. (2002) dies darauf zurück, dass Frauen einen stärkeren Fokus auf ihr Wohlbefinden bzw. ihre Gesundheit legen und bei Stress- bzw. Krankheitssymptomen eher zu Fehlzeiten neigen. Einen identisch gerichteten Zusammenhang lässt das Verhältnis vom Anteil der Beschäftigten mit Tätigkeitseinschränkungen und den Fehlzeiten erwarten.[93]

Hypothese 4: *Je höher der Frauenanteil in einer OE, desto höher sind die Fehlzeiten.*

Hypothese 5: *Je höher der Anteil an Beschäftigten mit Tätigkeitseinschränkungen, desto höher sind die Fehlzeiten.*

In Tabelle 7.2 sind die Ergebnisse der schrittweise aufgebauten unterschiedlichen Modellvarianten aufgeführt.[94] Der wichtigste Befund ist zunächst, dass die Einführung des neuen belastungsreduzierten Schichtmodells modellübergreifend – entgegen den Erwartungen – keinen signifikanten Einfluss auf die Entwicklung der Fehlzeiten zu haben scheint. Die Richtung des Zusammenhangs zwischen der Einführung des neuen Schichtmodells und den Fehlzeiten ist dennoch wie vermutet negativ. Die Ergebnisse sind überraschend, da das neue Schichtmodell explizit auch auf die Reduktion der Belastung der Beschäftigten ausgelegt ist. Als Folge der reduzierten Belastung waren geringere Fehlzeiten erwartet worden, wie in den vergleichbaren Studien der beiden vorangegangenen Kapitel dargestellt. Hypothese 1, dass die Einführung des neuen Schichtmodells zu verringerten Fehlzeiten führt, muss daher verworfen werden.

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[93] Eine positive Assoziation ist anzunehmen, da diese Beschäftigten physische und/oder psychische Gesundheitseinschränkungen aufweisen, die mit höheren zu erwartenden Fehlzeiten einhergehen.

[94] Weitere Schätzungen in denen die Variablen Alter, Frauenanteil und Tätigkeitseinschränkung mit der Umstellungsvariable interagiert worden sind ergeben keine signifikanten Koeffizienten für die Interaktionsterme.

Die Gründe für die ausbleibende Reduktion der Fehlzeiten können zum einen darin liegen, dass die Umstellung lediglich die Richtung sowie die Fristigkeit der Rotation betrifft.[95] Das Abschaffen der Wochenendarbeit, respektive der zu leistenden Schichten ist hingegen kein Umstellungsbestandteil. Zusätzlich kann der limitierte Betrachtungszeitraum von 12 Monaten nach der Umstellung einen weiteren Erklärungsansatz bieten, da gesundheitliche Verbesserungen durch die Umstellung möglicherweise erst über einen längerfristigen Zeitraum eintreten. Um mögliche motivationale Aspekte der Schichtmodellumstellung eingehender zu betrachten, werden im weiteren Verlauf der Studie zusätzliche Schätzungen vorgenommen.

Table 7.2: GLM-Schätzungen (abh. Variable: Fehlzeiten).

			GLM		
Variablen	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Neues Schichtmodell	-0,024	-0,039	-0,039	-0,012	-0,009
	(0,169)	(0,168)	(0,168)	(0,178)	(0,178)
Anzahl Beschäftigte	0,012	0,014	**0,016***	0,014	**0,016***
	(0,010)	(0,009)	(0,009)	(0,010)	(0,010)
Alter		**0,017***	**0,026****	0,016	**0,026****
		(0,010)	(0,012)	(0,011)	(0,013)
Frauenanteil			0,006		**0,008***
			(0,004)		(0,005)
Tätigkeits-einschränkung				**0,035**** (0,014)	**0,037***** (0,014)
Konstante	**-2,900****	**-3,634*****	**-4,050*****	**-3,572*****	**-4,102*****
	(0,195)	(0,453)	(0,549)	(0,476)	(0,597)
Beobachtungen			1,032		
Monatsdummies			Ja		

Geclusterte robuste Standardfehler (OE) in Klammern
*** p<0,01, ** p<0,05, * p<0,1
n = 1,032

Quelle: Eigene Berechnungen.

95 Mit Hilfe des STATA Befehls „sampsi“ wurde „power calculations“ durchgeführt, um zu überprüfen, ob die Insignifikanz des Umstellungskoeffizienten durch die relativ geringe Stichprobengröße zu erklären ist. Die „power calculations“ ergeben jedoch, dass es die Beobachtungszahl nicht als Erklärung herangezogen werden kann.

In Bezug auf die Größe der OE ist zu konstatieren, dass diese im finalen Modell (Modell 5) einen positiven Einfluss auf die Fehlzeiten hat, d.h. je größer die OE, desto höher sind die Fehlzeiten. Damit ist Hypothese 2 zu bestätigen. Diese Ergebnisse sind konträr zu aktuellen Befunden von Frick et al. (2013) sowie den Befunden aus den Kapiteln sechs und acht dieser Arbeit, die in ähnlichen Studien-Setups (Stahl/Automobilindustrie) keinen signifikanten Zusammenhang nachweisen konnten. Entgegen des in Hypothese 3 formulierten erwarteten Richtungszusammenhanges erweisen sich die Koeffizienten für das Durchschnittsalter der OE als positiv. Ein höheres Durchschnittsalter in der OE ist mit einem signifikanten (5%-Niveau) 0,15 Prozentpunkte-Anstieg der Fehlzeiten assoziiert (Modell 5).[96]

Da es sich in der betrachteten Stichprobe um OE aus der Produktion handelt, deren Tätigkeiten mit hohen körperlichen Belastungen verbunden sind, erscheint es jedoch plausibel, dass die Fehlzeiten bei annähernd gleichen Belastungen im Alter zunehmen.[97] Die Assoziation des Frauenanteils mit den Fehlzeiten weist ein weniger eindeutiges Bild auf. Im Gesamtmodell (Modell 5) zeigt sich ein positiver Zusammenhang von 0,05 Prozentpunkten (10% Niveau), der in die angenommene Richtung weist. Daher kann Hypothese 4 als bestätigt angesehen werden. Der Anteil der Beschäftigten mit Tätigkeitseinschränkungen weist deutlich in die erwartete Richtung, da ein Anstieg der Variable um einen Prozentpunkt mit einem Anstieg der Fehlzeiten um 0,21 Prozentpunkte assoziiert ist (auf dem 5% Niveau) – konstant über die unterschiedlichen Schätzungen hinweg. Dies lässt eine Bestätigung der fünften Hypothese zu. Mit dem Ziel, die Ergebnisse tiefgehender zu beleuchten und zu analysieren, sind weitere Schätzungen mit Sub-Panels vorgenommen worden. Dazu wurde der Datensatz am Median des Altersdurchschnitts (40,6 Jahre) geteilt. Anschließend wurden separate Schätzungen für die beiden Untergruppen vorgenommen (siehe Tabelle 7.3). Die Ergebnisse des geteilten Samples zeigen deutliche Unterschiede. So zeigt sich, dass für den Anteil der weiblichen Beschäftigten vor allem in tendenziell älteren OE ein deutlicher, wenn auch in absoluten Zahlen geringer Effekt auf die Fehlzei-

96 Zur Ermittlung der Ausprägung der Koeffizienten wurde der Margin-Befehl in STATA verwendet (für eine Übersicht der marginalen Effekte siehe Tabelle 7.6 im Anhang).

97 Im Vergleich zu Produktionsarbeiten weisen Bürotätigkeiten eher psychische als physische Belastungen auf.

ten besteht (+0,08 Prozentpunkte im Vergleich zu +0,05 Prozentpunkten in der Gesamtstichprobe).[98] In den jüngeren OE kann hier sogar eine negative Assoziation festgestellt werden (-0,01 Prozentpunkte), die jedoch keine statistische Signifikanz aufweist. Weiterhin wird ein ähnlicher Effekt für den Anteil von Beschäftigten mit Tätigkeitseinschränkung sichtbar. Es findet sich für das jüngere Sub-Sample kein signifikanter Effekt, für das ältere Subsample hingegen ein deutlich stärkerer als in der Gesamtstichprobe (0,34 (p<0,01) im Vergleich zu 0,27 Prozentpunkten). In älteren OE fällt der Anteil der Tätigkeitseinschränkungen also deutlich stärker ins Gewicht. Zusammenfassend bleibt an dieser Stelle allerdings zu konstatieren, dass die Einführung des neuen, nach arbeitsmedizinischen Empfehlungen gestalteten Schichtmodells keinen signifikanten Einfluss auf die Fehlzeiten ausübt.

Table 7.3: GLM-Split-Panelschätzungen für Alter (Abh. Variable: Fehlzeiten).

Variablen	**Alter**		**Gesamt-stichprobe**
	niedrig	**hoch**	
Neues Schichtmodell	0,132	-0,068	-0,009
	(0,204)	(0,297)	(0,178)
Anzahl Beschäftigte	0,019	0,011	**0,016***
	(0,014)	(0,017)	(0,010)
Alter	-0,023	0,007	**0,026****
	(0,023)	(0,022)	(0,013)
Frauenanteil	-0,002	**0,013***	**0,008***
	(0,005)	(0,007)	(0,005)
Tätigkeitseinschränkung	0,005	**0,054*****	**0,037*****
	(0,021)	(0,014)	(0,014)
Konstante	**-2,247****	**-3,231*****	**-4,102*****
	(0,940)	(1,073)	(0,597)
Beobachtungen	528	504	1.032
Monatsdummies	Ja	Ja	Ja

Geclusterte robuste Standardfehler (OE) in Klammern
*** p<0,01, ** p<0,05, * p<0,1

Quelle: Eigene Berechnungen.

98 Die Koeffizienten sind wiederum mit Hilfe des STATA Margin-Befehls berechnet (die Ergebnisse dazu finden sich in Tabelle 7.6 im Anhang).

Die aggregierte Kennzahl der Fehlzeiten auf Monatsebene kann jedoch keine Hinweise bezüglich der Art der Fehlzeiten liefern. Hierzu findet sich in der Literatur ein Konzept, das zwischen zwei Arten von Fehlzeiten unterscheidet: die „freiwilligen“ Fehlzeiten sowie die „unfreiwilligen“ Fehlzeiten (Kristensen et al. 2006, Lokke Nielsen 2008). Der vorliegende Datensatz bietet die Möglichkeit, sowohl die Wirkung der Schichtmodellumstellung auf den Proxy für die tendenziell motivationalen (voluntary) Fehlzeiten (Fälle von Abwesenheit) als auch für die unfreiwillgen (involuntary), z.B. gesundheitsbedingten, Fehlzeiten (Dauer der Abwesenheit) vorzunehmen. Dazu werden zunächst die beiden zugrunde liegenden Variablen (Abwesenheitsfälle und Abwesenheitsdauer je OE) in ein geeignetes Format überführt. Die Werte für die Variablen liegen jeweils auf dem OE-Level vor. Die Nutzung dieser Variablen ist problematisch, da es sehr wahrscheinlich ist, dass OE mit einer höheren Anzahl von Beschäftigten eine höhere Anzahl von Fehltagen aufweisen als OE mit einer geringeren Anzahl. Aus diesem Grund werden die Werte für die Abwesenheitsfälle und Abwesenheitstage jeweils durch die Anzahl der Beschäftigten in der OE dividiert, so dass sich Pro-Kopf-Werte ergeben, die im weiteren Verlauf für die Modellschätzungen genutzt werden. Um die Determinanten dieser beiden Variablen zu eruieren, dienen folgende Modelle:

(7.2) Abwesenheitsdauer

(7.3) Abwesenheitsfälle $= \beta_0 + \beta_1 Schicht + \beta_2 OE\text{-}Größe + \beta_3 Alter + \beta_4\ Frauenanteil + \beta_5\ Einschränkungen + \beta_6\ Monate + \varepsilon$

Hierbei ist *Abwesenheitsdauer* die durchschnittliche Anzahl an Fehltagen je Mitarbeiter, OE und Monat. Die *Abwesenheitsfälle* bezeichnen die Anzahl der Abwesenheitsfälle je Mitarbeiter, OE und Monat. Da es sich bei der Dauer der Fehlzeiten um Zähldaten handelt, bedarf es einer angepassten Methodik zur Untersuchung der Fragestellung. Die Variable weist eine von der Normalverteilung abweichende, rechtsschiefe Verteilung auf (vgl. Abbildung 7.5 im Anhang) und es liegt keine Überdispersion vor (vgl. Tabelle 7.7 im Anhang), daher findet ein Poisson Regressionsmodell Anwendung.[99] Hierbei ist zunächst

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[99] Die Schätzung der Güte der Modellanpassung des Poisson-Modells (vgl. Abbildung 7.6 im Anhang) bestätigt dessen Eignung. Als zusätzlicher Test fand eine negativ binomiale Modellschätzung Anwendung. Der Likelihood Ratio Test bestätigt, dass die negativ binomiale Verteilung in dem vorliegenden Fall äquivalent zur Poisson Verteilung ist. Dies unterstreicht die Verwendung der Poisson Modellschätzung

festzuhalten, dass die Einführung des neuen Schichtmodells nicht mit einer signifikanten Änderung der Abwesenheitsfälle assoziiert ist (siehe Tabelle 7.4). Dies bestätigt die vorangegangenen GLM-Ergebnisse ebenso wie die Ausprägungen und Signifikanzniveaus der Koeffizienten der weiteren unabhängigen Variablen.[100]

Table 7.4: Ergebnisse der Poisson- (Abwesenheitsdauer (Incident Risk Ratio) und OLS-Regression (Abwesenheitsfälle).

Variablen	**Poisson Dauer**	**OLS Fälle**
Neues Schichtmodell	1,021	0,025
	(0,187)	(0,240)
Anzahl Beschäftigte	**1,016***	**0,022***
	(0,009)	(0,013)
Alter	**1,003****	**0,037****
	(0,012)	(0,015)
Frauenanteil	**1,008****	**0,011****
	(0,004)	(0,005)
Tätigkeitseinschränkung	**1,037*****	**0,054****
	(0,014)	(0,021)
Konstante	**0,283*****	-0,756
	(0,015)	(0,684)
Beobachtungen	982	982
Monatsdummies	Ja	Ja

Geclusterte robuste Standardfehler (OE) in Klammern
*** p<0,01, ** p<0,05, * p<0,1
n = 982

Quelle: Eigene Berechnungen.

In Bezug auf die Größe der OE findet sich in ein signifikanter positiver Zusammenhang mit Abwesenheitsfällen (IRR: 1,016). Dieser bestätigt den aus der Literatur zu erwartenden

(vgl. Tabelle 7.8 im Anhang). Aus Gründen der Nachvollziehbarkeit der Interpretation der Koeffizienten werden diese als Incident Risk Ratio ausgegeben.

100 Die Zusammenhänge bestätigen sich auch für die Schätzungen der Variable Abwesenheitsfälle. Die Ergebnisse der OLS-Schätzungen sind in Tabelle 7.4 ausgewiesen. GLM-Schätzungen resultieren in fast identischen Ergebnissen, daher sind aus Gründen der Vereinfachung die OLS-Koeffizienten dargestellt.

Zusammenhang (Gibson 1966, Steers und Rhodes 1978) – je größer die OE, desto höher die Fehlzeiten. Die motivationale Wirkung der Einführung des neuen Schichtmodells kann auf Basis der obigen Befunde jedoch als gering eingeschätzt werden.[101] Der Blick auf die Schätzung mit der Response-Variable „Dauer der Abwesenheit“ zeigt keine signifikanten Auswirkungen der Schichtmodellumstellung. Die Größe der OE jedoch weist einen positiven Zusammenhang aus (0,022 Prozentpunkte). Es findet sich weiterhin ein deutlich positiver Zusammenhang in Bezug auf die Koeffizienten der weiteren Kontrollvariablen. Diese spiegeln die Ergebnisse aus der GLM-Schätzung wider.

Zusammenfassend für diese Untersuchung kann über alle vorgenommenen Schätzmodelle übergreifend konstatiert werden, dass keine Wirkung der Schichtmodellumstellung auf die Fehlzeiten der Beschäftigten identifiziert werden kann. Im Gegensatz dazu ist der Zusammenhang zwischen einzelnen OE-Charakteristika und den Fehlzeiten deutlich geworden. So hat der Anteil der Beschäftigten mit Tätigkeitseinschränkungen einen deutlichen Einfluss auf die Fehlzeiten der OE sowie die Dauer der Abwesenheit je Beschäftigtem. Gleiches gilt für das Durchschnittsalter der OE sowie für den Anteil an weiblichen Beschäftigten. Hinweise für einen motivationalen Effekt der Schichtmodellumstellung, der anhand der Untersuchung der Anzahl der Abwesenheitsfälle je Beschäftigtem modelliert wurde, blieben aus.

7.5 Zusammenfassung und Fazit

Kern dieser Arbeit ist die Analyse der Fehlzeitenwirkung nach der Einführung eines nach arbeitswissenschaftlichen Empfehlungen gestalteten belastungsreduzierenden Schichtmodells, welches in der Produktion eines Komponentenwerks eines großen internationalen Automobilherstellers angewendet wird. Die Untersuchungsergebnisse basieren auf Informationen über 43 Organisationseinheiten (OE) und weisen auf keinen signifikanten Zusammenhang zwischen der Einführung des neuen Schichtmodells und den Fehlzeiten der Beschäftigten hin. Ein Erklärungsansatz hierfür kann in der moderaten Natur der betrachteten Schichtmodellumstellung liegen, da lediglich die Rotationsrichtung und

[101] Die Kennzahl der Abwesenheitsfälle dient lediglich als Proxy für die motivationalen Fehlzeiten, da sie nicht-motivationale Abwesenheitsfälle beinhaltet. Für eine detaillierte Untersuchung der tendenziell motivationalen Aspekte bei der Einführung von Schichtmodellen, sind zusätzlich Befragungen der betroffenen Beschäftigten unerlässlich.

-geschwindigkeit von der Veränderung betroffen waren, nicht jedoch z. B. die Anzahl der zu leistenden Schichten. Weiterhin erscheint es plausibel anzunehmen, dass gesundheitliche Auswirkungen, die aus der Umstellung resultieren, erst langfristig sichtbar werden (Hornberger und Knauth 1995). Der betrachtete Zeitraum (24 Monate insgesamt) von 12 Monaten im neuen Modell kann hierüber jedoch keinen Aufschluss geben. Ein Nachweis für kurzfristige (< 12 Monate), ursächlich motivationale Auswirkungen der Schichtumstellung auf die Fehlzeiten kann nicht erbracht werden. Für zukünftige Forschungsvorhaben ist daher eine möglichst langfristige Betrachtung der Schichtsysteme zu empfehlen.

Von den Befunden darauf zu schließen, dass belastungsreduzierende Schichtmodelle generell keinen Einfluss auf Fehlzeiten ausüben bzw. die Studienergebnisse auf andere Unternehmen zu übertragen, erscheint aus unterschiedlichen Gründen vorschnell; zum einen aufgrund des verwendeten Unternehmenspanels bzw. der spezifischen Umstellung der Schichtmodelle, zum anderen aufgrund der bestehenden heterogenen Forschungsbefunde auf diesem Gebiet (vgl. Merkus et al. 2012). Die unterschiedlichen Ergebnisse der Studien, die sich mit der Verbindung zwischen Schichtarbeit und Fehlzeiten beschäftigen, machen deutlich, dass es ein sehr komplexer Forschungsgegenstand ist. Dies kann dadurch erklärt werden, dass die Studien unterschiedliche Schichtmodelle analysieren – aus diesen Analysen zu verallgemeinern, erscheint wie das sprichwörtliche „Äpfel mit Birnen vergleichen“. Die Betrachtung unterschiedlicher Schichtmodellumstellungen kann zukünftig jedoch dabei helfen, ein detaillierteres Verständnis des Zusammenhangs von Schichtumstellungen und Fehlzeiten der Beschäftigten zu erhalten.

Aus Sicht des Personalmanagements bleibt für diesen speziellen Fall zu konstatieren, dass sich die Einführung eines belastungsreduzierenden Schichtmodells nicht als Mittel zur kurzfristigen Reduktion der Fehlzeiten der Beschäftigten erwiesen hat. Die Untersuchung einer potentiellen langfristigen Wirkung erscheint jedoch als vielversprechender Ansatz für zukünftige Forschungsprojekte.

Ein weiterer Bestandteil der Studie war die Untersuchung OE-spezifischer Determinanten von Fehlzeiten. Diese beinhalteten die Anzahl der Beschäftigten, das Durchschnittsalter, den Frauenanteil sowie den Anteil von Beschäftigten mit Tätigkeitseinschränkungen. Für die Größe einer OE ergibt sich, wie erwartet, ein positiver Zusammenhang zu den Fehlzeiten. Für das Alter der Beschäftigten findet sich entgegen der angenommenen Richtung ein positiver Zusammenhang mit den Fehlzeiten. Aufgrund der schweren körperlichen Arbeit in den OE erscheint dieser Befund nachvollziehbar. Die beiden ausstehenden Determinanten „Anteil weiblicher Beschäftigter“ und „Anteil Beschäftigter mit Tätigkeitseinschränkungen“ weisen die erwartete positive Assoziation mit den Fehlzeiten auf. Beide Effekte treten verstärkt in OE mit einem höheren Durchschnittsalter auf.

7.6 Anhang

Table 7.5: OLS-Schätzungen (Abh. Variable: Fehlzeiten).

Variablen	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Neues Schichtmodell	-0,147	-0,243	-0,239	-0,0909	-0,0765
	(1,121)	(1,115)	(1,118)	(1,102)	(1,105)
Anzahl Beschäftigte	0,0771	0,0897	**0,0999***	0,0818	0,0939
	(0,0661)	(0,0613)	(0,0604)	(0,0582)	(0,0575)
Alter		**0,104***	**0,157****	0,0904	**0,155****
		(0,0631)	(0,0759)	(0,0621)	(0,0765)
Frauenanteil			0,0367		**0,0453***
			(0,0265)		(0,0264)
Tätigkeitseinschränkung				**0,216****	**0,229****
				(0,0920)	(0,0901)
Konstante	**5,410*****	1,063	-1,546	1,302	-1,903
	(1,272)	(2,704)	(3,289)	(2,664)	(3,389)
Beobachtungen			1,032		
Monatsdummies			Ja		

Geclusterte robuste Standardfehler (OE) in Klammern
*** p<0,01, ** p<0,05, * p<0,1
n = 982

Quelle: Eigene Berechnungen.

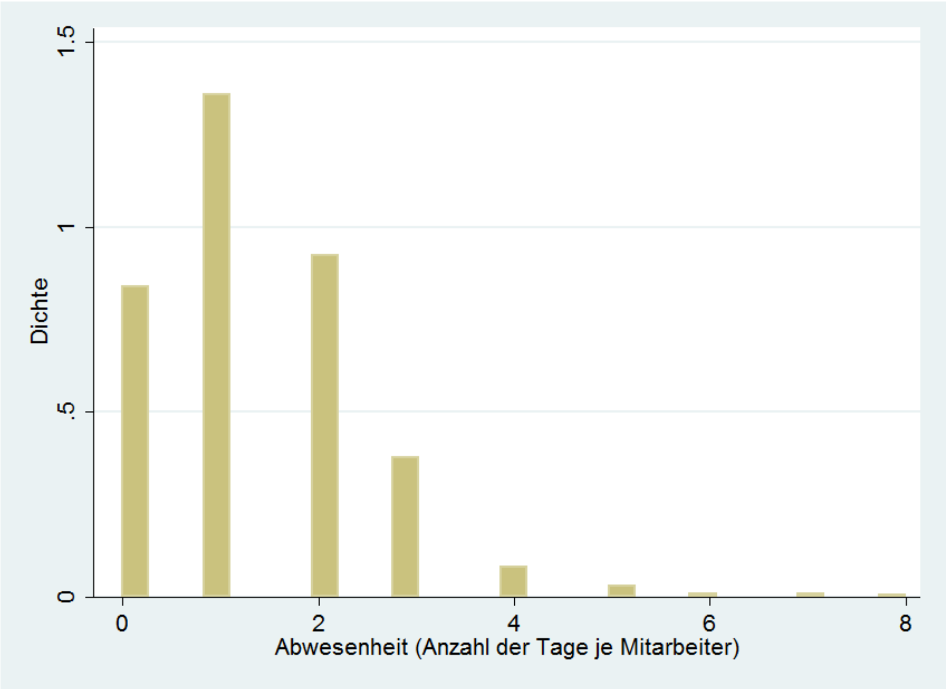
Table 7.6: Marginale Effekte zu GLM-Modell 5 und zur Split-Panel-Schätzung.

Variablen	**Alter** niedrig	**Alter** hoch	**Gesamtstichprobe**
Neues Schichtmodell	0,0072	-0,0043	-0,0005
	(0,65)	(0,23)	(0,05)
Anzahl Beschäftigte	0,0010	0,0007	**0,0009***
	(1,34)	(0,66)	(1,70)
Alter	-0,0012	0,0005	**0,0015****
	(1,01)	(0,33)	(1,99)
Frauenanteil	-0,0001	**0,0008****	**0,0005***
	(0,44)	(1,99)	(1,71)
Tätigkeitseinschränkung	0,0003	**0,0034*****	**0,0021*****
	(0,24)	(3,81)	(2,67)
N	528	504	1.032

t-Werte in Klammern

*** p<0,01, ** p<0,05, * p<0,1

Quelle: Eigene Berechnungen.



Quelle: Eigene Darstellung, basierend auf Unternehmensdaten.

Figure 7.5: Histogramm: Abwesenheit je Mitarbeiter (in Anzahl der Tage je Monat).

Table 7.7: Detaillierte Zusammenfassung der deskriptiven Statistiken (Anzahl der Fehltage).

	Percentiles	Smallest		
1%	0	0		
5%	0	0		
10%	0	0	Obs	982
25%	1	0	Sum of Wgt.	982
50%	1		Mean	1.360489
		Largest	Std. Dev.	1.130788
75%	2	6		
90%	3	7	Variance	1.278682
95%	3	7	Skewness	1.105589
99%	5	8	Kurtosis	5.571395

Quelle: Eigene Berechnungen.

```
Deviance goodness-of-fit =  751.9099
Prob > chi2(954)         =    1.0000

Pearson goodness-of-fit  =  749.4589
Prob > chi2(954)         =    1.0000
```

Quelle: Eigene Berechnungen.

Figure 7.6: Schätzung der Poisson-Modellgüte (Abh. Variable: Anzahl der Fehltage).

Table 7.8: Ergebnisse der Negativen Binomialen Regression (Abh. Variable: Anzahl der Abwesenheitsfälle).

Variablen	Abwesenheit Fälle
Neues Schichtmodell	1,007
	(0,181)
Anzahl Beschäftigte	1,0145
	(0,009)
Alter	**1,026****
	(0,012)
Frauenanteil	**1,008****
	(0,004)
Tätigkeitseinschränkung	**1,037*****
	(0,014)
Konstante	0,319
	(0,171)
Beobachtungen	984
Monatsdummies	JA
/lnalpha	-20,198
	(-)
alpha	0,000
	(-)
Likelihood-ratio Test alpha=0	Chibar2(01)=0,00 Prob>=chibar2 = 1,000

Robuste Standardfehler in Klammern
*** p<0,01, ** p<0,05, * p<0,1

Quelle: Eigene Berechnungen

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

8.1 Introduction

Shift work is a common standard in most industrialized countries. In the EU for example about 17 % of the entire workforce is subject to shift work (European Foundation for the Improvement of Living and Working Conditions 2012). In the US, the share of employees doing shift work is nearly identical (18 % or 21 million employees) (McMenamin 2007). The prevalence 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 large sectors of the manufacturing industry (e.g. steel 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 appears to be a necessity due to social as well as economic reasons. However, it is associated with a number of negative health and social risks/outcomes for workers. These include potentially detrimental effects, both physically and mentally, of shift work on employees, e.g. sleeping problems, gastrointestinal and cardiovascular diseases (e.g. Akerstedt 2003, Nakata et al. 2004, Knutsson and Boggild 2010). Since shift work has been found to increase the risk for a number of negative health outcomes it is assumed to induce increased absenteeism among workers compared to people working regular hours (Kleiven et al. 1998).

Given its economic relevance it is certainly surprising that empirical evidence on the impact of shift work on worker absenteeism is still rather limited (Catano and Bissonnette 2014). Moreover, the evidence that is available so far is inconclusive at best (Merkus et al. 2012). So far, research on the link between shift work and absenteeism has remained almost exclusively a domain of occupational medicine with the existing research focusing on absence spells longer than a full week (Tüchsen et al. 2008, Niedhammer et al. 2008). However, since shift work is presumably associated with rather short spells of sickness as well as contributing to long-term/chronic diseases such as cardiovascular diseases and metabolic disturbances (Costa 1997, Knutsson 2003, Li et al. 2011), short- as well as long-term absence periods should be taken into account when evaluating the impact of different shift systems on worker health.

Focusing on short absence spells Böckerman and Laukkanen (2009) have found a positive association between shift work and absenteeism. Taking this as our starting point, we have in an earlier paper looked at the impact of different shift models (e.g. a forward vs. a backward rotating system) on the absence behavior of workers (see chapter five). Here we analyzed the impact of shift work on absenteeism by investigating the impact of changes of the shift schedule on worker absence (including short-term absences). We 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 continuous night work) to an ergonomically more advantageous schedule (weekly forward rotation) resulted in a significant decrease in worker absence rates.[102] This, in turn, suggests that the design of the particular shift model (e.g. forward vs. backward rotation) is likely to have a considerable impact on worker health outcomes. These findings are in line with the evidence presented by e.g. Barton and Folkard (1993) as well as Van Amelsvoort et al. (2004).[103] However, due to the structure of the data (in our companion paper we used monthly instead of weekly data) it was by then not possible to separate the effects of the different positioning of the shifts (e.g. morning, evening, night) on absenteeism.

Hence, in this study we focus on how the different positioning of shifts (morning, evening, night) within a particular shift model influences absence rates. 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 some 150 organizational units over a period of 104 consecutive weeks. Over this period the units worked in a discontinuous shift model of six weeks of weekly backward rotation from evening shift to morning shift and a subsequent phase of three weeks of night shift.[104] During the preparatory stages of the

[102] A second change in the shift model – due to the intervention of the company´s work council – towards a weekly backward rotating model induced absence rates to return to the initial level.

[103] Similar findings are also presented by Engel et al. (2014) who examined the effects of changes in shift design (ergonomic improvements) on the strain experience of shift workers.

[104] The model is considered discontinuous since there is no work on weekends.

project several HR managers of the company suggested that a (large) part of the absence behavior of workers might be due to particular incentives generated by the obligatory taxation of the shift work premium in the case of a worker being absent. The design of the shift model at hand 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.

As expected, we find morning and night shifts to be associated with reduced absence rates compared to evening shifts. The first evening shift 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 to be equally plausible. One explanation is that high absence rates in the first evening 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 have an incentive to 'postpone' absence from the night shift towards the first week of evening shift to avoid taxation of the night shift premium.

The remainder of the paper is structured as follows: Section 8.2 provides a review of the relevant literature and section 8.3 presents the data including a description of the shift model used in the respective plant of the automobile company. Subsequently, section 8.4 presents the hypotheses guiding our research project. In section 8.5, descriptive evidence will be displayed while section 8.6 provides the econometric evidence on the absence effects of the different positioning of the shifts. Finally, section 8.7 concludes.

8.2 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 run (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 (Akerstedt 2003, Drake et al. 2004, Sallinen and Kecklund 2010). Furthermore, shift work is considered to increase the risk of physical health consequences such as gastrointestinal diseases, e.g. stomach pain, ulcer or diarrhoea (Knutsson 2003, Knutsson and Boggild 2010). Finally, 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, Boggild and Knutsson 1999). However, a more recent study by Wang et al. (2011) finds the relationship between shift work and coronary heart diseases to be rather weak.

Over and above the documented negative health effects, shift work is considered as a risk factor for the social 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 (Costa 1997, Jansen et al. 2004). The detrimental effects of shift work on social and family life have been documented over and over again. Nevertheless, in particular the effects of shift work on family life offer potential for future academic research (Kantermann et al. 2010).

Given the association of shift work with negative short- and long-term health outcomes for workers, it is reasonable to assume 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 absenteeism (Meyer et al. 2013). Perhaps surprisingly, the available research does not yet allow drawing any final conclusions. First, research on the relationship between shift work and absenteeism has remained very limited so far (Catano and Bissonnette 2014, Lesuffleur et al. 2014) and, second, the available findings are inconclusive and mixed. Kleiven, Boggild and Jeppesen (1998) for example fail to find a statistically significant difference in the probability of sick leave among shift workers compared to day workers in an 11-year study of workers in a Norwegian chemical plant.

Similarly, Catano and Bissonnette (2014) using data on more than 20,000 Canadian workers from different industries also fail to identify a robust relation between shift work and sickness absenteeism. This latter study, however, finds that working on rotating shifts increases absenteeism. Contrary to the results presented so far, Böckermann and Laukkanen (2009) identify an eight percent increase in absenteeism 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) report a statistically significant relationship between shift work and absenteeism 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.

However, the available research not 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 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 (Barton and Folkard 1993, Hakola and Härmä 2001, Van Amelsvoort et al. 2004, Härmä et al. 2006). In the companion paper already quoted above, we present evidence indicating a decrease in absence rates of production workers following the introduction of an ergonomically advantageous shift model (see chapter five).

Apart from the health consequences of shift work itself the question whether the different positioning of shifts – morning, evening 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 evening and morning shifts (Vidacek et al. 1986). Another important finding is that accident risks are higher during evening and night shifts compared to morning shifts (Smith et al. 1994). Furthermore, the relative risk of accidents is found to increase significantly over the course of successive evening shifts as well as night shifts (Folkard and Tucker 2003).

Finally, only a rather small portion of the literature on shift-work induced absenteeism takes into consideration other than health-related factors that may affect the absence decision of workers. Kristensen et al. (2006) as well as Lokke Nielsen (2008) emphasize the importance of motivational factors in the decision-making process of workers to absent themselves from work, but fail to document a robust relationship.

8.3 Data

We use a unique data set including weekly information on absenteeism on more than 150 organizational units in one particular plant of a large German automobile company to analyze the impact of the positioning of shifts (morning, evening or night shift) on worker absenteeism. Our data set offers complete information on all organizational units included in the analysis over a period of two years (104 consecutive calendar weeks). At the outset, our sample included almost 170 organizational units. However, since we wanted to construct a balanced panel some units had to be eliminated from the dataset due to incomplete information. This includes for example units that have been dissolved or newly installed over the observation period. Additionally, the company's data security guidelines only allow for the examination of units with five or more employees. Hence, units comprising less than five workers in any of the weeks during the observation period also had to be dropped from the sample.

The remaining 153 organizational units account for approximately 3,000 employees. Although the units are exclusively shop-floor units they are nevertheless heterogeneous in terms of the operational area they are located in (pressing plant, body shop, paint shop, assembly line, etc.). The observation period ranges from January 2009 to December 2010 and includes a total of 104 consecutive weeks (n=15,912 unit-week observations). Work for the different shift teams starts 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 evening to morning shift followed by three consecutive weeks of night shift (see figure 8.1). Rotation speed therefore is considered to be relatively low in this particular shift model. Moreover, the shift model is classified as discontinuous with working days ranging from Monday to Friday with weekends off. Furthermore, German mandatory legal requirements stipulate that employees have to be compensated for working late hours either through additional days off or through an adequate monetary premium which typically ranges between 30 and 50% of hourly wages.[105] Night shifts are always subject to this premium and are, therefore, particularly rewarding from an income perspective. 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 – is then subject to taxation (Einkommensteuergesetz (EStG), Income Tax Act 2009). Thus, workers have considerable incentives to 'postpone' absences from the night shift towards the first evening shift to avoid taxation of their night shift premium, which would result in an income loss of around 20 € per day.

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

Source: Own illustration, based on company records.

Figure 8.1: Shift Model (Jan 2009 until Dec 2010).

The data we use here comes from the company's records and was provided by the department of human resources controlling. This means that the quality of the data is certainly much better than in most studies using self-reported measures of absenteeism (Lokke and Nielsen 2008). Self-reported absence measures (e.g. Eriksen et al. 2003, Catano and Bissonnette 2014) appear to significantly underreport the true level of absenteeism since they are subject to individual assessment/understanding of absenteeism. A study by Johns (1994), for example, estimates the levels of absenteeism reported by individual workers to account for only half of the absences recorded by firms. Anoth-

105 The collective bargaining agreements the company has signed with IG Metall, the largest metal worker union in the world, stipulate that the compensation for working late hours is monetary and not in the form of days off.

er advantage of our study is the inclusion of short-term absence spells since in the data set absence spells are 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).

8.4 Hypotheses

Working night shifts is associated with a higher probability of particular health problems and/or a lower level of social well-being. Therefore, we expect absence rates among automobile workers to be higher during night shifts than during either morning or evening shifts (H1.1). If, on the other hand, workers forfeit the respective pay premium by not showing up for work during night shifts, absenteeism may be lower than during either morning or evening shifts (H1.2). The question whether the (negative) 'health effects' dominate the (positive) 'pay effect' or vice versa is an empirical one that we will answer in the descriptive as well as the econometric part of our paper (sections 8.5 and 8.6 below).

Working evening 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, we expect absence rates to be lower than during either morning or night shifts which both interfere substantially more with the circadian rhythm (H2.1). If, 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) absenteeism may be higher than during either morning or nights shifts (H2.2). The question, whether the (positive) 'health effects' dominate the (negative) 'social opportunity cost effect' or vice versa is again an empirical one that we seek to answer below. Finally, stress and strain associated with working night shifts accumulate over time and we expect absence rates to increase over the three consecutive weeks that automobile workers are on night shift (for a detailed exposition of the shift system implemented in the plant that we study in this paper see section 3 above) with the highest absence rate in the very last week (H3). If, on the other hand, the 'incentive effect' of the pay premium dominates the (negative) health effects of working in the night, absenteeism will be particularly high in the first week after night shifts, because workers have a monetary incentive to postpone sickness spells from the night shift phase to retain their pay premium (H4).

8.5 Descriptive Analysis

It is worth pointing out that the data used here includes only a small number of 'internal' explanatory variables (such as the respective unit´s projected absence rate and the number of employees per unit). In addition, we use various external sources to add a number of control variables including the amount of rain and snow, the average weekly temperature as well as a proxy for the general level of flus and colds (see table 8.1 for an overview of the variables used). However, 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.

Table 8.1: Descriptive Statistics I – Overall.

Variable	Mean	Std. Dev.	Min.	Max.
Employees	19.96	6.44	8.00	49.00
Observed Absence Rate	5.75	5.82	0.00	50.00
Projected Absence Rate	3.65	0.72	1.90	6.68
Air Temperature	9.32	7.64	-5.84	23.43
Precipitation	1.75	2.07	0.00	16.43
Flus & Colds	0.52	0.29	0.18	1.42
	n = 15,912			

Source: Own calculations.

Figure 8.2 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 month (e.g. weeks 25 to 35) emerges. A final observation from the graph is that absenteeism during evening 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, evening 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 evening shifts (6.00%-6.38%). 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 $H_{2.1}$.

Source: Own illustration, based on company records.

Figure 8.2: Absence Rates over the Different Shifts.

Furthermore, the health risks that are (presumably) associated with working night shifts do not show up in higher absence rates which – at the descriptive level – seems to contradict $H_{1.1}$.

A one-way analysis of variance (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 (E-M-E-M-E-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 evening shift compared to the remaining morning and night shift weeks. Moreover, the test results indicate that there is no difference in absence rates between morning and night shift weeks (for detailed results see table 8.5 in the appendix).

Table 8.2: Descriptive Statistics II – Absence Rates over the Different Shifts.

Variable	Mean	Std. Dev.	Min.	Max.
Shift Week 1 (Evening)	6.38	6.10	0.00	35.71
Shift Week 2 (Morning)	5.58	5.46	0.00	30.71
Shift Week 3 (Evening)	6.00	5.88	0.00	33.33
Shift Week 4 (Morning)	5.71	5.63	0.00	43.47
Shift Week 5 (Evening)	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

Note: Reported values take on the form of absence*100.
Source: Own calculations.

Thus, the descriptive evidence suggests statistically significant differences in absence rates, pointing to potential absence effects due to the positioning of shifts (see table 8.2).

8.6 Model, 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 is virtually impossible, as the works council will always object, arguing that employees must not be treated like 'examination objects'.

In order to analyze the impact of the positioning of shifts in a particular shift model on absence rates, the following general models will be estimated:

$$(8.1)\quad \textit{Absence Rate} = \beta_0 + \beta_1 \textit{Shift} + \beta_2 \textit{Projected Rate} + \beta_3 \textit{Unit Size} + \beta_4 \textit{Temperature} + \beta_5 \textit{Rain} + \beta_6 \textit{Flu} + \beta_7 \textit{Month} + \varepsilon$$

where

Absence Rate is the proportion of number of days absent divided by the scheduled number of working days per month per organizational unit;
Shift is a vector of three shift dummies;
Projected Rate is the expected rate of absence per month per organizational unit;
Unit Size is the average number of employees in an organizational unit (per month);
Temperature denotes the average weekly outdoor temperature (in °C);
Rain is the average weekly rainfall amount in millimeters;
Flu is the average weekly absence rate in Germany for reasons of flus and colds;
Month is a vector of month dummies; and
ε denotes the random error term.

$$(8.2)\quad \textit{Absence Rate} = \beta_0 + \beta_1 \textit{Shiftweek} + \beta_2 \textit{Projected Rate} + \beta_3 \textit{Unit Size} + \beta_4 \textit{Temperature} + \beta_5 \textit{Rain} + \beta_6 \textit{Flu} + \beta_7 \textit{Month} + \varepsilon$$

where

the variables are identical to equation *(8.1) with the exception* of *Shiftweek*, which is a vector of nine shift week dummies.

In order to account for the proportional nature of our dependent variable, we estimate a generalized linear model (GLM). We examine the effects of the different positioning of shifts on 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.

The estimations include control variables for the average weekly temperature, the rainfall per week as well as a variable indicating the prevalence of flus and colds. These 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 (2013). We use daily information provided by a weather station approximately 70 km away as this was the closest station that had complete data for the period under investigation. Initially, the information was available on a daily basis and subsequently aggregated to average weekly information to be 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 expected 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 for the prevalence of flus and colds is based on data that was 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 a representative 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 8.3 displays the results of our analysis. A first result worth mentioning is that unit size is found to have no 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. Lokke Nielsen 2008, or the empirical studies presented in chapters five and seven of the work at hand), but is in line with findings from the study in chapter six.

Table 8.3: GLM and FE Estimation (With Clustered Standard Errors, Dep. Variable: Absence Rate).

Variable	GLM	FE
Evening shift	**0.118****	**0.006*****
Morning shift	0.020	0.001
Night shift	reference category	
Projected Absence	**0.243****	0.001
Unit Size	-0.004	0.001
Temperature	-0.001	-0.000
Precipitation	**0.015****	**0.001*****
Flus & Colds	**0.989****	**0.049*****
Month-Year Dummies	included	
Constant	**-4.200****	0.0054
R2*100		2.71

*** p< 0.01; ** p < 0.05; * p < 0.1

n = 15,912

Source: Own calculations.

Moreover, the projected absence rate has a positive and significant effect on a unit´s observed absence rate (a one point increase in projected absenteeism is associated with a 1.31 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).[106] 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 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.

106 The coefficients are estimated using the margin command in STATA (see table 8.6 in the appendix for the detailed results).

Nevertheless, the GLM estimation suggests that health problems of female as well as older workers appear to be underestimated by the company´s human resources department.[107] 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 evening shifts and lowest during morning and night shifts. The evening shifts are associated with a 0.64 percentage point increase in absenteeism compared to night shifts. Hence, hypothesis H2.1, which assumes lower levels of absenteeism during evening 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 evening shifts, we offer a plausible and straightforward explanation: Evening shifts start at 2:30 pm and end at 10:30 in the evening, thus covering most of the time that can be spent with family and friends (i.e. the 'social opportunity costs' of working in the evening 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 evening shifts as they want to spend time with family and friends. Hence, our hypothesis H2.2 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, Lokke Nielsen 2008).

[107] This finding supports the results of an earlier study (Frick et al. 2013) which point in a similar direction.

Table 8.4: GLM and FE Estimation (With Clustered Standard Errors, Dep. Variable: Absence Rate).[108]

Variable	GLM	FE
Evening Shift (Week 1)	**0.132****	**0.0071*****
Morning Shift (Week 2)	-0.007	-0.0008
Evening Shift (Week 3)	**0.064***	**0.0035****
Morning Shift (Week 4)	0.015	0.0003
Evening Shift (Week 5)	**0.079***	**0.0039****
Morning Shift (Week 6)	-0.026	-0.0013
Night Shift (Week 7)	-0.009	-0.0007
Night Shift (Week 8)	**-0.071****	**-0.0040*****
Night Shift (Week 9)	reference category	
Projected Absence	**0.243****	0.0005
Unit Size	-0.004	0.0008
Temperature	-0.001	-0.0001
Precipitation	**0.015****	**0.0008*****
Flus & Colds	**0.970****	**0.0477*****
Month-Year Dummies	Included	
Constant	**-4.161****	0.0065
R2 * 100		2.76

*** p< 0.01; ** p < 0.05; * p < 0.1
n = 15,912

Source: Own calculations.

The structure of our data provides us with the opportunity to further evaluate the roots of the spike in absence rates during evening 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).[109] This enables us to identify which weeks of the shift model are the most susceptible to worker absenteeism.

[108] For the complete estimation results see table 8.7 and 8.8 in the appendix.
[109] The results are stable upon changes in the reference group.

Table 8.4 displays the results of our 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 evening 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 evening 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 evening shift (week 1) sees a 0.71 percentage points increase in comparison to the last night shift week of the complete cycle (week 9), leading us to accept H4.[110] A comparison of the regression coefficients reveals that the coefficient for the first evening shift (week 1) is significantly different from the coefficients for the second (week 3) and third (week 5) evening 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 and third evening shift do not differ significantly (F (1, 152) = 0.06). 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 evening 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 may have pronounced incentives to 'postpone' absences from the night shift towards the first evening shift. These incentives arise from the considerable premiums paid for night shifts (between 30 and 50% of hourly wages).[111] If a worker calls in sick during night shifts she/ he is entitled to continued (sick) pay.[112] However, the premium for the respective shift – which is under normal circumstances exempt from personal income tax – is then subject

[110] Again, coefficients are estimated with the help of STATA´s margin command (see table 8.9 in the appendix for the complete margin results).

[111] The night work premium is a mandatory legal requirement.

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

to taxation. On average this incentive is estimated to amount to approximately €20 per day.[113] This line of interpretation supports the arguments of Broström et al. (2004) who state that economic incentives created through costs of absenteeism influences absence behavior.

This 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 evening 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 evening shifts we find a sizeable 'tax evasion effect' of delaying absence spells from night to evening 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 H1.2 to exist for night shifts appears ambiguous since absence rates levels are only different between night and evening, but not between night and morning shifts.[114] Moreover, the higher probability of experiencing health and social problems when working in the night compared to morning and evening fail to translate into higher absence rates for night shifts (H1.1). Finally, no cumulative effect of the three successive night week shifts on absence rates seems to exist and, therefore, hypothesis H3 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.

In order to better understand our results, we have estimated a number of additional regression models. First, we split the dataset by absence rate, projected absence rate and

113 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 on respective shifts.

114 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.

unit size quartiles and estimate separate regressions for each set of quartiles (for detailed results see tables 8.10-8.12 in the appendix). By distinguishing different segments we aim to identify potential subgroups in the panel that may separately influence the overall results. It appears that the effects of the shift week dummies vary considerably between the subgroups – be it in term of unit size, in projected or in observed absence rate. These differences clearly warrant further investigation. What can be said so far is that the absence effect of the first evening week is driven by the two middle quartiles while the two remaining quartiles fail to exhibit any significant absence effect for the first evening week. This is surprising insofar as we expected the results to be driven by units that are projected to have the highest absence rates in the sample. The separate estimations for the different unit size quartiles reveal that absence in the first evening week is not significantly different from the previous night shift week (week 9) for the lowest unit size quartile. However, for the higher quartiles the effect becomes statistically significant. Moreover, in the two quartiles with the largest organizational units the absence effect of the first evening shift is most pronounced. These results are in line with the literature in so far as larger units have been found to experience increased absence levels compared to smaller units (Lokke Nielsen 2008). Nevertheless, we fail to find this effect in our main models.

8.7 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 evening shifts feature the highest rates of worker absenteeism. This is unexpected since night shifts are associated with increased health risks as well as increased risks of work related accidents (Folkard and Tucker 2003). However, evening shifts are associated with the highest 'social opportunity costs' of going to work, which may explain the higher tendency of workers reporting sick during this shift phase.

Summarizing, in a shift system consisting of six weeks of alternating shifts between evening and morning shift and a subsequent period of three weeks of night shift it appears that absence rates are highest during evening shifts while morning and night shifts display similar levels of absenteeism. The difference between evening and night shifts (the reference category in our estimations) is 0.64 percentage points or more than 11%. Furthermore, the shift from the final night week to the first evening week sees a massive increase in absence rates of 0.71 percentage points which is tantamount to a 12% increase in absence rate levels compared to the night shift.

This observation is best explained by the worker's incentives to 'postpone' absenteeism away from the night shifts towards the first evening shift. Night shifts come with a considerable premium (between 30 and 50% of hourly wages). If the worker calls in sick during night shifts he is entitled to continued sick pay. However, the premium – which is under normal circumstances exempt from personal income tax – is now subject to taxation. Hence, the increased absence rates during the first evening shift appear to be driven by this incentive for workers to 'postpone' health-related absenteeism in order to avoid taxation of the night shift premium. Thus, our results indicate that the debate about the design of shift work and its association with health risks and accompanying absenteeism has to be complemented by motivational aspects of absence behavior as well. These findings can be of practical relevance to management when designing new shift models since unintended incentives need to be taken into account.

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, it may serve as a starting point for further research exploring the potential impact of the design of shift models on health and productivity outcomes of workers in other firms and industries.

8.8 Appendix

Table 8.5: Tukey Post-Hoc Test – Pairwise Comparison of Absence Rates Means Between the Different Weeks of the Shift Model.

Shift Week	Contrast	Std. Err.	t	P>t
2 vs 1	**-0.7952774**	0.1960949	-4.06	***
3 vs 1	-0.3709838	0.1960949	-1.89	
4 vs 1	**-0.6630931**	0.1975108	-3.36	**
5 vs 1	-0.3209909	0.1960949	-1.64	
6 vs 1	**-0.8619835**	0.1960949	-4.40	***
7 vs 1	**-0.7963601**	0.1975108	-4.03	***
8 vs 1	**-1.1222920**	0.1960949	-5.72	***
9 vs 1	**-0.7242400**	0.1960949	-3.69	***
3 vs 2	0.4242936	0.1946687	2.18	
4 vs 2	0.1321843	0.1960949	0.67	
5 vs 2	0.4742865	0.1946687	2.44	
6 vs 2	-0.0667062	0.1946687	-0.34	
7 vs 2	-0.0010827	0.1960949	-0.01	
8 vs 2	-0.3270142	0.1946687	-1.68	
9 vs 2	0.0710374	0.1946687	0.36	
4 vs 3	-0.2921093	0.1960949	-1.49	
5 vs 3	0.0499929	0.1946687	0.26	
6 vs 3	-0.4909997	0.1946687	-2.52	
7 vs 3	-0.4253763	0.1960949	-2.17	
8 vs 3	**-0.7513078**	0.1946687	-3.86	***
9 vs 3	-0.3532562	0.1946687	-1.81	
5 vs 4	0.3421022	0.1960949	1.74	
6 vs 4	-0.1988904	0.1960949	-1.01	
7 vs 4	-0.1332670	0.1975108	-0.67	
8 vs 4	-0.4591985	0.1960949	-2.34	
9 vs 4	-0.0611469	0.1960949	-0.31	
6 vs 5	-0.5409926	0.1946687	-2.78	
7 vs 5	-0.4753692	0.1960949	-2.42	
8 vs 5	**-0.8013007**	0.1946687	-4.12	***
9 vs 5	-0.4032491	0.1946687	-2.07	
7 vs 6	0.0656234	0.1960949	0.33	
8 vs 6	-0.2603080	0.1946687	-1.34	
9 vs 6	0.1377435	0.1946687	0.71	
8 vs 7	-0.3259315	0.1960949	-1.66	
9 vs 7	0.0721201	0.1960949	0.37	
9 vs 8	0.3980515	0.1946687	2.04	

** p <.05; *** p < .01

Source: Own calculations.

Table 8.6: GLM Estimation – Shift Differences: Marginal Effects.

Variables	Marginal Effects	t
Evening Shift	**0.006****	6.41
Morning Shift	0.001	1.05
Projected Absence	**0.013****	5.65
Unit Size	-0.000	0.90
Temperature	-0.000	0.47
Precipitation	**0.001****	4.27
Flus & Colds	**0.053****	13.84
*** p< 0.01; ** p < 0.05; * p < 0.1		
n = 15,912		

Source: Own calculations.

Table 8.7: FE Estimation (With Clustered Standard Errors, Dep. Variable: Absence Rate).

Variable	Coeff.	t
Evening shift (Week 1)	**0.0071*****	5.59
Morning shift (Week 2)	-0.0008	-0.54
Evening shift (Week 3)	**0.0035****	2.09
Morning shift (Week 4)	0.0003	0.14
Evening shift (Week 5)	**0.0039****	2.28
Morning shift (Week 6)	-0.0013	-0.85
Night shift (Week 7)	-0.0007	-0.51
Night shift (Week 8)	**-0.0040*****	-
Night shift (Week 9)	reference category	
Projected Absence	0.0005	0.09
Unit Size	0.0008	1.28
Temperature	-0.0001	-0.53
Precipitation	**0.0008*****	4.03
Flus & Colds	**0.0477*****	13.70
Month-Year Dummies	included	
Constant	0.0065	0.24
R2	2.76	
*** p< 0.01; ** p < 0.05; * p < 0.1		
n = 15,912		

Source: Own calculations.

Table 8.8: GLM Estimation (Dep. Variable: Absence Rate).

Variable	Coeff.	Rob. Std. Err	t
Evening Shift (Week 1)	**0.132****	0.023	5.69
Morning Shift (Week 2)	-0.007	0.028	-0.27
Evening Shift (Week 3)	**0.064****	0.031	2.09
Morning Shift (Week 4)	0.015	0.033	0.46
Evening Shift (Week 5)	**0.079****	0.031	2.54
Morning Shift (Week 6)	-0.026	0.029	-0.90
Night Shift (Week 7)	-0.009	0.026	-0.35
Night Shift (Week 8)	**-0.071*****	0.022	-3.24
Night Shift (Week 9)		reference category	
Projected Absence	**0.243*****	0.042	5.82
Unit Size	-0.004	0.004	-0.91
Temperature	-0.001	0.003	-0.26
Precipitation	**0.015*****	0.004	4.05
Flus & Colds	**0.970*****	0.067	14.48
Month-Year Dummies		included	
Constant	**-4.161*****	0.202	-20.60
*** p< 0.01; ** p < 0.05; * p < 0.1			
n = 15,912			

Source: Own calculations.

Table 8.9: GLM Estimation – Shift Week Differences: Marginal Effects.

Variables	Marginal Effects	t
Evening Shift (Week 1)	**0.007*****	5.81
Morning Shift (Week 2)	-0.000	0.27
Evening Shift (Week 3)	**0.003****	2.10
Morning Shift (Week 4)	0.001	0.46
Evening Shift (Week 5)	**0.004****	2.56
Morning Shift (Week 6)	-0.001	0.90
Night Shift (Week 7)	-0.000	0.35
Night Shift (Week 8)	**-0.004*****	3.26
Projected Absence	**0.013*****	5.65
Unit Size	-0.000	0.90
Temperature	-0.000	0.26
Precipitation	**0.001*****	4.07
Flus & Colds	**0.052*****	13.48
*** p< 0.01; ** p < 0.05; * p < 0.1		
n = 15,912		

Source: Own calculations.

Table 8.10: Subgroup Analysis (Split by Unit Size, Dep. Variable: Absence Rate).

Variable	1st quartile	2nd quartile	3rd quartile	4th quartile
Evening Shift (Week 1)	0.260	**0.608****	**0.995*****	**0.837*****
Morning Shift (Week 2)	-0.201	**-0.648***	**-0.047***	**0.444****
Evening Shift (Week 3)	-0.131	0.025	0.466	**0.862*****
Morning Shift (Week 4)	-0.511	0.246	-0.007	0.389
Projected Absence	**1.374***	**1.458*****	**0.920****	**1.273*****
Evening Shift (Week 5)	0.114	0.244	0.350	**0.770*****
Morning Shift (Week 6)	-0.187	-0.193	-0.214	0.019
Night Shift (Week 7)	-0.450	-0.014	0.051	-0.045
Night Shift (Week 8)	**-0.715****	0.005	**-0.414****	**-0.508*****
Night Shift (Week 9)	reference category			
Unit Size	0.211	0.103	-0.101	0.025
Temperature	-0.020	-0.029	0.001	0.008
Precipitation	**0.098***	**0.156*****	**0.081*****	0.015
Flus & Colds	**5.552*****	**3.284*****	**5.798*****	**4.211*****
Month-Year Dummies	included			
Constant	-5.447	-1.854	0.981	-2.042
n = 15,912, *** p< 0.01; ** p < 0.05; * p < 0.1				

Note: Absence rate measure used here (absence rate *100).
Source: Own calculations.

Table 8.11: Subgroup Analysis (Split by Projected Absence Rate, Dep. Variable: Absence Rate).

Variable	1st quartile	2nd quartile	3rd quartile	4th quartile
Evening Shift (Week 1)	0.293	**1.180*****	**0.870*****	**0.493***
Morning Shift (Week 2)	-0.141	-0.221	0.204	-0.164
Evening Shift (Week 3)	0.228	-0.083	**0.995*****	0.242
Morning Shift (Week 4)	0.258	-0.568	**0.594***	-0.135
Evening Shift (Week 5)	0.201	-0.153	**1.212*****	0.265
Morning Shift (Week 6)	0.019	**-0.692***	0.340	-0.240
Night Shift (Week 7)	-0.055	**-0.498***	0.198	-0.025
Night Shift (Week 8)	**-0.405****	**-0.574****	-0.050	**-0.611****
Night Shift (Week 9)	reference category			
Projected Absence	1.042	1.236	0.618	0.404
Unit Size	0.002	-0.022	-0.016	0.007
Temperature	-0.001	0.014	-0.042	-0.001
Precipitation	0.034	**0.130*****	**0.102****	0.065
Flus & Colds	**3.384*****	**4.343*****	**5.071*****	**6.216*****
Month-Year Dummies	included			
Constant	-0.546	-0.793	0.208	3.132
n = 15,912, *** p< 0.01; ** p < 0.05; * p < 0.1				

Note: Absence rate measure used here (absence rate *100).
Source: Own calculations.

Table 8.12: Subgroup Analysis (Split by Absence Rate, Dep. Variable: Absence Rate).

Variable	1st quartile	2nd quartile	3rd quartile	4th quartile
Evening Shift (Week 1)	**0.707*** **	**0.962*** **	**0.470** **	**0.669** **
Morning Shift (Week 2)	-0.032	0.289	-0.380	-0.223
Evening Shift (Week 3)	-0.053	**1.028*** **	0.343	0.066
Morning Shift (Week 4)	0.070	**0.609** **	0.041	**-0.575* **
Evening Shift (Week 5)	0.275	**0.612** **	0.283	0.380
Morning Shift (Week 6)	-0.314	-0.094	0.022	-0.137
Night Shift (Week 7)	-0.230	-0.178	0.122	-0.003
Night Shift (Week 8)	-0.409	**-0.548*** **	-0.323	-0.312
Night Shift (Week 9)		reference category		
Projected Absence	**0.375** **	0.241	**0.595** **	**0.879** **
Unit Size	-0.030	-0.011	0.000	**-0.043** **
Temperature	-0.028	-0.002	-0.015	0.014
Precipitation	**0.128*** **	**0.077** **	-0.016	**0.133*** **
Flus & Colds	**2.969*** **	**4.359*** **	**4.318*** **	**7.401*** **
Month-Year Dummies		included		
Constant	0.137	**2.363** **	**2.045* **	1.927

*** p< 0.01; ** p < 0.05; * p < 0.1
n = 15,912

Note: Absence rate measure used here (absence rate *100).
Source: Own calculations.

9 Summary and Outlook

The dissertation at hand provides a comprehensive economic analysis of changes in shift schedules and their potential impact on worker absence. Using rich longitudinal – hitherto unavailable – datasets on shift and absence information of the various production lines of a large international automobile manufacturer three main research questions are addressed:

(1) Do changes in the design of shift models influence worker absence?
(2) Do ergonomic improvements in the design of shift models reduce worker absence?
(3) Are there different patterns of worker absence between varying shifts (morning, evening, night) of the same shift schedule?

Questions one and two are closely related and jointly build the core of three empirical studies presented over the course of chapter five to seven. In these studies, the implementation of different shift models in different plants of an automobile manufacturer is analyzed. In general, the evidence resulting from the three studies is diverse since the different shift schedule implementations evaluated in the studies resulted in divergent effects on worker absence. The abolishment of a shift schedule including three weeks of consecutive night shifts (regime1) and the introduction of an ergonomically more favorable shift schedule (weekly forward rotation, regime 2) are analyzed in chapter five. The change is – as expected – associated with a statistically significant decrease in absence. However, the abolishment of the newly implemented schedule (regime 2) after a few months – due to concerns regarding resting periods on weekends – and the associated introduction of a weekly backward rotating shift schedule (regime 3) result in an increase in absence rates back to the original level (under regime 1). This appears unexpected, as the weekly backward rotating schedule is considered to result in lower health risks for workers compared to the initial shift schedule.

In contrast to these findings, the empirical evidence presented in chapter six – focusing on the introduction of a fast forward rotating shift schedule instead of a weekly backward rotating scheme – supports the potential of ergonomically improved shift schedules as an adequate means for reducing worker absence. Moreover – using absence frequency as a proxy for voluntary and absence duration as a measure for involuntary absence as, among others, proposed by Kristensen et al. (2006) – additional analyses indicate that the decrease in absence appears to be mainly driven by motivational factors. The notion that absence effects may be a consequence of motivational rather than health aspects is further supported by the fact that in the present work, observation periods in the ergonomically improved shift schedules are rather short (<= one year) while health-related consequences of shift work are mainly expected to emerge after years (Knauth and Hornberger 1995). However, the analysis of long-term effects is beyond the scope of the present work and can be identified as an interesting field for future research.

The third empirical study of the present work (chapter seven) fails to identify any absence effect as a consequence of the introduction of a fast forward rotating, ergonomically improved shift schedule. At first sight, the results appear unexpected, since the new shift schedule aims at reducing health related stress for workers. However, these results need to be seen in the context of the rather moderate adaptations to the shift schedule since the rotation speed was already rather fast in the original shift system. Another possible explanation may be that workers value free days – which are apparent in both models – higher than the direction or speed of rotation.

In summary, the heterogonous results indicate that replacing traditional (e.g. backward-rotating) with ergonomically improved shift schedules may provide – under specific conditions – the potential for a significant reduction in worker absence. Hence, the results point out that ergonomically improved shift schedules do not per se lead to reduced worker absence and that contextual factors, such as the scope of the shift model change, motivational aspects etc., need to be considered. This appears in line with the inconclusive evidence of an association between shift work and absence with regard to the comparison of shift and day workers (Merkus et al. 2012). A viable option for shift schedule adaptations to result in lower worker absence may be the combination of considerable ergonomic improvements aligned with worker expectations – to account for motivational aspects. Involving shift workers in the development and implementation of shift schedules may, therefore, represent a valuable prerequisite for the acceptance and impact of new shift schedules (Knauth and Hornberger 2003) but is also associated with additional costs. Thus, in order to address the first research question of this work, it appears that in general, shift schedule changes influence worker absence behavior while showing divergent effects. With regard to the second question, however, the empirical evidence presented in chapters five to seven appears ambiguous. These findings appear in line with the literature, which assesses the evidence on shift work and worker absence to be inconclusive (see chapter three for an overview). Therefore, additional research appears necessary in order to clarify the specific conditions under which shift schedule changes induce reduced worker absence.

With regard to the remaining research question, the effects of the sequence of different shifts within a particular schedule are analyzed in chapter eight. The results reveal that absence rates differ substantially between morning, evening, and night shifts and that night shifts display the lowest absence rates while evening shifts are associated with the highest absence rates. These findings are fairly unexpected since night work is associated with a number of negative health outcomes (Harrington 2001) and increased accident risks (Smith et al. 1994). However, increased absence rates in evening shifts are explained by high 'social opportunity costs' since evenings display the highest utility with regard to leisure activities with family and friends (Costa 2010). The results show that, in particular, the first evening shift week after three weeks of consecutive night work is associated with the highest absence rates of the entire schedule. Again, motivational aspects serve as an adequate explanation since workers may be incentivized by a 'tax evasion effect' as the night shift premium is subject to income tax if a worker calls in sick during the night shift while being exempt from taxation if the employee attends work.

Notwithstanding the mixed nature of the empirical findings, the results fit in the theoretical economic frameworks. Under a labor-leisure choice framework as well as under the moral hazard approach, the expected absence effects of ergonomically improved shift models in comparison to traditional shift models are assumed to be negative. In a labor-leisure framework, absence rates are assumed to decrease as a consequence of ergonomic shift schedule adaptations with the rationale behind this being that ergonomically improved shift systems are understood to alleviate working conditions. This increase in the quality of working conditions is assumed to result in higher utility causing a decrease of absence rates. The moral hazard framework suggests the same association between ergonomically improved shift schedules and worker absence since the psychological costs associated with a dismissal are thought to increase as a consequence of the implementation of ergonomically improved shift schedules compared to traditional shift schedules. Although these expected outcomes do not consistently materialize in the empirical results, the theoretical considerations may also serve to explain the results at hand. The non-occurrence of significant absence effects as a consequence of the shift model changes in, for example, chapter seven may be explained by the fact that the increase in utility for the worker associated with the moderate shift schedule changes may only be marginal and insufficient to affect worker absence behavior.

Apart from the primary research goals of the work at hand, additional interesting findings emerge from the empirical analysis. For example, the size of organizational units reveals significant positive coefficients in only two (chapter five and seven) of the four studies. Hence, the argument of decreasing group cohesion with increasing group size (Porter and Lawler 1965, Barmby and Stephan 2000) does not univocally hold in the underlying context with regard to absence behavior. Hence, the mixed results do not enable a clear recommendation for practitioners with regard to the relevance of the size of production teams. An important aspect with regard to the practical relevance of the work at hand is the finding that projected absence rates consistently display a positive association with worker absence. The projected absence rate serves as an instrument for the human resource controlling department in calculating personnel requirements of the company and is computed based on the gender composition and age structure of the organizational units as well as on the job type (white/blue collar work). The pronounced positive coefficients for the projected absence rates indicate that health problems for female and older workers appear to be substantially underestimated by the human resource department. Hence, an evaluation of the projected absence rate and its algorithm appears warranted in order to produce a more realistic measure for the planning of personnel resources. Finally, the study provides additional evidence for a significant link between absence rates and age, gender as well as health impairments. In line with the literature, the share of female workers in an organizational unit is positively associated with worker absence (Voss et al. 2001, Bekker et al. 2009). The same holds true for health impairments. With regard to age, the literature supports heterogeneous assumptions. The positive association between age and absence rates identified in the present work is in line with findings by Barmby et al. (2004) and opposes the negative relationship expected by Kristensen et al. (2006) and Markussen et al. (2011).

Despite the mixed empirical evidence of the studies at hand, the present work poses a valuable contribution to the scarce literature on shift work and worker absence for different reasons. Firstly, the use of exact and objective information on shift work schedules depicts a clear advantage over most of the existing research, which predominantly uses vague information on shift work exposure (e.g. Tüchsen 2008b, Slany et al. 2014). Secondly, the use of objective information on worker absence instead of subjective self-reported absence measures (as applied by, for example, Catano and Bissonnette 2014), which are prone to underestimation (Johns 1994), depicts another advantage of this work. Finally, instead of focusing on potential differences between non-shift and shift workers the present work evaluates differences in absence rates as a consequence of shift schedule changes – a field that has not been focused on in greater detail. This depicts an important area for future research due to shift work depicting an economic and societal imperative, which is unlikely to be reduced in scope. Hence, alternative ways – such as the ergonomic design of shift schedules – to alleviate health and reduce worker absence need to be evaluated. As a contribution to future research on worker absence, this work makes a relevant claim for introducing the design of shift work rather than the mere presence of shift work as a determinant for absence and provides mixed empirical evidence on the case. Moreover, the evidence presented indicates that in addition to health related factors, motivational aspects are of relevance with regard to the absence effects of shift schedule design. The latter point, in particular, can be seen as a highly relevant aspect for practitioners since the motivational aspects suggest that, for example, acceptance of shift schedules may influence the effects of shifts schedule design on worker absence. Hence, as indicated by Knauth (2001), the involvement of workers in the actual design of shift schedules as well as a timely and adequate communication of shift model changes depict important levers with regard to the associated effects.

In spite of its significant contribution to the shift work literature, the present work also has certain limitations that need to be addressed. To begin with, an important aspect can be identified as inherent to the applied insider econometrics approach. The empirical research is conducted in a very specific environment and, therefore, generalizability of the results appears limited (Ichniowski and Shaw 2003). This aspect holds even more true in the area of shift work research since shift work depicts a broad classification for varying types of work organization (two-shift, three-shift, permanent, rotating). Nevertheless, this drawback is – at least partially – offset by the greater confidence in the empirical results provided through insider econometric studies. Additionally, the present work is – due to the nature of the respective shift schedule changes – unable to disentangle the specific effects of single shift work features (such as, for example, direction of rotation). Instead, the shift schedule changes predominantly evaluated bundles rather than isolated features of shift work design. Hence, the focus is on combined effects of different shift work features and excludes unique effects of single features. However, this problem concerns the majority of the research conducted on shift work (Barnes-Farrell et al. 2008).

Another noteworthy aspect is the use of absence rates as a measure for worker absence. The measure at hand – calculated as the proportion of the number of days absent divided by the scheduled number of working days (per month per team) – includes certified as well as non-certified absences. Based on the data at hand, no direct differentiation can be made concerning certified and non-certified sickness. This differentiation appears as an interesting field of research since it would enable researchers to gain a deeper understanding of potential motivational aspects with regard to the relationship between shift work and worker absence. Furthermore, the absence measure at hand provides no option to distinguish between short- and long-term absences. As a result, absence rates may be driven by few workers with long-term illness. These long-term absences are probably not affected in the short periods observed in the present work, which may indicate the reported effects to be conservative estimates. For future research, the differentiation between short- and long-term absence with regard to the implementation of ergonomically improved shift schedules appears as an interesting field. Nevertheless, the use of absence rates as a measure for worker absence appears warranted since it is the measure applied in the everyday practice of the evaluated automobile manufacturer and is, therefore, of substantial practical relevance.

In conclusion, the empirical evidence presented and discussed in the work at hand provides a valuable contribution to the understanding of the relationship between shift work design and worker absenteeism while valuable practical implications are presented and fields for future research are identified.

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Eidesstattliche Erklärung

Hiermit versichere ich, Friedrich Stein, die vorliegende Arbeit selbstständig und unter ausschließlicher Verwendung der angegebenen Literatur und Hilfsmittel erstellt zu haben. Alle Stellen, die wörtlich oder sinngemäß veröffentlichtem oder unveröffentlichtem Schrifttum entnommen sind, habe ich als solche kenntlich gemacht. Die Arbeit wurde bisher in gleicher oder ähnlicher Form keiner anderen Prüfungsbehörde vorgelegt und auch nicht veröffentlicht.

Wolfsburg, den 04.08.2015 Friedrich Stein