Trust-based Work-Time and Innovation:

Evidence from Firm Level Data*

Olivier N. Godart[a], Holger Görg[a,b] and Aoife Hanley[a]

[a] *Kiel Institute for the World Economy and University of Kiel, Germany*

[b] *IZA*

Abstract

We explore whether the introduction of trust based working hours is related to the subsequent innovation performance of firms. Employing a panel data set of German establishments, we implement a propensity score matching approach where we only consider firms that did not use trust based work contracts initially. Our results show that firms which adopt such contracts tend to be around 12 - 15 percent more likely to improve products, and 6 - 7 percent more likely to undertake process innovation. These results hold when we control for another form of flexible time work arrangements, namely working time accounts. Thus, the positive relationship between the adoption of trust based working hours and innovation seems to be driven by the degree of employee control and self-management over working time, rather than by merely allowing time flexibility.

Key words: Trust based work time, innovation, firm performance

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1 Introduction

The organization of work has changed dramatically over the last few decades. Decision making has become more decentralized and 'flatter', workers tend to be engaged in multiple tasks rather than one single task, and rigidly regulated working time has in many cases been abandoned (e.g. Brown et al., 2009). It is this latter issue that this paper is concerned with. Indeed, since the mid-1980s, flexible working hours systems have become an attractive human resource management option for numerous firms around the world (e.g., Berg et al., 2014).

Germany is no exception to this trend. Flexible time arrangements within firms started to take off following the collective agreement on working time in the metal industry in 1984 enabling firms to negotiate internally about the structure of working hours (Promberger, 2002). This led to the spread of similar agreements in other industries in the 1990s and the emergence of trust based working time in the mid-90s (Berg et al. 2014). In 2010, 36 percent of employees were entitled to some form of flexible working hours plan in Germany (German Statistical Office, 2012) while the share of employees with flexible work schedules in the US was 27.5 percent in 2004 (Bureau of Labor Statistics, 2005)[1].

Today, a firm in Germany wishing to set up flexible working time arrangements has to decide how much freedom over the work schedule to give to its employees and must consult the Works Council before its implementation (see also Section 2.2). It might on one extreme give up only a limited amount of control to employees by allowing employees to decide about their daily starting and finishing times. In return, employees would have to agree to work for a predefined number of hours each day. This form of flexible time arrangement is often called 'flexitime'. An alternative, on the other extreme, would be to shift completely away from the classic five-day, 9 to 5, 40-hour week. Employees would now be free to adjust their time schedule as they wish. Between these extremes, a range of working hours arrangements between employers and employees exists. The most prevalent is the working time account, which is a credit/debit time accounting system, in which overtime (undertime) is carried over as a credit (debit) balance. The time account must be balanced after a predetermined period of time.

[1] Unfortunately there is no more recent information on the share of population with flexible working hours agreements in the US. It should also be noted that firms and countries may rely on very different forms of working time flexibility (e.g., overtime work, working-time accounts, part-time work etc.)

Flexible and self-managed work has grown in importance over the last decade and is known as 'trust based working hours' (TBW).[2] Its distinguishing feature is that employers do not control the working time of their employees but rather control their output. It has become widespread in Germany. A German think tank (*Institut der Deutschen Wirtschaft*, 2010) found in a representative survey that roughly half of all firms surveyed used some variant of the so-called '*Vertrauensarbeitszeit*'. They also find that the number of firms that implement TBW nearly doubled since 2003. The data we use for our empirical analysis (described in Section 3) also show a steady increase in the use of TBW between 2004 and 2012 (Figure 1).[3]

Moreover, Germany has a large number of internationally competitive exporting firms which rely heavily on product design and the novelty and quality of their products. As such, innovation provides a strong impetus to the German economy – as in many other economies where firms compete internationally. The purpose of our paper is to examine whether there is an 'innovation premium' associated with trust based work contracts. This question is motivated by economic theory (reviewed in the next section) which argues that such a work arrangement may be most efficient if production takes place in an uncertain environment – and innovation activity is characterized by such uncertainty. Moreover, the management and psychology literatures contend that TBW stimulates employee creativity. Accordingly, TBW is predicted to impact positively on creative activities such as innovation.

We put this prediction to a systematic empirical test, exploring whether the introduction of TBW is related to the subsequent innovation performance of firms. We employ a panel data set of German establishments to investigate whether there is an innovation premium to firms which adopt TBW. Our baseline analysis exploits information on a cohort of firms that adopted TBW in 2008 and compares their subsequent innovation performance to that of a control group of firms which are similar in terms of characteristics in the 'pre-adoption' period but which did not adopt TBW.

[2] We use TBW rather than the term 'self-managed working hours' for two reasons: first, it is the translation suggested by the Institute for Employment Research (IAB) which provides our data and also carries out its own research on work arrangements. This makes it easier for readers curious about the IAB data and working time arrangements. Additionally, it better describes the concept of employees not having to report on the number of hours worked and being permitted to vary their daily working time (within some limitations) autonomously. The expression "self-managed working hours" might cause confusion with 'flexitime', by which workers decide when to arrive and quit work.

[3] Note that although the proportion of establishments implementing TBW appears high, the proportion of employees with trust-based working hours in those establishments may still be quite low, as TBW may only be provided to particular employee groups, especially to highly qualified employees and/or those in higher positions.

For this purpose, we implement a propensity score matching approach where we only consider firms that did not use TBW at the beginning of our sample period. In other words, our estimation strategy relies on firms adopting TBW. We estimate firms' propensities to adopt TBW within a given period. We then compare the innovation performance of firms that actually did adopt TBW to those firms that are similar in terms of the propensity score but that did not adopt TBW. We are the first to carry out such a large scale empirical analysis of the potential causal effect of TBW on the innovation performance of firms.

Our results show that there is indeed an innovation premium to the use of TBW. Firms which adopt TBW tend to be more likely to report innovative activity in terms of product or process innovation. These results hold even when we control for an alternative form of flexible time work arrangements within firms, namely working time accounts. Thus, the positive relationship between the adoption of TBW and innovation seems to be driven by the degree of control and self-management over working days that is transferred to employees, rather than by merely allowing time flexibility.

2 Background

2.1 Managing Uncertainty with Job Design

In the 'traditional' economics literature, the concept of employer-employees trust plays a special role when firms face rapidly changing environments. When the environment in which firms operate is highly uncertain, the problem of how best to assign tasks and decision-making authority is not trivial, an issue recognised early on by Knight (1921).

According to Dessein and Santos (2006), firms can deal with changing environments – e.g., uncertainty about product design or demand - in two ways: they can get employees to stick to a pre-arranged plan or, alternatively, firms can allow employees the autonomy to make changes in the plan as new knowledge (only observed to them) becomes available. In the latter case, employees are more autonomous, are responsible for several tasks and are best able to adapt to information flows that come with improvements in communication technology. This theoretical perspective is unlikely to map completely on to the practical issue of TBW vs 'traditional' organization of work. However, the idea that employees enjoy

high levels of autonomy about how to produce their output, captures a central feature of TBW.

Dessein and Santos (2006) demonstrate that the organization mode that grants more autonomy to workers is optimal under uncertainty. We posit that a firm's search for product novelty and technology improvements is an activity surrounded by uncertainty. Therefore, when uncertainty is present, as is the case for innovation activity, it may be more efficient for firms to choose TBW as this can provide workers with the flexibility and autonomy to tailor their actions to the local conditions and cope continuously with new information flows. Hence, we would expect that the adoption of TBW practices which increases the amount of worker autonomy, should be positively associated with a firm's innovation capability.

Complementing this 'traditional' economics view, we also appeal to other literatures to justify our research question. Research in psychology and management science (e.g., Scott and Bruce, 1994, Amabile and Mueller, 2008) argues forcefully that TBW is likely to foster worker creativity. This is because such work practices allow employees to coordinate their own leisure-working time allocation, thereby making work more satisfying and enjoyable. Moreover TBW may be more conducive to the development of new ideas. This happens when organizational obstacles that may impede creativity are dismantled. Examples of such organizational obstacles include excessive time pressure and onerous reporting requirements. Hence, there is a strong expectation that TBW, through fostering the creativity of workers, also enhance a firm's innovation activity.

Innovation can be broadly distinguished into process and product innovation. The introduction of TBW may be expected to impact differently on both innovation types. Utterback and Abernathy (1975), in their seminal article, describe how the two types of innovation differ from each other. Product innovation is closest to our understanding of a creative output. The output is a new or improved product enabling firms to charge a higher mark-up. The relative technological expertise required for product vs process innovation is high. In terms of job design, a group of individuals within the firm collaborates to make improvements to existing products or create new products. Whether or not an idea for such an improvement succeeds is highly uncertain. This may be somewhat different for process innovation. While process innovation is by its nature also uncertain, incremental changes in the production process with the aim of reducing production costs can be relatively costly

(Utterback and Abernathy, 1975). Hence, we may expect that the introduction of TBW has a higher relevance for and impact on product than process innovation because the former can be more easily coordinated and offers a higher scope for creativity.

Of course, firms considering TBW may be motivated by reasons unrelated to improving innovation. Apart from wanting to award more autonomy to workers and benefit from it, employers may simply wish to deregulate or extend plant-level work hours or avoid overtime pay. However, several studies in the German context question whether TBW is useful as a mere cost-cutting exercise (Herrmann, 1999; Promberger 2005). Opitz (2006) concludes that TBW cannot be considered as such for the following reasons. To be properly implemented, TBW often requires (i) hiring more, not fewer employees and (ii) better co-ordination among existing workers to make the arrangement work. TBW is therefore only a viable option for firms that have the organizational depth to implement it effectively. Similarly, Opitz argues that it can only be effective in the case of employees who identify with the company goals.

Our paper brings together two literatures. First, we position our analysis within the recent literature on human resource (HR) management practices and firm performance (e.g., Bloom and van Reenen, 2011a). A number of recent studies using quantitative methods reinforce the idea that flexitime and productivity are positively correlated (Beauregard and Henry, 2009; Stavrou, 2005; Shepard III et. al. 1996; Konrad and Mangel 2000). A similar relationship is supported by Bloom et al. (2011b) in the context of a study of the link between work-life balance and productivity for four countries. We focus on one particular aspect of HR management, and consider a very specific channel through which such HR practices may impact innovation activity through TBW.

Secondly, we extend the firm level literature on innovation (e.g. Aghion et al., 2005). This firm-level innovation literature generally considers mainly firm characteristics such as size or age, and factors external to the firm (such as the level of competition). Yet, aspects of worker autonomy are generally not considered. There is a related literature that looks at time flexibility at the workplace and innovation. For example, Arvanitis (2005) uses firm level data from Switzerland and finds that working time flexibility is positively correlated with innovation outcomes. Distinguishing product and process innovation, he finds no strong differences in the magnitude of this positive effect, however. Focusing on another aspect of time flexibility, Zhou et al. (2011) find some evidence that firms with higher shares of

temporary workers have higher sales of new products. They use data from the Netherlands. Distinguishing "imitative" and "innovative" products they find that this positive correlation only holds for the former, however. They do not consider process innovation.

None of the studies reviewed here deals directly with the focus of our study – the adoption of TBW. An exception is a recent study by Beckmann (2016). Using the German IAB Establishment Panel data set, he focuses on the link between TBW and firm productivity as well as wages. He finds that TBW is associated with a productivity premium of around 9 percent and a wage premium of similar size. We look at innovation activity, which is a highly uncertain task in a firm.

2.2 The Legal and Institutional Context in Germany

The introduction of TBW is legally compliant under German law, so long as the overtime hours are documented (Plessner, 2005). German law requires employers to document the number of overtime hours worked by employees (Section 3, paragraph 1 ArbZG). [4] When TBW is introduced, this provision is no longer binding. Instead, the task of recording hours falls on the employee though the employer is still held responsible for ensuring that valid records are kept (Section 22 paragraph 2 No9 ArbZG). The works council can have a say in whether the Human Resources division files the worker's timekeeping records or whether the works council undertakes this task itself.

It is important to add that, in Germany, TBW is not a unilateral management decision. Given strong worker representation in Germany, the implementation of this radical reorganization of work should be endorsed by the Works Council (Haipeter et al., 2002; Schmidt and Trinczek, 1999). This is why any study, such as ours, should control for the presence of a Works Council when looking at the implementation of TBW.

3 Data Description

In order to study the relationship between TBW and innovation we use data from the *IAB Establishment Panel*. This is a representative annual survey of approximately 16,000 plants located in Germany. The survey is undertaken by the Institute for Employment Research

[4] ArbZG is the acronym for *Arbeitszeitgesetz* or Hours of Work Law.

(IAB) at the Federal Employment Agency in Nuremberg. Since 1996, the panel offers a nationwide survey capturing all industries and establishment sizes[5]. The dataset covers 1% of all plants and 7% of all employment in Germany. The survey includes not only general information on establishments such as location, industry of activity, employment development, sales, composition of the workforce, performance, but also on the organization of work arrangements used in our empirical analysis.

More precisely, since 2004 the survey asks respondents (firm managers) every alternate year whether the establishment implements TBW for at least some of their employees. We combine this information with data on whether or not the establishment is engaged in product or process innovation. The innovation data are available for 2007 – 2011. Hence, we have a biennial snapshot of the implementation of TBW and returns to TBW in terms of two innovation outcomes.

Our research methodology allows us to observe the innovation performance of firms which initially do not use TBW and then adopt this work practice (Adopters) and compare their innovation performance with firms which do not implement such contracts (non-Adopters). We disregard establishments that continuously use TBW as these may be very different from firms that initially do not use TBW. The focus on such 'Adopters' vs. 'Non-adopters' thus allows us to eliminate one aspect of heterogeneity, namely differences between firms that continuously use TBW and those that do not. This may aid identification of a causal effect of TBW adoption on innovation.

We define different cohorts of firms for the analysis. Our main focus is on a '2008 cohort' which includes firms that adopted TBW in 2008, compared with a control group of firms that did not offer TBW in 2008. We focus on this group as it provides us with the longest available time horizon before and after TBW adoption, allowing us to look at innovation outcomes one and three years after TBW adoption. We also examine a 2010 cohort and a 2006 cohort in subsequent extensions to the econometric analysis.

[5] This random sample of establishment is based on the establishment file from the Federal Employment Agency which includes information about two million employers being surveyed repeatedly every year. A non-negligible additional source of information at the disposal of the Federal Employment Agency is an employee history of about two million employees of these firms.

We generate a dummy variable indicating the adoption of TBW, as follows: if a firm does not use any trust-based contracts in t-2 (i.e., 2006 for our 2008-cohort) but does so in t (2008), the 'adoption dummy' is set to 1. If the firm does not use TBW in either year, this variable is set to 0. Firms that use TBW only in t-2 or in both t-2 and t are dropped from the analysis.

Turning to our measurement of innovation, the dataset allows us to consider two different aspects. The first innovation measure captures whether an establishment improved or further developed one of their products/services. The second innovation measure captures whether the firm improved its production technology or introduced a production technology which was new to the firm. In our empirical analysis, both innovation variables are measured in t+1.

Other variables that we incorporate in our analysis and listed in Appendix Table A1 include logged employment as a measure of the size of an establishment, skill intensity measured as the share of skilled workers over unskilled workers, a dummy whether an establishment implements flexible working time (flexitime accounts), whether the firm conducts R&D, has a Works Council, or is bound by collective agreements. Furthermore, we include a variable that captures a firm's self-assessment of the technology used compared to others in its industry. These controls are important in order to identify precisely an effect of TBW on innovation.

Table 1 provides some summary statistics for some main firm characteristics. We compare three types of establishments: (i) those never using TBW, (ii) those adopting TBW in 2008 and (iii) those already using TBW in 2006. Note that the latter group is not part of our econometric analysis, where we only focus on Adopters and Non-adopters. Firms that use TBW (whether Adopters or TBW users in 2006) are, on average, more likely to implement product or process innovations. Also, they are larger, more skill intensive, more likely to be operating to a higher technological standard and to conduct R&D. They also tend to use flexitime accounts more frequently. Furthermore, employees in these firms are more likely to be represented by Works Councils and to be covered by collective wage agreements.

Table A2 in the appendix depicts some key bivariate correlations between variables in the data. Here we only use data for the first two groups of firms, i.e., those that are also used in the regressions below. The correlations suggest that TBW is more prevalent in large, R&D active, West German firms with works councils. Firms in the manufacturing sector appear less associated with this management practice.

As pointed out in Section 2, there could be a concern that the adoption of TBW by firms is a backhanded way to increase employee workload, thereby raising stress levels and reducing worker welfare (Opitz, 2006). Although the focus of our analysis is not on worker welfare, we nevertheless can observe some aspects of welfare in the IAB data: a) the number of hours worked, b) whether employees work overtime and c) how workers are compensated for overtime work. While we do not see much difference in the stated numbers of hours worked, or compensation for overtime work in non-TBW and TBW firms, looking at overtime is informative. Most importantly, overtime use is already higher before the implementation of TBW arrangements in 2008 and it increases similarly for Non-Adopters and TBW Adopters when looking at the post-adoption period. We see that 67 percent of firms that switch to TBW arrangement in 2006, already reported having used overtime work by their employees in 2004, when TBW arrangements were not yet in place. This number is 60 percent for non-TBW firms remaining without TBW in 2006 (non-Adopters). Thus TBW-Adopters had a higher incidence of overtime to start with. If we look at the incidence of overtime use in the adoption year, we see that it is higher for both non-TBW and for TBW firms. TBW is used by 66 percent of non-TBW firms and 73 percent of TBW firms. Hence we find that overtime usage is higher before the implementation of TBW arrangements but that it increases similarly for firms in the Non-Adopter and Adopter groups. Thus, based on this evidence it does not appear that, on average, TBW is used as a mechanism to exploit workers.[6]

4 Empirical Analysis

Baseline results

In order to investigate whether the use of trust-based contracts has an impact on innovation we start off using our 2008 cohort. We regress innovation activity in 2009 on the 'adoption dummy' in 2008, as well as other covariates in 2008, as shown in equation (1):

$$innov_{it+1} = \beta_1 \, Adopt\_TBW_{it} + \beta_2 \, X_{it} + d_r + d_j + \varepsilon_{it+1} \qquad (1)$$

[6] A parallel medical/sociological literature investigates the impact of work practices that blur the lines between professional and private life. Medical outcomes investigated include burn-out, depression and cardio-vascular diseases (e.g., Caruso et al. 2004; Cottini and Lucifora, 2013 and Takahashi et al., 2011). A consensus in these studies is that stress related disorders are less likely to arise when workers have control over working times.

Here, *innov* is alternatively defined as a dummy equal to one if the firm has improved products, or if it introduced new production processes, respectively. X is a vector of firm characteristics including firm size, skill intensity, and a dummy equal to one if a firm also uses flexitime. This latter variable allows us to be more confident that our TBW switching variable does not merely reflect the use of time flexibility. Furthermore, we include dummies to denote whether or not a firm has a Works Council and whether the firm has a collective agreement on wages. Additionally, we include lagged R&D as an additional covariate to help rule out the possibility that TBW adoption is merely correlated with a contemporaneous development in the firm's research capability.[7] Finally, d_r and d_j are dummies for West Germany (r) and a full set of industry dummies (j), respectively. Controlling for covariates in t and measuring innovation in t+1 helps to alleviate concerns about reverse causality in the innovation – TBW relationship.

Table 2 presents the results from equation (1) for both types of innovation performance using a Logit estimation for our 2008 cohort. These clearly show a positive association between TBW adoption and the two types of innovation, product and process innovation. Columns (1) and (4) report simple regressions of the two alternative innovation variables on the adoption dummy, without controlling for any additional firm level covariates. Columns (2) and (5) add the control variables as in equation (1). The coefficient size for TBW adoption is somewhat reduced following the inclusion of the controls, but it remains highly statistically significant.

What is the economic meaning of the estimated marginal effects? From the descriptive information in Table 1 we can see that the baseline probability of conducting product innovation - without TBW - is roughly 35 percent in 2008. The coefficient in column 3 of Table 2 (0.12) implies that the conditional probability of product innovation is, on average, about 12 percent higher in firms switching into TBW than in firms without[8]. This shows that this effect is not only statistically significant, but also economically relevant. The marginal effects for process innovation are similar in terms of sign and significance, but only around half of the magnitude.

[7] We should note that in the IAB data, the R&D and TBW adoption covariates are captured in alternate years.
[8] Implying that firms adopting TBW, ceteris paribus, would be 47 percent (35 + 12) likely to introduce a product innovation. The TBW Adopter group in Table 1, by way of comparison, is associated with a 54 percent innovation rate. The regression, by including additional information – skills, sector, size etc. – allows us to calculate the TBW innovation premium, all things equal.

One concern with the analysis thus far is that we pool data for manufacturing and services. On the one hand, working time flexibility has long been established in manufacturing industries (see the Introduction) and is, accordingly, an important issue for this sector. On the other hand, one may argue that the adoption of TBW may be particularly important for services activities such as research, design or software development, due to the nature of the tasks performed. Such activities may generally be more important in services firms. In fact, unconditional correlations in Table A2 in the appendix indicated that manufacturers are less likely to adopt TBW than services firms. Our identification strategy in the econometric analysis relies on focusing on these Adopters rather than on those firms that have for a long time used TBW.

The *IAB* data contains proportionately more firms active in the service sector than in manufacturing; only about 1 in every 4 firms in our sample is engaged in manufacturing. We, therefore, report in columns 3 and 6 in Table 2 results of estimations using data for the subsample of manufacturing establishments only. The impact on innovation (product and process) is generally positive but only marginally significant for process innovation in the manufacturing subsample. The reduced impact for manufacturing firms may be due to a number of reasons. Firstly, there may be reduced scope for worker autonomy in manufacturing. Granting such autonomy to workers in a production line would not be expected to increase innovation. Rather, it is autonomy for services activities, as pointed out in the previous paragraph that would be expected to generate most of these benefits. And these activities are likely to be more important for services firms – think of software development as an example.

A second possible explanation is that manufacturing firms are not able to reap the benefits from TBW as their innovation process may be too inefficient. To explore this idea, we use information from the 2007 wave of the IAB survey, which roughly translates as 'Have you in the past two years planned product or process innovations that were never carried out?' Answering 'yes' to this question suggests underlying inefficiencies in the firm's innovation/R&D processes because innovation that was planned by the firm was not carried out. We checked whether TBW Adopters had experienced historic R&D inefficiencies, and whether this problem may be more prevalent in manufacturing. We found that within the manufacturing firm sub-sample, 11.4 percent of firms reported such R&D inefficiencies. However, if we look within the Adopter group, this percentage rises to 24.7 and 17.3 for 2006

and 2008 TBW Adopters respectively. The R&D inefficiency problem is not confined to manufacturing, though the percentages are more striking in the case of manufacturing. In the overall sample, only 10.2 percent of 2006 Adopters and 12.0 percent of 2008 Adopters, report these R&D inefficiencies. On this basis, we may speculate that firms (predominantly in manufacturing) adopt TBW to reduce R&D inefficiencies. Our finding for the manufacturing sector may indicate that this only works with limited success. In what follows we use data for the full sample of establishments.

Propensity score matching

Our identifying assumption thus far is that, conditional on the covariates in the model, switching into TBW is uncorrelated with ε_{it}. This assumption would be undermined if there were reverse causality or unobserved third factors that are driving the correlation between innovation and TBW-switch. In a first attempt to control for this, we define covariates in t and the dependent variable in t+1 in equation (1).

Another potential bias may stem from unobserved third factors that are driving the observed correlation. For example, it might be that firms with better technology are both more likely to adopt flexible work practices as well as to introduce innovation.[9] In order to deal with this bias, we control for observable aspects of firm heterogeneity (size, R&D and technological capability, skill intensity, time flexibility, presence of collective wage agreements, technology used and presence of Works Council) on the right hand side of equation (1). Furthermore, we introduce industry dummies, which control for the technology intensity, or other relevant unobservable characteristics of industries.

In order to deal further with these two issues we also implement a Propensity Score Matching (PSM) model. In a nutshell, the purpose of matching is to pair each firm which adopts TBW with comparable firms that do not, on the basis of some observable variables. In this way, the control group of Non-adopters can be studied to generate the counterfactual for the TBW-Adopters. Under the matching assumptions, the only difference between the treated (Adopters) and control (Non-Adopters) group is the use of TBW and, hence, one can evaluate the effect of TBW adoption on innovation by estimating the difference in the innovation performance between the treated group and the matched control group. One crucial

[9] For example, Bresnahan et al. (2002) show that new management practices and IT usage are correlated.

assumption needed is that of conditional independence, i.e., controlling for observables, the selection into the TBW-Adopter group is random. PSM has been quite popular in the recent applied econometrics literature, we therefore refrain from going into detail about the methodology here (Imbens, 2004, provides an excellent survey).

In order to implement PSM, we first estimate the probability (or *propensity score*) of firm *i* implementing TBW using a probit model

$$P(Adopt\_TBW_{it} = 1) = F(Z_{it-1}) \qquad (2)$$

where *Z* is a vector of covariates observed in the time period before TBW adoption. The sample is restricted to firms that did not do any product or process innovation in t-1, and *Z* includes dummies for whether or not a firm conducted product or process innovation in *t*-2. This ensures that our treatment and control groups are comprised of firms that are similar in terms of past innovation activity. Thus, we can then see whether switching into TBW has any additional impact on their innovation activity after switching. In order to also take other characteristics into account, the vector Z furthermore includes the same variables as in the estimation of equation (1).

Let p_i denote the predicted probability of switching into TBW for firm *i* in the group of TBW users (say group A) and let p_j denote the predicted probability of TBW for firm *j* in the control group (say group C). Following Heckman et al (1997), the matching estimator is defined as:

$$\delta = \sum_{i \in A} \left(y_i - \sum_{j \in C} g(p_i, p_j) y_j \right). \qquad (3)$$

where y is innovation activity in the treated (*i*) and control group firms (*j*) in t. g(.) is a function assigning the weights to be placed on the comparison firm *j* while constructing the counterfactual for acquired firm *i*.

The crucial identifying assumption, as alluded to above, is that of selection on observables. While it is difficult to control exhaustively and convincingly for all possible unobservables, we would make a strong case for our approach. Firstly, we only focus on those firms that adopt – or alternatively do not adopt - TBW. In other words, all establishments in our

regression sample are non-users of TBW at the start of the period. Then some of them adopt TBW, others do not. Hence, we control for unobservables related to establishments that have already had TBW at the start of the period of analysis. TBW adoption may not be random, however, and we control for this with the observables in our model. Here, crucially, we only consider establishments that did not have any product or process innovation respectively in t-1, and control for innovation performance in t-2. This feature allows us to control for unobservables that may drive the firm's historic innovation performance and that may be correlated with TBW adoption. We may therefore be reasonably confident that we can control for unobservables related to the heterogeneity between firms with and without TBW, and related to past innovation performance. If there are unobservables that are uncorrelated with these two issues but drive current innovation - and are correlated with switching into TBW - then our results may still be unable to reflect causal effects. This should be kept in mind when interpreting our results.

Balancing VAZ Adopting firms with VAZ non-Adopters

The first part of Table 3 reports the results from the estimation of the propensity score model. The estimation is carried out separately for establishments without product innovation and process innovation, respectively. The results show that firms are more likely to adopt trust-based work rules if they reported a product or process innovation two years ago. Hence, it is necessary to control for the lagged innovation capability of firms in our sample. Skill intensity is positively correlated with the likelihood that the firm adopts TBW. This is in line with the idea that high skilled workers are more likely to have TBW contracts. Also, establishments in West Germany are more likely to implement TBW as are establishments with Works Council representation – for product, not process innovation.

We generate the propensity scores as predicted values from the Probit regression. We need to balance the propensity scores for the Adopter and non-Adopter firms. An iterative procedure then assigns the Adopters and non-Adopters to blocks of establishments. Within these blocks, the group averages for size and other attributes of the establishments are checked for statistical equivalence across the two groups. The accompanying STATA *pscore* procedure indicates that the propensity scores can be balanced across the group of Adopter and non-Adopter firms.[10] We also impose the Common Support condition, meaning that the

[10] The authors can supply the complete output for the propensity scoring and balancing tests on request.

overlapping region of the propensity score where treatment and control group firms can be considered equal in terms of observed covariates.

Premium to VAZ Adoption - PSM

Following on from this, the second part of Table 3 reports the results of the PSM approach, i.e., the average treatment effect on the treated as the difference in the probability that a firm innovates between treated and untreated firms. We report the results using product innovation as outcome variable in the first column, using only establishments that did not report any product innovation in t-1. The second column reports results for process innovation using only firms that did not report any process innovation in t-1. The results on both innovation activities are similar in terms of sign, significance and magnitude to those seen in the Logit estimations.

Adopting TBW has a statistically significant and positive impact on innovation activity in the firm. The point estimates for establishments adopting trust-based working hours in 2008 were 15 percent and 7 percent for product and process innovation, respectively. In other words, a TBW Adopter is 15 percent more likely to introduce an innovation than a firm that does not. Hence, TBW adoption is associated with an innovation premium for product and process innovations 1 year following adoption.

It remains to be seen whether this innovation premium is persistent over time. In order to do this, we look at innovation performance in 2011 – i.e., three years after the introduction of TBW - for the same samples of firms. Results for both innovation outcomes are presented in column (3) and (4). These show that even after 3 years, the innovation premium is still positive for both product innovation and process innovation, though it is clearly reduced in magnitude. It is statistically significant only at the 10 percent level for product innovation while highly statistically significant at the 1 percent level for process innovation. This suggests that adopting TBW seems to have an enduring effect on innovation.

Thus far we have looked at establishments that switched into TBW in 2008 and their comparison group. However, we can also examine a different cohort of firms, namely those that switched into TBW in 2010 compared to their counterparts that did not have TBW in 2010. The outcome variable is innovation performance in 2011. Results again show positive

average treatment effects for both product and process innovation, though the magnitude of the estimated effects is somewhat reduced compared to Table 3, in particular for process innovation. Nevertheless, these results still suggest that switching into TBW is associated with a positive innovation premium in the year following the switch. Results are not reported here to save space but are available upon request.

Extension: Intensity of TBW use

Up to now, we only examined firms that adopted TBW without considering that firms might be heterogeneous with respect to the *share of employees* that are eligible for this new working hours scheme. This heterogeneity may be important, however. If, say, only firms with high skilled worker shares extended TBW to all employees, then our results so far might be biased. Thus it is of interest to examine whether firms that introduce TBW for a restricted subset of employees, also exhibit an innovation premium.

Unfortunately, the dataset used for TBW-adopters in 2008 and 2010 does not provide information on the share of employees eligible. However, such information is available for 2006.[11] This comes at the cost of having no information on process innovation in the earlier data, which is one reason why we do not use this data for the main part of the analysis.

With this drawback in mind, we start by replicating our Logit estimation (equation 1) using data for the 2006 cohort, i.e., establishments that adopted TBW in 2006 and a control group of firms not having TBW in the same year. We extend the specification by entering the share of employees eligible for TBW on the right hand side of our estimation. Our results for product innovation are presented in Table 4. In column (1) we have the baseline specification for the 2006 cohort. The coefficient is positive, highly significant and only slightly lower than for the 2008 cohort in Table 2. In column (2) we introduce the share of eligible employees. The coefficient is highly significant and negative but smaller than the positive coefficient on the TBW adopters. Thus the adoption of TBW is positively related to product innovation, but the higher the share of employees eligible for TBW, the lower this positive effect.

[11] Care must be taken when interpreting the 'adoption of TBW for all workers' variable in the data. IAB issued some guidelines on interpretation of the former question because of concerns that firms reporting TBW arrangements for "the whole company" might overstate the share of employees eligible to use these working practices. (See http://doku.iab.de/fdz/iabb/hinweise_n62b.pdf for more details)

Now we turn again to PSM. Note that we cannot exactly reproduce our first stage Probit estimation for our 2006 cohort because we lack information on lagged product innovation variables. In order to implement the matching, we distinguish three types of 'treatment'. Firstly, we consider all firms that switch into TBW in 2006 – which is similar to the treatment as defined in Table 4. Second, we only consider those firms as treated that adopted TBW in 2006 but that only extend eligibility of TBW to a share of workers. The third treatment is the adoption of TBW in 2006 only if TBW is extended to all employees in the establishment. The control group is in all cases made up of firms that do not have TBW in 2006.

The first part of Table 5 reports the results from the estimation of the selection Probit for our three treatments. Column (1) shows results for all Adopters, column 2 for Adopters with only some eligible employees and column (3) for establishments adopting TBW for all employees. An interesting difference emerges between the results in columns 2 and 3: in the latter, establishment size is negatively related to adopting TBW. This indicates that small firms are more likely to implement TBW for all workers, while larger firms seem more likely to implement it only for a share of workers (column 2). This may suggest that the costs of implementing TBW are increasing with the number of people involved, as it may become more difficult to co-ordinate large groups of people that need to work together to achieve the firm's objectives. Another explanation may be that in smaller firms working time arrangements are less regulated and that it may therefore be easier to implement TBW.

We calculate the matching estimate for the three different treatments relative to the untreated group. Results in column 1 for all Adopters depict a premium of 9.1 percent. This is in line with our previous estimations for product innovation. However, when we turn to those firms that introduced TBW for less than 100 percent of the workforce, we see that the product innovation premium stands much higher, at around 20 percent. By contrast, we do not find any innovation premium for establishments that introduced TBW for the whole workforce.

This suggests that, from the point of view of innovation, the optimal level of TBW coverage in the workforce is less than 100 percent. This is intuitively quite plausible. It may not be optimal to extend TBW to every single worker, but may only make sense for those employees for which one may expect benefits in terms of higher innovation. Workers in a production line may not generate such benefits, while employees engaged in product design may benefit hugely if they are given the additional flexibility through TBW.

5 Conclusions

This paper looks at a possible link between the use of trust based working hours (TBW) by firms and innovation activity. We explore this question using firm level data for Germany. The empirical analysis is motivated not only by recent economic theory arguing that such work arrangement may be beneficial if production occurs in an uncertain environment (such as innovation), but also by the management and psychology literatures which argue that TBW stimulates employee creativity and, thus, impacts positively on creative activities such as innovation.

Results comparing ex ante similar firms that adopt TBW and those that do not, show that firms adopting TBW tend to be between 12 to 15 percent more likely to improve their products in the year after adoption. They are also more likely to engage in process innovation. The magnitude of this effect is around 3 to 7 percent. These results hold when we control for another form of flexible time work arrangements within firms, namely working time accounts. Thus, the positive relationship between the adoption of TBW and innovation seems to be driven by the degree of control and self-management over working time that is transferred to employees, rather than by merely allowing workers increased flexibility.

Our research highlights an important aspect of innovative activity that has been generally overlooked in the literature on the economics of innovation. Working arrangements in firms that give the potential to employees to develop their own creativity may have significant impacts on innovative activity as well as other aspects of firm performance (see also Beckmann, 2016). Of course, more work is needed to better substantiate this conclusion.

We focused on Germany in this paper as it is a country where TBW is used extensively and where the legal and institutional framework is well established. How generalizable are our findings to other countries? In our view, there is no reason to think that our result cannot be generalized to firms in other countries. Giving employees the ability to manage their work time, in a way that seems most efficient to them and that more optimally frees up their potential, should be beneficial to a firm – with the proviso that this potential may not be there for all but only for certain types of workers. This conclusion is backed by Bloom et al. (2015)

who show, using data from a field experiment in China that the introduction of home office work to employees substantially increased productivity of those workers.

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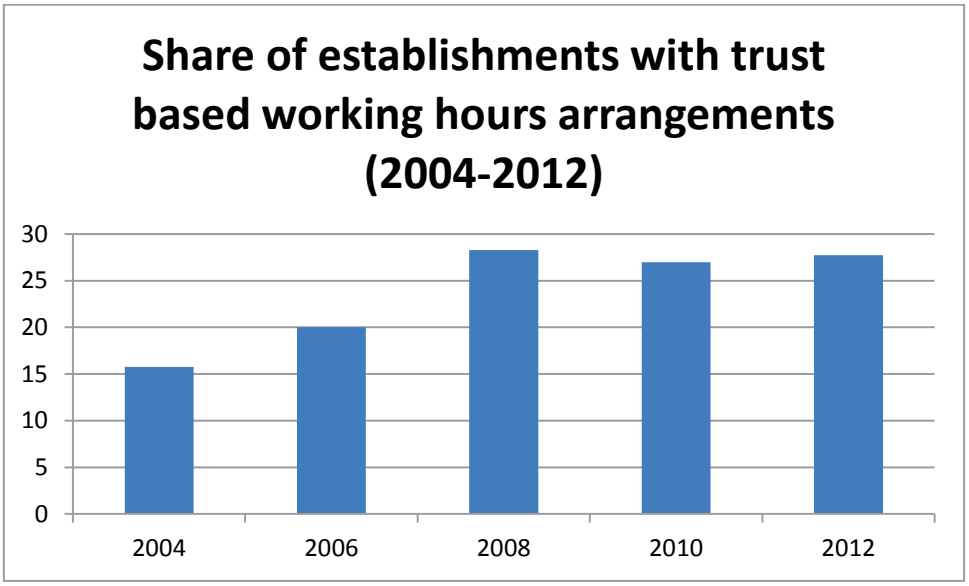
Figure 1: Share of establishments with TBW arrangements



Source: IAB Betriebspanel, own calculation excluding the primary sector.

Table 1: Summary Statistics for key variables: All establishments with and without TBW in 2008.

		Product innovation	Process innovation	Flexitime accounts	Log Empl.	West Germany	Technol. used	Skill Intensity	Binding collective agreement	Works council	R&D
Never TBW	Mean	0.346	0.124	0.412	3.026	0.485	0.659	0.829	0.459	0.228	0.121
	Std.	0.476	0.330	0.492	1.479	0.500	0.474	0.264	0.498	0.420	0.327
	N	2740	2743	2799	2800	2800	2799	2706	2800	2798	2749
TBW in 2008	Mean	0.536	0.242	0.485	3.640	0.622	0.720	0.833	0.475	0.382	0.213
	Std.	0.499	0.429	0.500	1.904	0.485	0.449	0.260	0.500	0.486	0.410
	N	481	480	495	495	495	493	478	495	495	483
TBW in 2006 (All)	Mean	0.564	0.295	0.574	3.843	0.689	0.735	0.845	0.534	0.429	0.272
	Std.	0.496	0.456	0.494	1.835	0.463	0.442	0.239	0.499	0.495	0.445
	N	1137	1137	1137	1137	1137	1135	975	1137	1	1135

Note: "Never TBW" includes all establishments that never implemented TBW from 2004 to 2010. "TBW in 2008" includes firms that started implementing TBW in 2008. "TBW in 2006 (All)" includes all establishments with TBW in 2006 even if they adopted TBW at a point earlier in time. All variables are measured in 2008 when available. Product innovation, process innovation are measured in 2009 while R&D is measured in 2007.

Table 2: Logit estimation for 2008 adopters

	y: product innovation in 2009			y: process innovation in 2009		
Variable	(1)	(2)	(3) Manuf. only	(4)	(5)	(6) Manuf. only
TBW adopter	0.133***	0.119***	0.073	0.077***	0.063***	0.131*
	(0.037)	(0.036)	(0.083)	(0.027)	(0.024)	(0.078)
Flexitime accounts in use		0.007	0.013		0.021*	0.021
		(0.018)	(0.040)		(0.011)	(0.028)
Log employment		0.016**	0.022		0.016***	0.021*
		(0.007)	(0.018)		(0.004)	(0.011)
West-Germany		0.062***	0.081**		-0.003	-0.021
		(0.016)	(0.041)		(0.009)	(0.025)
Technology in use		0.029*	-0.068*		-0.005	-0.011
		(0.016)	(0.039)		(0.010)	(0.025)
Skill intensity		0.017	0.140*		0.001	-0.024
		(0.028)	(0.075)		(0.016)	(0.046)
Binding collective agreement		-0.002	0.002		-0.014	-0.005
		(0.017)	(0.042)		(0.010)	(0.137)
Works council		0.018	0.073		0.017	0.060
		(0.026)	(0.069)		(0.016)	(0.047)
R&D department		0.057	0.156*		0.028	0.040
		(0.047)	(0.091)		(0.026)	(0.049)
2-digit industry dummies	yes	yes	yes	yes	yes	yes
Nb of obs.	2472	2472	495	2449	2449	475
Adj. R squared	3.53	5.0	7.04	4.06	8.31	14.74

Note: Marginal effects are reported. Robust Standard errors in parentheses. Significance levels are indicated by * (10%), ** (5%), ***(1%).

Table 3: TBW adoption in 2008 and innovation (Propensity Score Matching)

First Stage: Propensity Score Probit

	2008 TBW adoption			
	Without Product Innovation in 2007		Without Process Innovation in 2007	
	(1)	(2)	(3)	(4)
	Coeff.	Robust Std. Err	Coeff.	Rob. Std. Err.
Product innovation$_{t-2}$	0.069	(0.216)	0.370**	(0.151)
Process innovation $_{t-2}$	0.667***	(0.260)	0.217	(0.195)
Log employment	-0.068	(0.081)	0.089	(0.060)
West Germany	0.555***	(0.177)	0.399***	(0.143)
Skill intensity	0.284	(0.329)	0.521*	(0.278)
Flexitime accounts in use	0.205	(0.190)	0.169	(0.147)
Works council	0.509**	(0.259)	-0.222	(0.194)
Binding industry agreement	-0.620	(0.201)	-0.489***	(0.157)
Technology standard	-0.209	(0.178)	-0.107	(0.150)
R&D department	0.226	(0.419)	0.277	(0.252)
2-digit industry dummies	yes		Yes	
Observations	2451		3363	
LR chi2(39/41)	97.48		143.20	
Prob > chi2	0.000		0.000	
Pseudo R2	7.79		7.54	
Balancing condition passed	yes		yes	
Number of final blocks	7		5	
Common support condition	yes		yes	

Second Stage: Kernel Density - Propensity Score Matching

	1 year experience with TBW		3 years' experience with TBW	
	2009 product innovation	2009 process innovation	2011 product innovation	2011 process innovation
Adopter Premium	14.0%	6.5%	5.6%	4.5%
t-value for Difference	4.60	2.52	1.84	2.2
Number of Adopters (Treatment)	173	274	173	274
Number of non-Adopters (Control)	2206	3037	2206	3037
Total number of observations	2379	3311	2379	3311
Number of repetitions	50	50	50	50

Note: PSM uses *Stata* 'attk' procedure and uses first-stage estimates from Selection Probit. Our 2 Cohorts introduced TBW in 2008 and the 2 outcome variables are measured for 2009 (1 year experience) and 2011 (3 years´experience) respectively. Covariates are lagged by one year beside the technology used and the lagged innovation variables which are lagged twice. The latter is not collected yearly. Significance levels are indicated by * (10%), ** (5%), ***(1%).

Table 4: Logit estimation for 2006

	y: product innovation	
Variable	(1) All	(2) All
TBW adopted	0.097***	0.154***
	(0.031)	(0.062)
Share of employees entitled to TBW		-0.129**
		(0.061)
Flexitime accounts in use		0.047***
		(0.018)
Log employment		0.049***
		(0.007)
West-Germany		0.067***
		(0.016)
Skill intensity		0.030
		(0.027)
Works council		0.040
		(0.024)
Technology in use		0.036**
		(0.015)
Binding collective agreement		-0.034**
		(0.017)
Research and Development		0.142**
		(0.046)
2-digit industries	yes	yes
N	3390	3390
Adj. R squared	8.96	9.36

Marginal effects are reported. Significance levels are indicated by * (10%), ** (5%), ***(1%).

Table 5: TBW adoption in 2006 and innovation (Propensity Score Matching)

First Stage: Propensity Score Probit

	(1) All Adopters		(2) Some workers eligible Only		(3) All workers eligible Only	
	Coeff.	R. Std. Err.	Coeff	R. Std. Err.	Coeff	R Std. Err.
Log employment	0.074	(0.062)	0.451***	(0.094)	-0.256***	(0.093)
Skill Intensity	0.333	(0.253)	0.562	(0.456)	0.230	(0.300)
Flexitime accounts in use	0.261	(0.160)	0.784***	(0.262)	-0.101	(0.235)
Works council	-0.159	(0.210)	-0.497*	(0.302)	-0.026	(0.320)
Binding collective agreement	-0.107	(0.158)	-0.032	(0.257)	-0.517*	(0.269)
Technology standard	-0.238	(0.148)	-0.266	(0.241)	-0.207	(0.186)
R&D department	0.422	(0.310)	0.345	(0.402)	0.278	(0.488)
2-digit industry dummies	yes		yes		yes	
Observations	3028		2719		2435	
LR chi2(38/34/29)	102.50		139.30		64.54	
Prob > chi2	0.000		0.000		0.000	
Pseudo R2	6.13		17.05		5.90	
Balancing condition passed	yes		yes		Yes	
Number of final blocks	4		6		5	
Common support condition	Yes		yes		yes	

Second Stage: Kernel Density - Propensity Score Matching

	TBW adopted in 2006		
	(1)	(2)	(3)
	Cohort 1 + Cohort 2: All Adopters	Cohort 1: Some workers eligible Only	Cohort 2: All workers eligible Only
Adopter Premium	9.1%	20.0%	0%
t-value for Difference	3.13	3.26	0.14
Number of Adopters (Treatment)	239	94	144
Number of non-Adopters (Control)	2655	2392	2219
Total number of observations	2894	2486	2363
Number of repetitions	50	50	50

Note: PSM uses *Stata* 'attk' procedure and uses first-stage estimates from Selection Probit. Our 3 Cohorts introduced TBW in 2006 with different share of workers eligible for TBW arrangements. Covariates are lagged by one year.

Appendix:

Table A1: List of variables

Variable	Description
Process innovation	Did you develop or implement procedures in the last business year which have noticeably improved production processes or services? Yes/No
Product innovation	Has your enterprise improved or further developed a product or service, which has been part of ist line beforehand, in the last business year? Yes/No
Trust based working hours arrangements	Please state for each following mechanism whether or not it is applied in your establishment/office. - Trust-based working hours/self-managed working hours (without operational timekeeping): Yes or No?
Log employment	Total number of employees on 30 June.
Skilled workers	Personnel structure of your establishment: No of Employees for qualified jobs – requiring a vocational qualification or comparable training on the job or relevant professional experience. – requiring a university degree or higher education
Unskilled workers	Personnel structure of your establishment : Employees for menial jobs, requiring no specific vocational educational.
Skill intensity	Skilled workers/ Unskilled workers
Flexitime	Does your establishment/office offer working time accounts such as flexitime or annual working time agreements? Working time accounts are…in operation
Works Council	Does your establishment have…a works or staff council in accordance with the Works Council Constitution Act or the Staff Representation Act? Yes/No
Research and development	Do you have a research and development department? (Yes/No)
Binding collective agreement	Is this establishment bound by a collective agreement (industry wide wage agreement)
Technology standard	How do you assess to overall technical state of the plant and machinery, furniture and office equipment of this establishment compared to other establishments in the same industry? Please give your assessment using the scale below. Scale: 1 – 5 where “1” indicates that the establishment has state-of-the-art equipment and “5” indicates that the equipment is obsolete.
West Germany	Main address is in West Germany
Industries	According to the establishment identification number registered with the Federal Employment Agency this establishment was assigned to the following industry (17 sectors- 43 industries)

Table A2: Correlations for key variables:

	TBW	Product inno	Process inno	flexitime	ln employment	West Germany	tech in use	skill intensity	binding agreement	Works Council	R&D
TBW	1										
product inno.	0.118***	1									
process inno.	0.101***	0.386***	1								
flexitime	0.044**	0.185***	0.275***	1							
ln employment	0.124***	0.308***	0.287***	0.458***	1						
West Germany	0.078***	0.108***	0.043**	0.028*	0.103***	1					
tech in use	0.037**	0.086***	0.065***	0.055***	0.120***	0.029*	1				
skill intensity	0.012	-0.007	-0.034**	0.043***	-0.096***	-0.236***	0.066***	1			
binding agreement	0.013	0.081***	0.060***	0.233***	0.350***	0.182***	0.046***	0.001	1		
Works council	0.0114***	0.223***	0.214***	0.375***	0.632**	0.095***	0.042***	-0.010	0.403***	1	
R&D department	0.067***	0.314***	0.304***	0.234***	0.3720***	-0.002	0.075***	0.029	0.073***	0.277***	1
manufacturing	-0.060***	0.167***	0.165***	0.138***	0.160***	-0.113***	-0.065***	0.017	-0.083***	0.072***	0.325***

All variables are for 2008 beside the process and product innovation variables in 2009. Significance levels are indicated by * (10%), ** (5%), ***(1%).