TI 2022-052/V
Tinbergen Institute Discussion Paper

The Impact of Absent Coworkers on Productivity in Teams

Sam Hoey[1,2]
Thomas Peeters[1,2]
Jan C. van Ours[1,2]

1 Erasmus University Rotterdam
2 Tinbergen Institute

The Impact of Absent Coworkers on Productivity in Teams*

Sam Hoey† Thomas Peeters‡ Jan C. van Ours§

Draft version July 25, 2022

Abstract

We study how workers in production teams are affected by the temporary absence and replacement of a coworker. When a substitute coworker is absent, the remaining coworkers produce less output per working time. They compensate for this by increasing their working time at the expense of the (less able) replacement worker, such that the output loss per remaining worker is not significant. When a complementary coworker is absent, we see a similar loss in output per minute worked, but this directly leads to a loss of output produced, because remaining workers do not take over the absent worker's tasks.

Keywords: absenteeism, worker productivity, team production, ice hockey.

JEL-codes: M50, M54, J24

*We thank Raf van Gestel, Tom van Ourti and Hans van Kippersluis for their comments and suggestions on this paper.

†Erasmus School of Economics, Tinbergen Institute and Erasmus Center for Applied Sports Economics, (Rotterdam), The Netherlands hoey@ese.eur.nl

‡Erasmus School of Economics, Tinbergen Institute, ERIM and Erasmus Center for Applied Sports Economics (Rotterdam), The Netherlands, peeters@ese.eur.nl

§Erasmus School of Economics, Tinbergen Institute and Erasmus Center for Applied Sports Economics (Rotterdam), The Netherlands; Department of Economics, University of Melbourne (Parkville), Australia, CEPR (London), IZA (Bonn), vanours@ese.eur.nl

1 Introduction

Since the start of the Covid-19 pandemic developed economies have witnessed a dramatic increase in the absenteeism of workers from their jobs. Absenteeism may severely depress the output firms produce, particularly when production involves teamwork. Output loss due to absenteeism occurs through two channels, direct and indirect. First, the firm may be unable to hire an equally productive worker to replace the absentee, resulting in a direct loss of production (Herrmann and Rockoff, 2012). Second, there is an indirect production loss if remaining coworkers of the absentee produce less because their productivity depends on their absent (and replaced) coworker (Bartel et al., 2014). In this paper, we study both effects. We first focus on the indirect effect by analyzing the impact of a worker's temporary absence and replacement on the output production of the remaining coworkers in a production team. We then compare the production of the absentee with the production of the replacement worker such that we can decompose the total effect of the absence on team production into its components.

The contribution of our analysis is threefold. First, we estimate the effect of an absence on the productivity, working time and output produced by the remaining coworkers. Second, we distinguish between two types of absent worker, those who perform the same task as the coworker we investigate (substitute coworker) and those with a complementary task in the production team (complimentary coworker). The absence of both types has a negative impact on the productivity of the remaining coworkers, as they produce less output per minute worked. In case a substitute worker is absent, the remaining coworkers compensate for this productivity loss by increasing their working time. The increase in working time counteracts the loss of worker productivity. This is not possible if the absentee is a complementary coworker. Therefore, the absence of a complementary coworker has a more severe impact on the total output produced per remaining worker than the absence of a substitute worker. Third, we show how the indirect coworker effects combined with the direct effect of the lower average ability of replacement workers impact the production of the team.

In the economic literature on absenteeism, most studies focus on the causes of absenteeism (see e.g., Markussen et al. (2011); De Paola, Scoppa and Pupo (2014); Godøy and

Dale-Olsen (2018)). By contrast, we focus on the consequences of absenteeism for production, which has attracted far less academic interest to date. Herrmann and Rockoff (2012) show that student grades obtained under the supervision of regular teachers are significantly higher than grades obtained under temporary replacements. As such, they document the direct production loss of replacing a regular worker by a temporary replacement. Bartel et al. (2014) evaluate the production effects of composition disruptions in nursing teams, finding negative effects from nurse departures or new hires on team production. We connect these two insights by disentangling the decrease in team production into the effect of productivity losses of the remaining coworkers (as in Bartel et al. (2014)) and the direct productivity loss from replacing absent workers by less able replacements (as in Herrmann and Rockoff (2012)). Our empirical strategy directly addresses the issue of endogenous staffing changes by exploiting quasi-random coworker injuries as a source of temporary absences and replacements. To this end, we rely on detailed worker injury and performance data from the National Hockey League (NHL). Thus, our paper builds on previous work using injury data from professional athletes to examine health shocks in the labor market. For example, Carrieri, Jones and Principe (2020) calculate the wage loss soccer players incur when they suffer an injury, Stuart (2017) evaluates the team productivity effects of injuries for different types of injured players, Gregory-Smith (2021) uses injuries to examine whether NFL players are paid according to their marginal revenue product and Fischer, Reade and Schmal (2021) investigate the productivity effects of COVID-19 on the performance of top league soccer players in Germany and Italy. Finally, the literature has extensively documented two plausible mechanisms for the coworker effects we identify: peer effects due to complementarities in the production function (Arcidiacono, Kinsler and Price, 2017; Azoulay, Graff Zivin and Wang, 2010; Gould and Winter, 2009) and productivity gains from coworking experience between workers (Berman, Down and Hill, 2002; Shamsie and Mannor, 2013). While our analysis clearly relates to this line of work, we do not empirically distinguish between these mechanisms.

2 Setting and Data

To perform our analysis we use a detailed game-by-game database of performance and injuries in the National Hockey League (NHL), the primary North American ice hockey competition. A typical game roster of an ice hockey team consists of two goalies, six defense and twelve offense players. As decided by the coach, at any given moment one goalie, two defense and three offense players are on the ice. During a game, players from the roster can freely rotate on and off the ice. The team that scores the most goals wins the match. Offense players' main objective is to score goals to increase the chance of the team winning. Defense players and goalies perform tasks which are more complex and multifaceted, making it more difficult to quantify their performance. In our analysis we therefore focus on the output of offense players and define team output as the number of goals scored by the offense players during a game.[1] During games, ice hockey players rotate regularly from playing to resting and back again. An average shift on the ice lasts about 45 seconds. An offense player is on average active for 15 out of the 60 of minutes total game time, but the most skilled players account for a larger share of time than the less skilled players. The total amount of working time for the offense team is ultimately constrained by the duration of the game as the number of offense players on the team is typically fixed.[2]

Worker absenteeism in ice hockey has three defining features, which warrant further attention. First, the total working time of the team is constrained by the duration of the game, meaning that production must be realized within a given time period. Consequently, ice hockey is comparable to other settings where total working time cannot easily be adjusted. Examples include retail stores with set opening hours such as grocery stores (see Mas and Moretti (2009)) or 24/7 institutions such as hospitals or chemical production plants (see Bartel et al. (2014)). Second, the number of workers in a team is constant, meaning that absent workers are always replaced. This implies that production losses in this setting can best be considered a lower bound for settings where a replacement worker is not always available.

[1] A simple regression of a win indicator on the number of goals scored by a team's offense players (excluding defense goals) shows that each offense goal increases the chance of the team winning by 18%. Goals scored by offense players alone explain 30% of a team's chance of winning, as measured by the R-squared.

[2] For a more detailed description of ice hockey see Section B of the online appendix.

Remarkably, the remaining workers also work more during the absence of a coworker, meaning they compensate a substantial share of the injured player's lost working time instead of letting the replacement fill in this void. Finally, worker preferences and behavior play a relatively minor role in determining worker absenteeism in our context.[3] Worker health is closely monitored in the NHL, leaving little room for workers to wrongfully claim an illness or injury. Moreover, worker absenteeism is usually caused by clearly identifiable injuries, which are arguably caused by random events. As such, absenteeism in our context is exogenously determined, alleviating endogeneity concerns present in previous research on the team productivity effects of worker absenteeism.

To study the effect of absenteeism we distinguish between three categories of offense players, i.e., three groups of workers. First, "regular workers" are workers who were in the line-up for every game during the measure period around an injury. These workers will be the first focus of our analysis and make up the vast majority of our player-game observations (around 78% in our main specifications).[4] Second, "occasional workers" are workers who were present in some games before and possibly also after the injury, but do not play every game during the measure period. Third, "replacement workers" are workers who were called up to take the injured worker's spot. We define a "replacement worker" as a player who has not played in the pre-injury period, but appears in the team after the injury of the absent worker. Given that replacement workers are not the coach's first choice, they are in expectation less productive than the injured worker.

We analyze two types of coworker absenteeism. When an offense player gets injured, the team usually calls up a replacement player, but in addition the regular and occasional offense players may be assigned more working time. Given our focus on the production of offense players, we classify these injuries as "substitute" worker absences. When a defense injury occurs, offense players cannot replace the absent worker. As such, offense players' working time should not be directly affected. We dub these instances "complementary"

[3] De Paola, Scoppa and Pupo (2014) show that pay-incentives around sick leave have a clear effect on worker absenteeism in the Italian public sector, indicating that worker preferences and behavior are important determinants of worker absenteeism in some labor markets.

[4] See Table A.1 for details on these numbers under various choices of the injury measure period.

worker absences.[5]

We derive data from two sources. Using data from *www.nhl.com* we observe how many goals a player scored and how many minutes he played (i.e., was on the ice, not on the bench) in each game. Data from *www.mangameslost.com* allow us to identify which games each injured player missed. The data ranges from the 2010-2011 season until the 2018-2019 season, totaling nine seasons. Our analysis is based on information from the (injury) measure period which we define as the five matches before the injury and the five matches after the injury occurred. Therefore, we apply the following steps in assembling the data set. First, we link each injury to all players in the team for the five games before and after the injury occurs. We exclude the game in which the player gets injured, which is the last game before the first game missed by the injured player. In case an injury is shorter than 5 games, we remove the games in which the injured player has recovered from injury. Then, we exclude games where less than twelve offense or less than six defense players are present to remove rare cases in which a coach deviates from the standard team formation.[6] Finally, we remove all observations related to injuries where the injured player did not play in the five games prior to their injury.

This procedure leaves us with a dataset consisting of 4783 injuries, 3028 for substitute workers (offense) and 1755 for complementary workers (defense). These injuries affect 1903 unique non-goalie players, either as absentee or coworker, of which 1262 exclusively played in offense, 635 exclusively in defense and 6 played in both roles. In our analysis we only consider the effect of absentees on the performance of the exclusively offense players. As such, we analyze a total of 453,384 player-game observations, 284,772 related to substitute worker absences and 168,612 related to complementary worker absences.

Table 1 gives an overview of pre- and post-injury statistics by injury and worker type. For each worker type we measure the total number of workers in the pre- and post-injury periods and how many of these workers are actually selected to play a game. We collect

[5]Defense players' injuries may result in a team conceding more goals if substitute defense players perform worse. The nature of the complementarity between offense players and defense players can be twofold. First, substitute defense players may provide less support to the goal-scoring activities of offense players (fewer assists). Second, with substitute defense players offense players need to be more involved in defense activities to the detriment of their offensive activities.

[6]This removes approximately 6% of the games in our sample.

two performance statistics, output, expressed in goals scored per game, and working time, expressed in minutes played in a game. Using these two variables we calculate worker productivity, defined as output per 15 minutes of working time.[7] For regular workers, there are on average 8.41 players who play in pre- and post-injury period. By construction, these workers are always selected to play, which is why the statistics for the number of players selected to be in the lineup are equal to the worker pool statistics. This means that approximately 70% (8.41/12) of workers are consistently in the lineup throughout the measure period of an injury. The output of these workers does not change much between the pre- and post-injury periods. Yet, their average working time goes up from 15.68 minutes to 16.06 minutes per game. As a result, their productivity decreases from 0.200 to 0.195 goals per 15 minutes, representing a 2.4% decrease.

The second part of Table 1 shows that the worker pool of replacement players contains 1.35 players on average, meaning that there is often more than one player who replaces the injured player. However, on average, out of these 1.35 replacement players, only 0.99 are selected to play in any given game, suggesting that replacement players can alternate between games in the post injury period. When selected, they score 0.15 (-39%) fewer goals per game, but also spend nearly 4 minutes (-24%) less on the ice per game in comparison to the absent player. Still, this implies that replacements are less productive per unit of time, scoring around 0.04 (-22%) fewer goals per 15 minutes on the ice. For occasional workers, the statistics show an increase in output, working time and productivity per game, but not in the average number of occasional workers selected to play. Notably, the worker pool of occasional workers decreases, suggesting that a subset of the occasional workers are selected more often in the post-injury period and another subset is completely dropped from the team. Combined with the increase in output and productivity, this appears to be an indication that less skilled occasional players are dropped from the lineup following an injury.

For the complementary worker injuries in Panel B, we cannot compare absent to replacement workers, because there is no absent offense player. Here we see a clear drop in output and productivity for regular workers. As is to be expected, the increase in working

[7] We divide by 15 minutes because this represents the average working time during a game for offense players.

time is negligible compared to the increase in working time following a substitute worker's absence. The statistics for occasional players relating to complementary worker injuries are very similar to those of the substitute worker injuries.

Table 1: Descriptive Statistics

Panel A: Substitute worker absence *(N injuries = 3,028)*

	Pre-injury				Post-injury			
Regular workers	Average	Std. Dev.	Min.	Max	Average	Std. Dev.	Min.	Max
Worker Pool/Selected lineup	8.41	1.37	3	11	8.41	1.37	3	11
Output	0.22	0.47	0	5	0.22	0.48	0	5
Working Time	15.68	3.86	0.02	32.07	16.06	3.89	0.02	30.47
Productivity	0.200	0.446	0	8.491	0.195	0.438	0	4.383
Absent/replacement worker								
Worker Pool	1	0	1	1	1.35	1.11	0	9
Selected lineup	0.91	0.19	0.20	1	0.99	0.81	0	6
Output	0.19	0.45	0	4	0.12	0.34	0	3
Working Time	14.95	4.05	0.38	28.68	11.43	4.10	0.03	25.22
Productivity	0.183	0.443	0	4.096	0.142	0.438	0	6.122
Occasional workers								
Worker Pool	4.27	2.10	0	16	3.13	1.77	0	11
Selected lineup	2.67	1.38	0	8	2.60	1.43	0	8.0
Output	0.12	0.36	0	3	0.14	0.38	0	3
Working Time	12.34	4.38	0.02	28.20	12.61	4.40	0.02	27.68
Productivity	0.137	0.432	0	18.000	0.149	0.441	0	7.826

Panel B: Complementary worker absence *(N injuries = 1,755)*

	Pre-injury				Post-injury			
Regular workers	Average	Std. Dev.	Min.	Max	Average	Std. Dev.	Min.	Max
Worker Pool/Selected lineup	8.84	1.47	4	12	8.84	1.47	4	12
Output	0.22	0.48	0	5	0.21	0.47	0	4
Working Time	15.81	3.84	0.03	30.58	15.88	3.85	0.02	30.47
Productivity	0.200	0.448	0	7.200	0.193	0.437	0	7.826
Occasional workers								
Worker Pool	4.83	2.15	0	12	4.23	2.24	0	12
Selected lineup	3.16	1.47	0	8	3.16	1.47	0	8
Output	0.12	0.36	0	4	0.13	0.38	0	3
Working Time	12.29	4.42	0.02	32.42	12.43	4.35	0.03	26.95
Productivity	0.133	0.414	0	6.250	0.148	0.453	0	18.000

Notes: This table shows descriptive statistics at the worker-game level, split by worker group. The worker pool statistics are calculated on the basis on the total number of workers who are present in either the pre- and post-injury periods of a given injury. The selected lineup statistics are calculated on the basis of how many players are selected to play on average in the pre- and post-injury period of an injury. As such, both the worker pool and selected lineup variables are measured at the pre- and post-injury levels. Output is measured in goals, working time in minutes on ice and productivity as goals per 15 minutes. These statistics are measured at the worker-game level, only taking into account games in which the worker was selected in the game lineup. Table A.1 details the exact amount of player-game observations the various sub-samples hold.

3 Empirical Strategy

We quantify the effect of absences on the coworkers in the team through the following regression model,

$$Y_{mit} = \beta_0 + \beta_1 * Post_{mt} + \gamma_{mi} + \varepsilon_{mit}. \tag{1}$$

Y_{mit} represents the dependent variable, which is either goals scored per game, working time per game or goals scored per minute for player i in game t relative to injury m. The main explanatory variable is an indicator, which equals 0 if game t is before injury m and equal to 1 when game t is after injury m.

We estimate Equation (1) on the full sample of player-games and sub-samples of regular, occasional and absent-replacement workers. In our preferred specification, we include injury-worker fixed effects γ_{mi}, such that the change in the dependent variable as measured by β_1 is relative to the worker's own pre-injury average. We also report estimates with simple injury fixed effects, because this allows to include absent and replacement workers as well as occasional workers who only appear prior to the injury. This raises selection issues, but is necessary to gauge the effects on team-level production.

Next, we decompose the overall team-level effect of substitute and complementary worker injuries into parts attributable to the productivity effect on remaining regular and occasional coworkers and the difference in skill between the injured worker and his replacement. To this end, we sum the output and working time of each player-game to the team-game level and by game-worker category (regular, occasional, injured/replacement). When there are no players in a particular category for a given game we set output and working time to zero.[8] As a result, we obtain totals for the entire team and each worker group during each game. Subsequently, we implement regression models similar to those outlined in Equation (1) using aggregated worker-group data for each game. The resulting model is given by,

$$\sum_{i \in g} Y_{mit} = \delta_0 + \delta_1 * Post_{mt} + \phi_m + \epsilon_{mgt}. \tag{2}$$

[8]Given that these instances exist where working time is zero we do not calculate group level productivity in the aggregated model.

Here, $\sum_{i \in g}^{G} Y_{mit}$ represent the sums of output and working time per game of all players within group g[9], which are then regressed on a post-injury indicator ($Post_{mt}$) controlling for injury fixed effects ϕ_m.

The aggregated model complements the within-player model (Equation (1)) as follows. First, by construction the team level injury effect δ_1 is equal to the weighted sum of the β_1 coefficients for each of the sub groups of players, yielding a clear decomposition of the team level effects into parts attributable to the various worker groups. Second, the aggregate model explicitly accounts for changes in the number of players in each group following a worker absence, which is not captured by the within-player model.

4 Results

4.1 Within-Player Results

Table 2 reports the parameter estimates corresponding to Equation (1) for substitute worker (offense player) absences. In our preferred specification we use injury-worker fixed effects such that the coefficients are estimated by comparing a worker's performance after a coworker injury to their performance before the injury. As a result, only workers who are present both before and after the injury are included in the analysis, meaning that there is no comparison between the absent worker and their replacement. These estimates are reported in the first three rows of Table 2. For all workers combined, the results show that there is no effect on worker output measured in goals scored per game. However, the working time per worker goes up by 0.336 minutes per player, which can be explained by the fact that only a subset of players is included here. The net result is that worker productivity is significantly negatively affected. When looking at regular and occasional workers we see that this negative productivity effect is primarily driven by regular workers having a large drop in their productivity. On average these players score 0.0054 fewer goals per 15 minutes of play[10], representing a 2.7% drop in productivity compared to their pre- injury productivity as reported in Table 1. Occasional workers do not see a significant change in their productivity

[9]There are four groups: (1) the entire offense team, (2) the regular workers, (3) the occasional workers and (4) the absent-replacement workers.

[10]In Table 4 we show what this means for team-level performance.

as both their working time and output increase similarly. In this case we see two potential explanations for the productivity loss of regular workers. They may be more exhausted because of their increased working time or they may suffer from working with less familiar or less able peers.

In order to also consider workers who do not play in both the pre- and post-injury periods, we redo our estimates using injury fixed effects. This means we are able to compare the performance of the injured worker and their replacement as well as include occasional workers who only work in the pre-injury period. These estimates are reported in the last four rows of Table 2. First, we notice that the output of all players combined now becomes significantly negative and that there is no effect on working time. This is purely the result of adding back the players who are not included in the injury-worker estimates as is indicated by the increase in observations. The drop in output can be primarily attributed to the difference in output between the injured player and their replacement. As shown in the last row, the replacement player(s) score on average 0.069 less goals per game in comparison to the injured player they replace. This results from replacement workers having less working time and being less productive than the absent worker. Also in the occasional worker category the number of observations goes up substantially as now workers who only play before the injury are included in the estimates. The resulting output, productivity and working time coefficients become significantly positive. This can be explained by a selection effect where less productive occasional workers are selected to play less often in the post-injury period in comparison to the pre-injury period.[11] In the regular worker category there are no changes in the coefficients in comparison to the injury-worker fixed effect estimates, because the set of workers in the pre-and post-injury periods are by construction the same in this worker category.

[11]This is in line with the statistics shown in Table 1, which show that the total worker pool of occasional workers becomes smaller following a coworker injury, while the number occasional workers who are selected play remains the same.

Table 2: Effect of Substitute Worker Absence on Output, Productivity and Working Time

Worker Category	Output *(goals×100)*	Productivity *(goals×100/15 min.)*	Working Time *(minutes played)*	Observations *(player-games)*	Fixed effects
All	0.070	−0.371	0.336	252,296	Injury-worker
	(0.186)	(0.186)	(0.012)		
Regular	−0.062	−0.538	0.346	197,706	Injury-worker
	(0.222)	(0.211)	(0.015)		
Occasional	0.548	0.230	0.302	54,590	Injury-worker
	(0.323)	(0.387)	(0.026)		
All	−0.388	−0.464	−0.001	284,772	Injury
	(0.174)	(0.178)	(0.006)		
Regular	−0.062	−0.538	0.346	197,706	Injury
	(0.222)	(0.211)	(0.015)		
Occasional	1.054	0.974	0.238	64,146	Injury
	(0.304)	(0.354)	(0.032)		
Absent vs.	−6.884	−3.701	−3.600	22,920	Injury
Replacement	(0.621)	(0.686)	(0.099)		

Notes: Each cell represents a separate regression for each variable and worker category. For our estimates using injury-worker fixed effects we only include workers who work both before and after the injury in question as only these workers aid in the identification of our estimates. As a result, the absent vs. replacement worker group and workers who only work before the injury contained in the occasional worker category drop out. Standard errors are clustered at the injury level and reported in parentheses.

Table 3 shifts the focus to complementary worker (defense player) absences. The estimation results in the first three rows of Table 3 include injury-worker fixed effects. The first row shows the within worker change for all workers who played both before and after the complementary worker injury. The results indicate that working time is not significantly affected, which is in line with our expectations as offense players cannot take over the tasks of an absent defense player. Worker output and productivity decrease by 0.0064 goals and 0.0075 goals per 15 minutes. These values are higher in absolute terms in comparison to substitute worker injuries, suggesting that defense workers play a large role in the productivity of offense workers. Note that this productivity loss cannot be explained by increased fatigue, as offense players do not increase their working time. This suggests an important role for peer or familiarity effects between defense and offense players. In addition, there are more offense players than defense players on a team, making it more likely that an absent defender played a crucial role before their absence. The second and third row show the results for regular and occasional workers respectively. Regular workers are most affected by complementary worker injuries, scoring significantly fewer goals per game and having significantly lower productivity. Occasional workers on the other hand are mostly unaffected by complementary worker injuries, apart from their working time going down slightly.

The last three rows show the results using only injury fixed effects. Starting with all offense players combined, we see no significant changes in output and productivity, which seems to be partially caused by an increase in occasional worker productivity and a decrease in regular worker productivity following a complementary worker injury. The regular workers by construction have the same coefficients as when using injury-worker fixed effects. For the occasional workers, we suspect that under-performing occasional players are dropped from the lineup in the post injury period, causing an increase in occasional worker performance. The results here show a small increase in offense player working time, which may be due to the team playing more overtime or incurring less penalty time when a defense player is absent.

Table 3: Effect of Complementary Worker Absence on Output, Productivity and Working Time

Worker Category	Output *(goals×100)*	Productivity *(goals×100/15 min.)*	Working Time *(minutes played)*	Observations *(player-games)*	Fixed effects
All	−0.644	−0.749	−0.011	157,458	Injury-worker
	(0.226)	(0.229)	(0.014)		
Regular	−0.772	−0.871	0.012	122,826	Injury-worker
	(0.269)	(0.258)	(0.017)		
Occasional	−0.185	−0.311	−0.092	34,632	Injury-worker
	(0.401)	(0.501)	(0.032)		
All	−0.264	−0.295	0.020	168,612	Injury
	(0.216)	(0.221)	(0.008)		
Regular	−0.772	−0.871	0.012	122,826	Injury
	(0.269)	(0.258)	(0.017)		
Occasional	1.060	1.204	0.042	45,786	Injury
	(0.356)	(0.417)	(0.040)		

Notes: Each cell represents a separate regression for each variable and worker category. For our estimates using injury-worker fixed effects we only include workers who work both before and after the injury in question as only these workers aid in the identification of our estimates. As a result, the absent vs. replacement worker group and workers who only work before the injury contained in the occasional worker category drop out. Standard errors are clustered at the injury level and reported in parentheses.

4.2 Team Production Results

Table 4 presents the effects of substitute and complementary worker absences on team production (see Equation (2)).

Table 4: The Effect of Injuries on Team Performance, Productivity and Working Time

	Substitute worker injury		*Complementary worker injury*	
	Output *(goals×100)*	Working Time *(minutes played)*	Output *(goals×100)*	Working Time *(minutes played)*
All Workers	−4.659	−0.013	−3.169	0.243
	(2.088)	(0.073)	(2.592)	(0.095)
Regular Workers	−0.516	2.860	−6.698	0.103
	(1.838)	(0.124)	(2.335)	(0.151)
Occasional Workers	1.201	−0.890	3.529	0.140
	(0.865)	(0.221)	(1.183)	(0.135)
Absent vs. Replacement	−5.344	−1.983		
	(0.587)	(0.212)		
Observations (team-game)	23,731		14,051	

Notes: Each cell represents a separate regression for each variable and worker category. We add injury fixed effects in all of our specifications. Standard errors are clustered at the injury level. Standard errors are reported in parentheses.

The first two columns show the coefficients for output and working time resulting from substitute worker injuries. Starting with the first row, the coefficients for all offense players together show that substitute worker injuries have a negative effect on output. On average, all offense players combined score nearly 0.05 fewer goals in the post-injury period in comparison to the pre-injury period. When subdivided into parts, the results indicate that the difference in output between the injured player and their replacement is the main cause for this drop in output. As is to be expected, there is no working time effect at the aggregate level. When looking at the individual parts of working time, the table shows that the regular players combined play nearly three minutes more in the post-injury period, representing a large share of the injured player's pre-injury working time. This is counterbalanced by the replacement player(s) playing nearly two minutes less than the injured player and the occasional players playing nearly one minute less in the post-injury period.

The last two columns of Table 4 show results for complementary worker injuries. Here we find that there is no significant effect on output for all players together. When subdivided into parts the results indicate that this is the net result of a large negative effect for the regular players and a smaller positive effect for the occasional players. This positive effect for occasional players is likely due to selection on players as the occasional group of players is not constant throughout the measure period. The working time results indicate a slight increase in aggregate working time in the post-injury period. This can be the result of there being more overtime in games in the post-injury period or fewer team penalties, both of which would increase total playing time. Moreover, the effect on aggregate playing time is only 0.243 minutes, which is tiny when compared to the average total playing time of 179 minutes. For the two subgroups of regular and occasional players, there are no significant effects on working time.

All in all, the mechanism through which an absent workers has a negative effect on team production is very different depending on nature of the relationship between the worker and the team If the worker is a substitute, the replacement of the absent workers by a less productive worker can be at least partly compensated by increasing the working time of the regular workers in the team. The absence of a complementary worker cannot be compensated by an increase of working time of the regular workers.

5 Robustness

We test the robustness of our within-player results against various alternative sample selection methods. First, we investigate whether our within-player estimates are sensitive to the number of games included in the sample before and after the injury. This is plausible, because the number of players in the regular worker category increases as window widths become shorter. Moreover, any pre- and post-injury trends in the outcome variables induce more bias when more games are included.[12] To investigate these issues, we estimate the regular worker coefficients from Equation (1) using window widths, ranging from one to four games before and after the injury.[13] The results (in online appendix Table A.2) show that our estimates are not statistically different across window widths. Hence, our conclusions

[12]Such trends would occur when injury timing is not exogenous to the performance of the team.

[13]Obviously the number of observations is strongly correlated with the length of the measure period; see online appendix Table A.1.

are robust against the number of games we include in the sample.

Second, it regularly occurs that the measure periods of different injuries in a team overlap each other. The post-injury period of one injury is then part of the pre-injury period of another injury of the same team, adding noise to our estimates. To examine the severity of this issue, we rerun the regressions outlined in Equation (1) after removing all observations which are affected by other coworker injuries or recoveries. The results for substitute workers in online Table A.3 point to more negative productivity effects than our baseline results. We still observe increase in working time, but this falls short of fully compensating the output loss. For complementary worker injuries (Table A.4), the output and productivity coefficients remain negative, but become insignificant due to a large loss in the observation count.

6 Conclusion

We have investigated how the absence and replacement of workers in production teams affect the productivity, working time and output of their coworkers. In our setting there are two types of absentees, those who perform substitute tasks and those who perform complementary tasks to the absent worker we examine. We find that both types of worker absenteeism lead to a reduction in productivity of the remaining regular workers. For substitute worker absenteeism, the regular workers increase their working time to compensate for this loss in productivity and the replacement worker therefore takes over only a share of the absentee's working time. Following complementary worker absences, the remaining workers also experience a decrease in productivity, which they cannot compensate for by an increase in working time. As a result, the output per worker decreases significantly for a complementary worker's absence. At the team level, the difference in productivity between the absent workers and their replacements turns out to be more important than the productivity effects on the set of remaining workers.

Following a coworker injury, the production teams in our setting simultaneously experience a disruption to their coworker network and a decrease in coworker skill, because the replacement worker is on average less productive than the absent worker. Both peer effects and the loss of coworking experience are potential mechanisms behind the decrease in remaining worker productivity. Declining marginal productivity resulting from the increase in working time for the remaining workers seems less likely to play an important role. After all, complementary worker absences also lead to decreases in productivity, while leaving working time unchanged. Future research may seek to better understand to which degree each of these channels contribute to the productivity losses from coworker absenteeism.

References

Arcidiacono, Peter, Josh Kinsler, and Joseph Price. 2017. "Productivity spillovers in team production: Evidence from professional basketball." *Journal of Labor Economics*, 35(1): 191–225.

Azoulay, Pierre, Joshua Graff Zivin, and Jialan Wang. 2010. "Superstar extinction." *The Quarterly Journal of Economics*, 125(2): 549–589.

Bartel, Ann P, Nancy D Beaulieu, Ciaran S Phibbs, and Patricia W Stone. 2014. "Human capital and productivity in a team environment: evidence from the healthcare sector." *American Economic Journal: Applied Economics*, 6(2): 231–59.

Berman, Shawn L, Jonathan Down, and Charles WL Hill. 2002. "Tacit knowledge as a source of competitive advantage in the National Basketball Association." *Academy of Management Journal*, 45(1): 13–31.

Carrieri, Vincenzo, Andrew M Jones, and Francesco Principe. 2020. "Productivity shocks and labour market outcomes for top earners: Evidence from Italian Serie A." *Oxford Bulletin of Economics and Statistics*, 82(3): 549–576.

De Paola, Maria, Vincenzo Scoppa, and Valeria Pupo. 2014. "Absenteeism in the Italian public sector: The effects of changes in sick leave policy." *Journal of Labor Economics*, 32(2): 337–360.

Fischer, Kai, J. James Reade, and W. Benedikt Schmal. 2021. "The Long Shadow of an Infection: COVID-19 and Performance at Work." DICE Discussion Paper No. 368.

Godøy, Anna, and Harald Dale-Olsen. 2018. "Spillovers from gatekeeping–Peer effects in absenteeism." *Journal of Public Economics*, 167: 190–204.

Gould, Eric, and Eyal Winter. 2009. "Interactions between workers and the technology of production: Evidence from professional baseball." *The Review of Economics and Statistics*, 91(1): 188–200.

Gregory-Smith, Ian. 2021. "Wages and labor productivity: Evidence from injuries in the national football league." *Economic Inquiry*, 59(2): 829–847.

Herrmann, Mariesa A, and Jonah E Rockoff. 2012. "Worker absence and productivity: Evidence from teaching." *Journal of Labor Economics*, 30(4): 749–782.

Markussen, Simen, Knut Røed, Ole J Røgeberg, and Simen Gaure. 2011. "The anatomy of absenteeism." *Journal of Health Economics*, 30(2): 277–292.

Mas, Alexandre, and Enrico Moretti. 2009. "Peers at work." *American Economic Review*, 99(1): 112–45.

Shamsie, Jamal, and Michael Mannor. 2013. "Looking inside the dream team: Probing into the contributions of tacit knowledge as an organizational resource." *Organization Science*, 24(2): 513–529.

Stuart, H Colleen. 2017. "Structural disruption, relational experimentation, and performance in professional hockey teams: A network perspective on member change." *Organization Science*, 28(2): 283–300.

Online Appendix

A Additional Tables

Table A.1: Observations Pre- and Post-Injury per Player Type

		Offense Injury		Defense Injury	
Sample	Player Category	Pre Obs	Post Obs	Pre Obs	Post Obs
-1 to + 1	Regular	27,191	27,191	16,982	16,982
	Injured vs. Replacement	2,606	4,081	-	-
	Occasional	1,475	0	1,498	1,498
-2 to + 2	Regular	54,238	46,448	32,851	29,559
	Injured vs. Replacement	5,372	6,152	-	-
	Occasional	7,242	4,820	5,549	5,133
-3 to + 3	Regular	78,910	59,913	47,430	38,365
	Injured vs. Replacement	8,057	7,646	-	-
	Occasional	15,933	11,257	11,286	9,599
-4 to + 4	Regular	10,1294	69,218	61,034	44,691
	Injured vs. Replacement	10,689	8,745	-	-
	Occasional	26,473	18,013	18,250	14,433
-5 to + 5	Regular	121,857	75,849	73,555	49,271
	Injured vs. Replacement	13,257	9,663	-	-
	Occasional	38,910	25,236	26,345	19,441

Notes: This table shows the number of player-games for various window widths around injuries, subdivided per player group. The results reported in the main body of our paper are derived using the -5 to +5 window.

Table A.2: Effect of Injury on Output, Productivity and Working Time of Individual Regular Worker for Various Analysis Windows

	(1)	(2)	(3)	(4)
Sample/Injury Type:	Output *(goals×100)*	Productivity *(goals×100/15 min.)*	Working Time *(minutes played)*	Observations *(player-games)*
-1 to +1				
Substitute worker	−0.022	−0.460	0.357	54,382
	(0.383)	(0.375)	(0.018)	
Complementary worker	−1.048	−1.095	−0.058	33,964
	(0.493)	(0.500)	(0.021)	
-2 to +2				
Substitute worker	−0.260	−0.669	0.355	100,686
	(0.292)	(0.283)	(0.016)	
Complementary worker	−0.768	−0.891	−0.022	62,410
	(0.365)	(0.356)	(0.018)	
-3 to +3				
Substitute worker	−0.298	−0.729	0.341	138,823
	(0.252)	(0.241)	(0.015)	
Complementary worker	−0.842	−0.964	−0.014	85,795
	(0.314)	(0.305)	(0.017)	
-4 to +4				
Substitute worker	−0.091	−0.565	0.344	170,512
	(0.231)	(0.221)	(0.015)	
Complementary worker	−0.705	−0.760	0.004	105,725
	(0.290)	(0.280)	(0.017)	
-5 to +5 (full sample)				
Substitute worker	−0.062	−0.538	0.346	197,706
	(0.222)	(0.211)	(0.015)	
Complementary worker	−0.772	−0.871	0.012	122,826
	(0.269)	(0.258)	(0.017)	

Notes: Regular players in the pre- injury period form the base category. We add injury-worker fixed effects in all of our specifications. Standard errors are reported in parentheses. Standard errors are clustered at the injury level.

Table A.3: Effect of Substitute Worker Absence on Output, Productivity and Working Time - Restricted Sample

Worker Category	Output *(goals×100)*	Productivity *(goals×100/15 min.)*	Working Time *(minutes played)*	Observations *(player-games)*	Fixed effects
All	−1.333	−1.807	0.345	23,285	Injury-worker
	(0.652)	(0.649)	(0.029)		
Regular	−1.496	−2.009	0.342	21,651	Injury-worker
	(0.700)	(0.688)	(0.033)		
Occasional	0.732	0.756	0.383	1,634	Injury-worker
	(1.592)	(2.031)	(0.135)		
All	−1.675	−1.623	−0.072	25,632	Injury
	(0.612)	(0.618)	(0.020)		
Regular	−1.496	−2.009	0.342	21,651	Injury
	(0.700)	(0.688)	(0.033)		
Occasional	1.764	1.869	0.476	1,899	Injury
	(1.451)	(1.854)	(0.145)		
Absent vs.	−6.367	−0.612	−5.025	2,028	Injury
Replacement	(1.922)	(2.274)	(0.235)		

Notes: For our estimates using injury-worker fixed effects we only include workers who work both before and after the injury in question as only these workers aid in the identification of our estimates. As a result, the absent vs. replacement worker group and workers who only work before the injury contained in the occasional worker category drop out. Standard errors are clustered at the injury level and reported in parentheses.

Table A.4: Effect of Complementary Worker Absence on Output, Productivity and Working Time - Restricted Sample

Worker Category	Output *(goals×100)*	Productivity *(goals×100/15 min.)*	Working Time *(minutes played)*	Observations *(player-games)*	Fixed effects
All	−1.065	−1.229	0.002	17,016	Injury-worker
	(0.728)	(0.713)	(0.027)		
Regular	−1.068	−1.117	0.001	15,805	Injury-worker
	(0.769)	(0.740)	(0.031)		
Occasional	−1.015	−2.654	0.014	1,211	Injury-worker
	(1.786)	(2.462)	(0.135)		
All	−0.748	−0.925	0.033	17,736	Injury
	(0.704)	(0.697)	(0.023)		
Regular	−1.068	−1.117	0.001	15,805	Injury
	(0.769)	(0.740)	(0.031)		
Occasional	1.899	0.660	0.299	1,931	Injury
	(1.424)	(1.990)	(0.129)		

Notes: For our estimates using injury-worker fixed effects we only include workers who work both before and after the injury in question as only these workers aid in the identification of our estimates. As a result, the absent vs. replacement worker group and workers who only work before the injury contained in the occasional worker category drop out. Standard errors are clustered at the injury level and reported in parentheses.

B Appendix: How Ice Hockey Works

An NHL ice hockey game consists of two teams of six players playing a match of three 20 minute periods. A team has one goal keeper, two defense players and three offense players. The aim of the match is to score more goals than the opponent team does. A goal is scored by shooting the puck in the net of the opposing team.

The game roster size of a hockey team is a subset of its active roster and is capped at twenty players. Each team's game roster consists of three defense lines and four offense lines, containing two and three players respectively. The coach decides who plays when. Players can freely rotate on and off the ice. A player is on the ice for 45 seconds of playing time on average. When a player commits a foul he usually has to sit in the penalty box for two, four or five minutes depending on the severity of the foul. During this time the team plays with one less player. A team can have a maximum of two penalties at any given time. A third penalty is added to the end of the first penalty.

The periods of 20 minutes are actual playing time. The clock is stopped when the referee blows the whistle after which the game resumes with a face-off. During a face-off the referee drops the puck on the ice and the players battle for puck possession. The standard rink sizer in the NHL is 200 feet long and 85 feet wide. The nets are positioned 11 feet from either side of the rink, which makes it possible for a player to skate behind the net.

The team that has scored the most goals during regular time wins the game. If the score is equal, the game goes into a five minute sudden-death overtime period in which each team has three players on the ice. Having less players increases the probability that a goal is scored. If both teams do not score, the game is decided via a penalty shootout. The team that wins obtains two points towards their league standing. The losing team obtains one point if they lose in overtime or the penalty shootout and zero points if they lose in regulation time.