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# The impact of absent co-workers on productivity in teams☆

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ABSTRACT

We study how workers in production teams are affected by the temporary absence and replacement of a co-worker using data on injuries in the National Hockey League. We distinguish between the absence of a substitute worker, who performs the same tasks as the focal workers, and the absence of a complementary co-workers, who performs complementary tasks to the focal workers. When either type of co-worker is absent, remaining workers produce less output per working time. In the case of a substitute absentee, they compensate for this by increasing their working time at the expense of the (less able) replacement worker. This renders the output loss per remaining substitute worker to be insignificant. For the absence of a complementary worker, the productivity loss leads to a loss of total output per worker, because remaining workers cannot take over the absent co-worker's tasks.

## 1. Introduction

Absenteeism may severely depress the output firms produce, particularly when production involves teamwork. Output loss due to absenteeism occurs through two channels, one direct and one indirect. First, the firm may be unable to hire or assign 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 co-workers of the absentee produce less because their productivity depends on their absent (and perhaps replaced) co-worker (Bartel et al., 2014). In this paper, we decompose the total effect of a worker's absence into this direct and indirect component. We first focus on the indirect effect by analyzing the impact of a worker's temporary absence and replacement on the output of the remaining co-workers in their production team. We then compare the production of the absentee with the production of their replacement worker and show how much these two effects contribute to the total output loss at team level.

In the economic literature on absenteeism, most studies focus on the causes of absenteeism (see e.g., De Paola et al. (2014); Godøy and Dale-Olsen (2018); Markussen et al. (2011)). 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 co-workers (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)).[1]

Our analysis fits in the literature on co-worker effects of absenteeism and turnover. This literature has extensively documented several

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[1] Some studies investigate the effect of absenteeism on overall firm productivity without exploring the channels through which productivity is affected. Zhang et al. (2017) and Grinza and Rycx (2020) conclude that the negative effect of absenteeism on firm productivity varies with the nature of the firm and the characteristics of the absent worker. Ge and Lopez (2016) do not study individual absenteeism but the productivity consequences of a league-wide lockout in the NHL. They conclude that the post lockout performance of hockey players was hardly affected by the lockout. Other studies focus on employment effects of worker absence stemming from parental leave (Brenøe et al. (2019), Schmutte and Skira (2022)) or death of workers (Jäger and Heining (2019)).

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plausible mechanisms for the co-worker effects we identify: peer effects due to complementarities in the production function (Arcidiacono et al., 2017; Azoulay et al., 2010; Gould and Winter, 2009), productivity gains from co-working experience between workers (Berman et al., 2002; Shamsie and Mannor, 2013) and productivity losses associated with the onboarding costs of replacement employees (Kuhn and Yu, 2021).[2]

Our empirical strategy addresses the issue of endogenous staffing changes by exploiting quasi-random co-worker injuries in sports teams as a source of temporary absences and replacements. To this end we use data from the National Hockey League. In this regard, our paper builds on previous work using injury data from professional athletes to examine health shocks in the labor market. For example, Carrieri et al. (2020) calculate the wage loss Italian football 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 National Football League players are paid according to their marginal revenue product and Fischer et al. (2022) investigate the productivity effects of COVID-19 on the performance of top league football players in Germany and Italy.

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 co-workers. Second, we distinguish between two types of absent worker, those who perform the same task as the remaining co-workers (substitute co-worker) and those with a complementary task in the production team (complementary co-worker). The absence of both types has a negative impact on the productivity of the remaining co-workers, as they produce less output per minute worked. In case a substitute worker is absent, the remaining co-workers compensate for this productivity loss by increasing their working time. The increase in working time counteracts the loss of worker productivity. An increase in working time does not occur when the absentee is a complementary co-worker. Therefore, the absence of a complementary co-worker has a more severe impact on the resulting output produced per remaining worker than the absence of a substitute co-worker. Third, we show how the indirect co-worker effects combined with the direct effect of the lower average ability of replacement workers impacts the total production of the team.

In Section 2 we discuss the institutional features of the National Hockey League and explain how we exploit these to identify the impact of absences. We then discuss the construction of our data set in Section 3 and empirical strategy in Section 4. Section 5 presents the main results of our analyses, followed by a set of robustness checks in Section 6. We provide our conclusions in Section 7.

## 2. Setting and identification

Our analysis is based on a detailed game-by-game database from the National Hockey League (NHL), the primary ice hockey competition in North America. We use information about in-game performance and injuries which are responsible for players being absent from games. 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. An average shift on the ice lasts about 45 seconds. 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. This is achieved by shooting at goal, preferably from a favourable position on the ice. 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. We use the number of goals scored by the offense players during a game as our primary measure of team output and use shots taken as a secondary output measure. While it is clear that taking shots is a crucial element in creating offensive output, it is less directly linked to team success. Offense players may take more "desperate" shots with small probability of scoring when they find it difficult to create clear-cut scoring opportunities. In that regard, shots can be considered a combination measure of offensive output and the degree of shot effectiveness. Shots are far more frequent than goals however, which makes the measure an attractive empirical alternative when implementing more granular analyses. 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.[3]

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.[4] 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).[5] 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.[6] 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 co-worker absenteeism. When an offense player gets injured, the team 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" worker absences.[7]

Team production in ice hockey has three specific features, which warrant further attention. First, the number of workers in a team is constant, meaning that absent workers are always replaced. This feature is reminiscent of high-stakes production teams such as airline cockpit crews, surgery teams, and military crews in tanks, airplanes and submarines. Yet, several lower skilled work environments such as retail stores and production plants with continuous shifts also have target

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[2] While our analysis clearly relates to this line of work, we do not empirically distinguish between these mechanisms.

[3] We provide a more detailed description of ice hockey in online Appendix B.

[4] We use the term "measure period" to refer to the set of games before and after the injury which we take into account for our empirical analysis of the injury's effect. In our baseline results, these are the 5 games prior to the injury and 5 games after the injury unless the injured players re-appears in the team sooner. In those cases we cut the after period to the games where the player was effectively absent.

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

[6] Here, pre injury period refers to the 5 games before the injury as part of the measure period. Replacement players may have played before an injury specific measure period only to have been dropped again. They may also appear as regular, injured or occasional players in the analysis period of other injuries in the sample.

[7] 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 is twofold. First, replacement defense players may provide less support to the goal-scoring activities of offense players (fewer assists). Second, in the presence of replacement defense players offense players need to be more involved in defense activities to the detriment of their offensive activities.

team sizes (see Kuhn and Yu (2021)). Chemical production plants for example cannot interrupt production at will and have a fixed number of operators at each point in time. From a research perspective this implies that we can clearly isolate the effect of the absence and replacement on remaining co-workers because firms cannot increase team size to overcome the production loss due to an absent worker. This has two implications. On the one hand, our estimates of the production loss are a lower bound for settings where a replacement worker is not always available or assigned. On the other hand, the production loss we pick up may be higher than in settings where firms can increase team size in response to an absence, e.g. by using multiple replacement workers to fill in for one absentee.

Second, the total working time of an ice hockey team is constrained by the duration of the game, meaning that the total working time of all workers combined is fixed. In this regard, ice hockey is comparable to other settings where total working time cannot easily be adjusted, such as retail stores with set opening hours (see Mas and Moretti (2009)) or 24/7 facilities such as chemical production plants or hospitals (see Bartel et al. (2014)). In our setting the remaining workers put in more working time during the absence of a substitute co-worker. Since total working time is fixed, this means that they compensate a share of the absent worker's lost working time instead of letting the replacement completely fill in this void.

Finally, worker preferences and behavior play a relatively minor role in determining worker absenteeism in our context.[8] Worker health is closely monitored in the NHL, leaving little room for workers to wrongfully claim an illness or injury. Worker absenteeism is usually caused by clearly identifiable injuries. A crucial feature for our identification strategy is that the timing of these injuries is random from the perspective of individual players. This does not mean that there are no determinants of the likelihood of an injury occurring. There is evidence that age of the player and playing time influence the occurrence of injuries (Warnock (2018)). For example, older players are more likely to be confronted with an injury when a foul is committed against them. The effect of playing time is straightforward. Assuming a constant injury rate the probability of an injury occurring is proportional to playing time. Furthermore, players differ in their playing style. Some are more aggressive, some more technical. Conditional on age and playing time, players with an aggressive playing style are more likely to be confronted with an injury. However, such systematic differences in injury rates between individual players and teams are cancelled out by the player-injury fixed effects design we use in our analysis. Some players will indeed have a higher injury rate than other players but crucially this does not provide any information about when an injury might occur. Conditional on the injury rate, the timing of an injury is random and this is what matters in our analysis. As such, the timing of absenteeism in our context is exogenously determined, alleviating endogeneity concerns present in previous research on the team productivity effects of worker absenteeism.

## 3. Data set

We obtain our dataset from two sources. From *www.nhl.com* we observe how many goals players scored, how many shots they took and how many minutes they played (i.e., were on the ice, not on the bench) in each game. Data from *www.mangameslost.com* (Man Games Lost Inc., 2019) 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.[9] For our analysis we define a measure period around each injury consisting of the five matches before the injury and the five matches after the injury occurred. We apply the following steps in assembling the data set. First, we link each injury to all player-game statistics in the affected 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. This removes approximately 6% of the games in our sample. 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 data set consisting of 4764 injuries, 3024 for substitute workers (offense) and 1740 for complementary workers (defense). These injuries affect 1896 unique non-goalie players, either as absentee or co-worker, of which 1262 exclusively played in offense, 634 exclusively in defense and 6 played in both roles.[10] In our analysis we only consider the effects of absentees on the performance of the offense players. We analyze a total of 450,707 player-game observations, 283,933 related to substitute worker absences and 166,774 related to complementary worker absences.

Table 1 gives an overview of pre and post injury statistics by worker type for substitute worker absences. 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 two performance statistics, output, expressed in goals scored and shots on goal per game, and working time, expressed in minutes played in a game. Using the output and working time measures we calculate worker productivity, defined as output per 15 minutes of working time.[11] 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 number of goals scored of these workers does not change much between the pre and post injury periods, while shots taken goes up from 1.938 to 1.977 per player-game (2.01% increase), suggesting that shot effectiveness (shots/goal) is lower in the post injury period. At the same time, their average working time goes up from 15.68 minutes to 16.07 minutes per game. As a result, their goal scoring productivity decreases from 0.200 to 0.195 goals per 15 minutes, representing a 2.4% decrease, while shot frequency is more or less unchanged.

The absent/replacement worker panel shows that the worker pool of replacement players contains 1.34 players on average, meaning that there is often more than one player who replaces the injured player. However, on average, out of these 1.34 replacement players, only 0.98 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 0.07 (-37%) fewer goals per game, take 0.53 fewer shots (-29%), but also spend nearly 4 minutes (-23%) less on the ice per game in comparison to the absent player. Still, this implies that replace-

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[8] De Paola et al. (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.

[9] The replication material can be found under doi:10.25397/eur.23142317.

[10] We removed the 6 players who played in both roles. Because of the strict distinction between offense and defense players we assume that the relevant substitutes for absent offense players are other offense players, and vice versa, that offense players cannot substitute for absent defense players. This is the basis for making an ex-ante distinction between both categories of absences, which we dub "substitute" and "complementary" in the paper. In other words, these terms relate to the degree a remaining worker may act to substitute an absentee. Note that we do not intend these classifications to imply anything about the degree of complementary in the actions of players on the ice. It is indeed possible that offense players regularly cooperate with each other in games, which one may interpret as them being "complementary" to one another.

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

**Table 1**
Descriptive statistics - substitute worker absence *(N injuries = 3,024)*.

| | 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 (goals) | 0.22 | 0.47 | 0 | 5 | 0.22 | 0.48 | 0 | 5 |
| Output (shots) | 1.94 | 1.62 | 0 | 14 | 1.98 | 1.63 | 0 | 14 |
| Working Time | 15.68 | 3.86 | 0.02 | 32.07 | 16.07 | 3.89 | 0.02 | 30.47 |
| Productivity (goals) | 0.20 | 0.45 | 0.00 | 8.49 | 0.19 | 0.44 | 0.00 | 4.38 |
| Productivity (shots) | 1.82 | 1.46 | 0.00 | 19.56 | 1.81 | 1.44 | 0.00 | 19.56 |
| Absent/replacement worker | | | | | | | | |
| Worker Pool | 1 | 0 | 1 | 1 | 1.34 | 1.11 | 0 | 9 |
| Selected lineup | 0.91 | 0.19 | 0.20 | 1 | 0.98 | 0.80 | 0 | 6 |
| Output (goals) | 0.19 | 0.45 | 0 | 4 | 0.12 | 0.34 | 0 | 3 |
| Output (shots) | 1.82 | 1.58 | 0 | 12 | 1.29 | 1.32 | 0 | 9 |
| Working Time | 14.95 | 4.05 | 0.38 | 28.68 | 11.44 | 4.09 | 0.03 | 25.22 |
| Productivity (goals) | 0.18 | 0.44 | 0.00 | 4.10 | 0.14 | 0.44 | 0.00 | 6.12 |
| Productivity (shots) | 1.78 | 1.50 | 0.00 | 18.75 | 1.65 | 1.65 | 0.00 | 14.06 |
| Occasional workers | | | | | | | | |
| Worker Pool | 4.25 | 2.09 | 0 | 16 | 3.11 | 1.77 | 0 | 11 |
| Selected lineup | 2.66 | 1.38 | 0 | 8 | 2.59 | 1.43 | 0 | 8.60 |
| Output (goals) | 0.12 | 0.36 | 0 | 3 | 0.14 | 0.38 | 0 | 3 |
| Output (shots) | 1.40 | 1.41 | 0 | 12 | 1.45 | 1.43 | 0 | 14 |
| Working Time | 12.36 | 4.37 | 0.02 | 28.20 | 12.63 | 4.39 | 0.02 | 27.68 |
| Productivity (goals) | 0.14 | 0.43 | 0 | 18.00 | 0.15 | 0.44 | 0.00 | 7.83 |
| Productivity (shots) | 1.65 | 1.63 | 0.00 | 50.00 | 1.66 | 1.59 | 0.00 | 15.65 |

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.

ments are less productive per unit of time, scoring around 0.04 (-22%) fewer goals and taking around 0.13 (-7.3%) fewer shots per 15 minutes on the ice. For occasional workers, the statistics show an increase in goals scored, working time and goal scoring productivity per game, but not in the average number of occasional workers selected to play and the number of shots taken, per game, and per unit of time. 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.

The descriptive statistics for the complementary worker injuries are presented in Table 2. Here, we cannot compare absent to replacement workers, because there is no absent offense player. Here we see a small drop in goal scoring output and productivity for regular workers, while shot output and productivity remain relatively stable, suggesting decreased effectiveness of shots taken in the post injury period. As is to be expected, the increase in working 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.

## 4. Empirical strategy

We quantify the effect of absences on the co-workers in the team through the following regression model,

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

$Y_{mit}$ represents the dependent variable, which is either output (goals or shots on goal), working time or productivity (goals or shots per 15 minutes of play) 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 Eq. (1) on the full sample of player-games and subsamples of regular, occasional and absent-replacement workers. We include injury-worker fixed effects $\gamma_{mi}$, such that the change in the dependent variable as measured by $\beta_1$ is relative to the worker's own pre injury average. However, when we investigate the difference between absent workers and their replacements we use injury fixed effects.

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 co-workers and the difference in skill between the injured worker and their 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.[12] 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 Eq. (1) using aggregated worker-group data for each game. The resulting model is given by,

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

Here, $\sum_{i \in g}^{G} Y_{mit}$ represent the sums of output and working time per game of all players within group $g$[13], which are then regressed on a post injury indicator ($Post_{mt}$) controlling for injury fixed effects $\phi_m$.

The aggregated model complements the within-player model (Eq. (1)) as follows. First, by construction the team level injury effect

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

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

**Table 2**

Descriptive statistics - complementary worker absence *(N injuries = 1,740)*.

| | Pre injury | | | | Post injury | | | |
|---|---|---|---|---|---|---|---|---|
| Regular workers | Average | Std. Dev. | Min. | Max. | Average | Std. Dev. | Min. | Max. |
| Worker Pool/Selected lineup | 8.83 | 1.47 | 4 | 12 | 8.83 | 1.47 | 4 | 12 |
| Output (goals) | 0.22 | 0.48 | 0 | 5 | 0.21 | 0.47 | 0 | 4 |
| Output (shots) | 1.97 | 1.63 | 0 | 14 | 1.95 | 1.62 | 0 | 13 |
| Working Time | 15.82 | 3.83 | 0.03 | 30.58 | 15.88 | 3.84 | 0.02 | 30.47 |
| Productivity (goals) | 0.20 | 0.45 | 0.00 | 7.20 | 0.19 | 0.44 | 0.00 | 7.83 |
| Productivity (shots) | 1.83 | 1.46 | 0.00 | 30.68 | 1.81 | 1.45 | 0.00 | 50.00 |
| Occasional workers | | | | | | | | |
| Worker Pool | 4.79 | 2.15 | 0 | 12 | 4.20 | 2.24 | 0 | 12 |
| Selected lineup | 3.14 | 1.47 | 0 | 8 | 3.14 | 1.47 | 0 | 8 |
| Output (goals) | 0.12 | 0.36 | 0 | 4 | 0.13 | 0.38 | 0 | 3 |
| Output (shots) | 1.39 | 1.40 | 0 | 12 | 1.43 | 1.43 | 0 | 12 |
| Working Time | 12.31 | 4.41 | 0.02 | 32.42 | 12.45 | 4.35 | 0.03 | 26.95 |
| Productivity (goals) | 0.13 | 0.41 | 0.00 | 6.25 | 0.15 | 0.45 | 0.00 | 18.00 |
| Productivity (shots) | 1.63 | 1.63 | 0.00 | 50.00 | 1.66 | 1.66 | 0.00 | 50.00 |

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.

$\delta_1$ is equal to the weighted sum of the $\delta_1$ 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.

## 5. Results

### 5.1. Player-Level results

Panel A of Table 3 reports the parameter estimates corresponding to Eq. (1) for substitute worker (offense player) absences. Since we use injury-worker fixed effects the coefficients are estimated by comparing a worker's performance after a co-worker 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 and occasional workers who do not appear after the injury. These injury-worker fixed effects estimates are reported in the first three rows of Table 3. For all workers combined, the results show that there is no effect on worker output measured in goals scored per game. However, there is a positive effect for shots on goal, suggesting a lower shot effectiveness post injury. At the same time, working time 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 both goal scoring productivity

**Table 3**

Effect of worker absence on output, productivity and working time.

| Panel A: Substitute worker absence | | | | | | | |
|---|---|---|---|---|---|---|---|
| Co-worker | Output | | Productivity | | Working Time | Observations | Fixed |
| Category | *goals×100* | *shots×100* | $\frac{goals\times100}{15\ mins}$ | $\frac{shots\times100}{15\ mins}$ | *minutes played* | *player-games* | Effects |
| All | 0.085<br>(0.187) | 2.620$^{***}$<br>(0.648) | −0.359$^{*}$<br>(0.186) | −1.616$^{**}$<br>(0.643) | 0.336$^{***}$<br>(0.012) | 251,603 | Player-injury |
| Regular | −0.043<br>(0.223) | 2.670$^{***}$<br>(0.742) | −0.520$^{**}$<br>(0.212) | −1.235$^{*}$<br>(0.692) | 0.346$^{***}$<br>(0.015) | 197,319 | Player-injury |
| Occasional | 0.546$^{*}$<br>(0.324) | 2.436$^{**}$<br>(1.158) | 0.221<br>(0.389) | −2.990$^{**}$<br>(1.416) | 0.300$^{***}$<br>(0.027) | 54,284 | Player-injury |
| Absent vs. Replacement | −6.794$^{***}$<br>(0.621) | −51.773$^{***}$<br>(2.802) | −3.599$^{***}$<br>(0.687) | −12.251$^{***}$<br>(2.695) | −3.580$^{***}$<br>(0.100) | 22,829 | Injury |
| Panel B: Complementary worker absence | | | | | | | |
| All | −0.616$^{***}$<br>(0.227) | −2.511$^{***}$<br>(0.822) | −0.722$^{***}$<br>(0.231) | −2.441$^{***}$<br>(0.828) | −0.011<br>(0.014) | 155,768 | Player-injury |
| Regular | −0.755$^{***}$<br>(0.271) | −2.597$^{***}$<br>(0.952) | −0.850$^{***}$<br>(0.260) | −2.563$^{***}$<br>(0.901) | 0.011<br>(0.018) | 121,563 | Player injury |
| Occasional | −0.117<br>(0.404) | −2.204<br>(1.459) | −0.260<br>(0.506) | −2.000<br>(1.816) | −0.091$^{***}$<br>(0.032) | 34,205 | Player injury |

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. All workers in the top row therefore refers to all workers except the injured - replacement and these occasional workers. Standard errors are clustered at the injury level and reported in parentheses. Significance is indicated as follows: $^{*}$ p-value< 0.1; $^{**}$ p-value< 0.05; $^{***}$ p-value< 0.01.

**Table 4**
The effect of injuries on team performance and working time.

| | *Substitute worker absence* | | | *Complementary worker absence* | | |
|---|---|---|---|---|---|---|
| Co-worker Category | Output *goals×100* | Output *shots×100* | Working Time *minutes played* | Output *goals×100* | Output *shots×100* | Working Time *minutes played* |
| All | −4.503$^{**}$ | −22.355$^{***}$ | −0.080 | −2.762 | −12.024 | 0.264$^{***}$ |
| | (2.087) | (7.216) | (0.074) | (2.601) | (9.535) | (0.099) |
| Regular | −0.357 | 22.065$^{***}$ | 2.859$^{***}$ | −6.533$^{***}$ | −22.483$^{***}$ | 0.093 |
| | (1.839) | (6.131) | (0.124) | (2.344) | (8.247) | (0.152) |
| Occasional | 1.198 | −9.921$^{**}$ | −0.899$^{***}$ | 3.771$^{***}$ | 10.459$^{**}$ | 0.171 |
| | (0.866) | (3.925) | (0.222) | (1.189) | (4.766) | (0.139) |
| Absent vs. Replacement | −5.343$^{***}$ | −34.498$^{***}$ | −2.040$^{***}$ | | | |
| | (0.587) | (3.357) | (0.212) | | | |
| Fixed Effects | | Injury | | | Injury | |
| Observations | | 23,701 | | | 13,926 | |

Notes: Each cell represents a separate regression for each variable and worker category. We add injury fixed effects in all of our specifications. Observation counts are measured at the team-game level. Standard errors are clustered at the injury level and reported in parentheses. Significance is indicated as follows: $^{*}$ p-value< 0.1; $^{**}$ p-value< 0.05; $^{***}$ p-value< 0.01.

and shot frequency are significantly negatively affected. When looking at regular and occasional workers we see that this negative goal scoring productivity effect is primarily driven by regular workers having a large drop in their productivity. On average these players score 0.0052 fewer goals per 15 minutes of play[14], representing a 2.6% drop in productivity compared to their pre injury productivity as reported in Table 1. Occasional workers do not see a significant change in their goal scoring productivity as both their working time and output increase similarly. For shot frequency, both regular and occasional workers are negatively affected. 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 be able to compare the performance of the injured worker and their replacement we cannot use injury-worker fixed effects as injured workers only played before their injury and replacement workers played only after the injury occurred. Therefore, we use injury fixed effects in the estimates reported in the last row of Panel A of Table 3. Clearly, replacement workers have a substantially lower output than the workers they replace. The replacement player(s) score on average 0.068 less goals and take 0.52 fewer shots per game in comparison to the injured player they replace. This results from replacement workers having less working time and being less productive, both in terms of goals scored and shots taken, than the absent worker.

Panel B of Table 3 shifts the focus to complementary worker (defense player) absences. 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. For goals scored, worker output and productivity decrease by 0.0062 goals and 0.0072 goals per 15 minutes. For shots taken, worker output and productivity are also significantly negatively affected. 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. This is unsurprising as there are more offense players than defense players on a team. First, this implies that a defense injury affects relatively more offense players, because the ratio defense to offense players is lower than the ratio offense to offense. Second, an injured defense player makes on average more ice time than an offense player before their injury. A weaker replacement is therefore active during relatively more production time, leading to lower peer production for a longer period.

The second and third row of Panel B show the results for regular and occasional workers respectively. Regular workers are most affected by complementary worker injuries, scoring significantly fewer goals and taking fewer shots per game along with having significantly lower productivity in terms of goals and shots per 15 minutes. Occasional workers on the other hand are mostly unaffected by complementary worker injuries, apart from their working time going down slightly.

## 5.2. *Team production results*

Table 4 presents the effects of substitute and complementary worker absences on team production (see Eq. (2)). The first three columns show the coefficients for goals scored, shots taken 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 both types of output. On average, all offense players combined score nearly 0.05 fewer goals and take 0.22 fewer shots in the post injury period in comparison to the pre injury period. When subdivided into parts, the results indicate that the differences 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 around two minutes less than the injured player and the occasional players playing nearly one minute less in the post injury period.

The last three columns of Table 4 show results for complementary worker injuries. Here we find that there is no significant effect on both output types 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 0.264 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 worker has a negative effect on team production is very different depending on nature of

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

**Table 5**
Effect of injury on individual regular workers for various sample windows.

| Sample | Output | | Productivity | | Working Time | Observations |
|---|---|---|---|---|---|---|
| | *goals×100* | *shots×100* | $\frac{goals\times100}{15\ mins}$ | $\frac{shots\times100}{15\ mins}$ | *minutes played* | *player-games* |
| Panel A: Substitute worker absence | | | | | | |
| -1 to + 1 | 0.000 | 2.150$^{*}$ | −0.438 | −2.146$^{*}$ | 0.357$^{***}$ | 54,234 |
| | (0.384) | (1.307) | (0.375) | (1.282) | (0.018) | |
| -2 to + 2 | −0.218 | 1.352 | −0.632$^{**}$ | −2.980$^{***}$ | 0.355$^{***}$ | 100,441 |
| | (0.292) | (0.977) | (0.283) | (0.936) | (0.016) | |
| -3 to + 3 | −0.273 | 1.364 | −0.704$^{***}$ | −2.874$^{***}$ | 0.341$^{***}$ | 138,518 |
| | (0.252) | (0.856) | (0.242) | (0.811) | (0.015) | |
| -4 to + 4 | −0.074 | 1.754$^{**}$ | −0.551$^{**}$ | −2.516$^{***}$ | 0.344$^{***}$ | 170,146 |
| | (0.232) | (0.785) | (0.222) | (0.735) | (0.015) | |
| -5 to + 5 | −0.043 | 2.670$^{***}$ | −0.520$^{**}$ | −1.235$^{*}$ | 0.346$^{***}$ | 197,319 |
| | (0.223) | (0.742) | (0.212) | (0.692) | (0.015) | |
| Panel B: Complementary worker absence | | | | | | |
| -1 to + 1 | −1.036$^{**}$ | −4.251$^{***}$ | −1.086$^{**}$ | −4.308$^{***}$ | −0.058$^{***}$ | 33,596 |
| | (0.497) | (1.646) | (0.504) | (1.623) | (0.021) | |
| -2 to + 2 | −0.717$^{*}$ | −2.888$^{**}$ | −0.844$^{**}$ | −3.118$^{**}$ | −0.022 | 61,782 |
| | (0.367) | (1.252) | (0.358) | (1.211) | (0.018) | |
| -3 to + 3 | −0.807$^{**}$ | −2.661$^{**}$ | −0.929$^{***}$ | −2.728$^{***}$ | −0.015 | 84,920 |
| | (0.315) | (1.077) | (0.306) | (1.029) | (0.018) | |
| -4 to + 4 | −0.670$^{**}$ | −2.265$^{**}$ | −0.723$^{**}$ | −2.233$^{**}$ | 0.003 | 104,648 |
| | (0.291) | (1.002) | (0.281) | (0.951) | (0.017) | |
| -5 to + 5 | −0.755$^{***}$ | −2.597$^{***}$ | −0.850$^{***}$ | −2.563$^{***}$ | 0.011 | 121,563 |
| | (0.271) | (0.952) | (0.260) | (0.901) | (0.018) | |

Notes: The sample is restricted to only include regular workers. We add injury-worker fixed effects in all of our specifications. The -5 to + 5 parameter estimates for substitute workers (complementary workers) are identical to those for the regular workers presented in Table 2 (Table 3). Standard errors are clustered at the injury level and reported in parentheses. Significance is indicated as follows: $^{*}$ p-value< 0.1; $^{**}$ p-value< 0.05; $^{***}$ p-value< 0.01.

the relationship between the worker and the team. If the worker is a substitute co-worker, the replacement of the absent worker 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.

## 6. Robustness tests

### 6.1. Accounting for pre and post injury trends

A first concern with our results is that timing of injuries is non-random and tied to (co-) worker performance. Indeed, online appendix Figures A.1 and A.2 show that visually there are some trends in pre and post injury output and productivity. We address this concern by including pre and post injury trends in our analyses. We do this by re-specifying Eq. (1) as follows:

$$Y_{mit} = \beta_0 + \beta_1 * Post_{mt} + \beta_2 * PreTrend_{mt} + \beta_3 * PostTrend_{mt} + \gamma_{mi} + \epsilon_{mit}. \tag{3}$$

Here, the pre (post) trend variable is a linear function of the number of games that have occurred before (after) the injury. The $\beta_1$ essentially captures the change in performance from just before the injury (time to injury = -1) to just after the injury (time to injury = 1), after controlling for linear trends in both pre and post injury performance.

We present the results for regular workers using goal and shot count as the performance measure in Tables A.2 and A.3. In the goal count results (Table A.2), pre and post injury trends are mostly insignificant apart from a downward pre trend for goals scored per 15 minutes and very small trends in working time. Notably, the signs of the coefficients for the shifts in performance remain intact, but are less precisely estimated and therefore insignificant. The statistical power of our dataset is not large enough to pick up significant changes in performance while also estimating time trends and injury-worker fixed effects.

Using shot count as the performance measure might help in this regard. Shots on goal are more frequent events than actual goals scored, which increases the precision at which it measures performance along with the subsequent performance effect estimates. The results for shot count variable are in Table A.3. As in our main results, the output coefficient for substitute worker injuries is insignificant although there is a significant drop in productivity. We also find a significant upward pre injury trend. The coefficients for output and productivity following a complementary worker injury are very similar to those found in the baseline results, but do lose their significance due to the inclusion of trends. The working time results are the same as in Table A.2 and only included for completeness.[15]

On the whole, there seem to be some trends present in pre and post injury performance. However, these trends are often insignificant and inconsistent in terms of direction. Conditional on these trends, we find that the coefficients for level shifts in performance following both types of injuries are not affected in terms of their sign, but do lose their significance in some cases due to loss of statistical power. All in all, we conclude that our main findings do not change if we account for pre and post injury trends

### 6.2. Varying sample sizes

Our result may be sensitive to the number of games included in the sample before and after the injury, 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 would

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[15] As additional sensitivity analysis we include the strength of the opponent in the analysis. We measure the strength of the non-affected team by the logarithm of the wage sum of that team. Note that the strength of the affected team is controlled for by the fixed effects. This hardly affects the parameter estimates presented in Tables 3 and 4. Whereas differences in team strengths are likely to affect match outcomes they do not influence the performance of individual players in response to an injury.

**Table 6**

Effect of worker absence - restricted sample.

| Co-worker Category | Output | | Productivity | | Working Time | Observations | Fixed effects |
|---|---|---|---|---|---|---|---|
| | *goals×100* | *shots×100* | $\frac{goals\times100}{15\ mins}$ | $\frac{shots\times100}{15\ mins}$ | *minutes played* | *player-games* | |
| **Panel A: Substitute worker absence** | | | | | | | |
| All | −1.303$^{**}$ | 1.580 | −1.778$^{***}$ | −2.591 | 0.345$^{***}$ | 23,273 | Injury-worker |
| | (0.651) | (2.204) | (0.648) | (2.231) | (0.029) | | |
| Regular | −1.463$^{**}$ | 1.582 | −1.978$^{***}$ | −2.574 | 0.342$^{***}$ | 21,641 | Injury-worker |
| | (0.699) | (2.318) | (0.687) | (2.302) | (0.033) | | |
| Occasional | 0.733 | 1.559 | 0.757 | −2.803 | 0.385$^{***}$ | 1632 | Injury-worker |
| | (1.595) | (5.301) | (2.034) | (7.525) | (0.135) | | |
| Absent vs. Replacement | −6.260$^{***}$ | −65.626$^{***}$ | −0.518 | −4.983 | −4.993$^{***}$ | 2077 | Injury |
| | (1.929) | (7.610) | (2.286) | (8.474) | (0.235) | | |
| **Panel B: Complementary worker absence** | | | | | | | |
| All | −0.970 | −0.917 | −1.131 | −1.614 | 0.004 | 16,774 | Injury-worker |
| | (0.729) | (2.657) | (0.714) | (2.601) | (0.027) | | |
| Regular | −0.966 | 0.059 | −1.009 | −0.162 | 0.006 | 15,581 | Injury-worker |
| | (0.771) | (2.761) | (0.740) | (2.600) | (0.031) | | |
| Occasional | −1.032 | −13.396$^{*}$ | −2.697 | −20.170$^{*}$ | −0.018 | 1193 | Injury-worker |
| | (1.816) | (7.684) | (2.502) | (10.680) | (0.134) | | |

Notes: The sample is restricted to only include regular workers. We add injury-worker fixed effects in all of our specifications. Standard errors are clustered at the injury level and reported in parentheses. Significance is indicated as follows: $^{*}$ p-value< 0.1; $^{**}$ p-value< 0.05; $^{***}$ p-value< 0.01.

induce more bias when more games are included. To investigate these issues, we estimate the regular worker coefficients from Eq. (1) using various window widths, ranging from one to four games before and after the injury.[16]

Table 5 presents the results of this sensitivity analysis. The two bottom rows of the table replicate the parameter estimates using the main sample specification with a window from -5 to +5 games. For substitute co-worker injuries, we find insignificant effects on goal scoring output for all sample lengths and significantly negative effects for goal scoring productivity in all samples except for the window -1 to +1. For output and productivity measured using shots we find positive output effects and negative productivity effects with various levels of significance across samples. Notably the shots on goal effect in the -1 to +1 sample is very similar to the one found in the -5 to +5 sample. As in the main results, we document significantly positive effects for working time in all samples. For complementary coworker injuries, both types of output and productivity effects are significantly negative throughout. The working time effects differ across various windows of analysis; significantly negative for the window -1 to +1 and insignificantly different from zero for the wider windows. Despite the large difference in number of observations, Table 5 shows that our estimates are qualitatively similar across window widths. We find no significant sign reversions in any of our variables of interest. Hence, our conclusions are robust in terms of the number of games we include in the analysis.

### 6.3. *Removing overlap between injuries*

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 Eq. (1) after removing all observations which are affected by other co-worker injuries or recoveries. Because of this selection the number of observations drops substantially. For example in the estimates with injury-worker fixed effects the number of observations of substitute workers goes down from more than 250,000 to about 23,000, i.e., less than 10% of the observations are left after imposing the restrictions on overlap with other co-worker injuries or recoveries. Nevertheless, the results for substitute workers shown in Panel A of Table 6 indicate that the effects on working time are very similar to the ones in the baseline estimates of Table 3. Both productivity effects are more negative than our baseline results. The increase in working time falls short of fully compensating the output loss.

The sample selection also has a big effect on the number of injuries for complementary workers which drops from more than 150,000 in the estimates with injury-worker fixed effects to about 17,000. Nevertheless, the main parameter estimates are similar. As shown in Panel B of Table 6 for complementary worker injuries, the output and productivity coefficients remain negative, but become mostly insignificant due to a large loss in the observation count.

## 7. Conclusions

We investigate how the absence and replacement of workers in production teams affects the productivity, working time and output of their co-workers. In our setting, the National Hockey League, there are two types of absentees, those who perform substitute tasks and those who perform complementary tasks to the co-workers 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. The replacement worker therefore takes over only a part 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 co-worker injury, the production teams in our setting simultaneously experience a disruption to their co-worker network and a decrease in co-worker skill, because the replacement worker is on average less productive than the absent worker. Both peer effects and the loss of co-working 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.

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[16] Naturally the number of observations is strongly correlated with the length of the measure period; see online Appendix Table A.1.

Clearly, the setting of our analysis has some defining features which have implications for the generalizability of our results. For example, the total working time and size of the production team are fixed. Furthermore, an absent worker will always be replaced and firms anticipate absenteeism by carrying extra players. Therefore, firms have ample experience in dealing with worker absences. Nevertheless, also regular firms often have a fixed working time like firms in retailing or firms with a 24/7 work process like hospitals or chemical plants. The fixed team size is reminiscent of other environments where team size cannot be altered at will or in the short run like for example production plants with continuous shifts or a fixed number of operators. Furthermore, firms in regular industries will also anticipate absenteeism because workers becoming ill is a recurrent phenomenon. Therefore, these firms may have workers stand-by through contracts with temporary work agencies. Or, alternatively in case of worker absence they may stimulate co-workers to increase their hours of work on a temporary basis.

All in all, we think that our study has a clear external validity, offering a deeper understanding of the relationship between absenteeism and firm productivity. By presenting various ways an absent co-worker is replaced, we show an anatomy of absenteeism, disentangling productivity effects of changing working hours of incumbent workers and replacements through substitute workers with a lower productivity. Nevertheless, given the full replacement of absentees our results may underestimate the production loss absenteeism causes when worker replacement is uncommon. On the other hand, firms in our setting cannot use larger teams to mitigate the damage which may be also possible in other settings. Future research may seek to better understand the combined effect of these two countervailing powers.

## Data availability

The replication material can be found under doi: https://doi.org/10.25397/eur.23142317.

## Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.labeco.2023.102400

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