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The effect of a minor health shock on labour market outcomes: The case of concussions*

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Abstract

The literature on health shocks finds that minor injuries have only a short-term impact on labour market outcomes. However, mild traumatic brain injuries (mTBIs, commonly referred to as concussions) may be different as the medical literature highlights that they can have long-term health and cognitive effects. We use administrative data on all medically-diagnosed mTBIs in New Zealand linked to monthly tax records to examine the labour market effects of suffering a mTBI up to four years after the injury. We use a comparison group of those who suffer a mTBI but at a later date to overcome potential endogeneity issues, and employ a doubly-robust difference-in-differences method. We find that suffering a mTBI has negative effects on both employment and earnings. Rather than dissipating over time, these negative effects grow, representing a decrease in employment rate of 20 percentage points and earning losses of about a third after 48 months. Our results highlight the need for timely diagnosis and treatment to mitigate the effect of mTBIs on individuals' labour market outcomes to reduce economic and social costs.

Keywords: health shock; mild traumatic brain injury; labour market outcomes

JEL classification: I10, I14, J01, J31

*_**Disclaimer:**_ These results are not official statistics. They have been created for research purposes from the Integrated Data Infrastructure (IDI) which is carefully managed by Stats NZ. For more information about the IDI please visit https://www.stats.govt.nz/integrated-data/. The results are based in part on tax data supplied by Inland Revenue to Stats NZ under the Tax Administration Act 1994 for statistical purposes. Any discussion of data limitations or weaknesses is in the context of using the IDI for statistical purposes, and is not related to the data's ability to support Inland Revenue's core operational requirements.

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1 Introduction

There is a growing economics literature on the impact of health shocks on labour market outcomes. Previous studies have shown negative effects of such shocks on both employment and income (e.g., García Gómez & López Nicolás, 2006; García-Gómez et al., 2013; Lenhart, 2019). However, to the best of our knowledge, there are no existing economic studies on the effects of mild traumatic brain injuries (mTBIs, commonly referred to as concussions) on subsequent labour market outcomes, despite the increasing awareness of the potential health and cognitive consequences of TBIs and the high incidence of such injuries. Moreover, while there are studies on mTBI in the health literature, very few examine the longer-term effects of mTBI on labour market outcomes, and virtually none account for potential endogeneity and attempt to establish causal links.

A traumatic brain injury (TBI) is defined in the International Classification of Diseases (ICD-10) as "*a traumatically induced structural injury or physiological disruption of brain function as a result of external force that is indicated by new onset or worsening of at least one of the following clinical signs immediately following the event: any alteration in mental status (e.g., confusion, disorientation, slowed thinking, etc.); any loss of memory for events immediately before or after the injury; any period of loss of, or a decreased level of, consciousness, observed or self-reported*". While there is increasing awareness of the impact of repeated concussions among athletes in contact sports, most mTBIs are caused by falls during everyday activities, with less than 30% occurring while playing sports (Accident Compensation Corporation, 2022). Thus, the risk of mTBIs is widespread.

In New Zealand, more than 36,000 people experience a TBI each year, with 95% of these cases being considered mild (Feigin et al., 2013). Worldwide, TBI is one of the most common causes of disability and death in adults and the leading cause of disability in children and young adults (Hyder et al., 2007; Langlois et al., 2006). Further, significant costs are associated with this health shock. For example, in the U.S., the total estimated healthcare spending attributable to non-fatal TBI was more than $40 billion in 2016, with the costs relating to mTBI being greater than more severe cases of TBI due to the higher incidence rate (Miller et al., 2021).

While apparently minor in nature, mTBIs may have persistent symptoms and long-term effects (Dean & Sterr, 2013). The exact mechanisms involved are complex and are not yet fully understood. However, van der Horn et al. (2020) summarises the existing evidence, highlighting the importance of the interplay between physiological and psychological processes. This evidence suggests that in the early stages, the physiological issues (e.g. cell injury and inflammation) and the acute stress response leads to neural network dysfunction. Patients often report symptoms such as fatigue, headaches, poor concentration and unstable moods. As time passes, psychological processes become more influential, and factors such as coping styles, personality, emotional regulation and the extent of other life demands come into play. Long-lasting symptoms can emerge, potentially leading to negative impacts on social integration, educational and labour market outcomes, and even to increases in antisocial behaviour (Theadom et al., 2023; Wehman et al., 2017; Williams et al., 2015). Moreover, while public awareness is growing of the issues caused by repeated mTBIs in contact sports, just one mTBI can have negative effects, further highlighting the potential implications for the general population (Theadom et al., 2023).

Given the persistent health and cognitive outcomes for mTBI cases, it is likely that labour market effects will differ from other forms of minor or temporary health shocks. Existing evidence suggests that temporary health issues (specifically those that last 3 months or less) do not have long-term effects on employment and income (Pelkowski & Berger, 2004), and that effects on labour market outcomes generally increase as the severity of the health shock increases (Crichton et al., 2011). Given this evidence, we could expect mTBI to have limited effects on future employment or earnings. However, mTBIs are, by their nature, potentially different from other minor injuries and may have long-lasting effects.

Therefore, this paper examines (1) if mTBI has an effect on future employment and earnings; (2) if any effect is limited to the short term or if it remains significant after a longer time period; and (3) how the effects of mTBIs differ by age, gender, ethnicity or occupational skill level. In addition, we also explore the extent to which the accident compensation system offsets earning losses.

To this end, we use a staggered difference-in-differences framework (Callaway & Sant'Anna, 2021) that allows us to study the monthly effects of the health shock on earnings and employment, while taking into account the fact that not all individuals experience the shock at the same time. Because individuals who experienced a mTBI might have specific unobservable characteristics that affect both their risk of TBI and their labour outcomes, we follow Fadlon and Nielsen (2019) and construct counterfactuals for individuals suffering from a mTBI using individuals who experience one in the future. This is facilitated by New Zealand's linked administrative data, which includes Accident Compensation Corporation (ACC) injury data linked to Inland Revenue (IR) income data. These data allow us to estimate the monthly treatment effects on both earnings and employment up to 48 months after the shock.

These data provide advantages over existing studies. First, ACC data covers all medically-diagnosed mTBIs whereas other studies are typically reliant on hospital data, which is more limited in terms of identifying TBIs, particularly mild ones (Graff et al., 2019). Indeed, only about a fifth of individuals in our sample were treated at a hospital, with the majority being treated by a primary care physician. Moreover, IR income data are available on a monthly rather than an annual basis, allowing for the short- and medium-term effects of mTBIs to be better observed.

In addition to these data advantages, this paper offers methodological and policy contributions. First, there are few existing studies that examine the longer-term effects of mTBI on labour market outcomes (Graff et al., 2019; Theadom et al., 2017). Given that mTBI can, in contrast to most other minor physical injuries, have long-lasting effects, it is important to examine longer-term outcomes.

There also appears to be only one existing paper which analyses this issue using quasi-experimental methods to account for the potential endogeneity of suffering a TBI and labour market outcomes. Specifically, Fallesen and Campos (2020) use those who suffer TBIs at a later date as a comparison group, as our analysis also does. Relative to that paper, we make a number of further contributions to the literature. First, as mentioned, we use all medically-diagnosed mTBIs and monthly earnings, which has advantages over the Fallesen and Campos (2020)'s use of Danish hospital and emergency room data to identify those who suffer a TBI and annual earnings data. Moreover, Fallesen and Campos (2020) applies a two-way staggered DiD method, which may not be adequate to identify an average treatment effect when effects are heterogeneous (de Chaisemartin & D'Haultfœuille, 2020; Goodman-Bacon, 2021). Thus, we apply Callaway and Sant'Anna (2021)'s doubly-robust staggered difference-in-differences approach. We believe that there are just a handful of studies to date to apply this approach, and to the best of our knowledge our paper is the first to apply it to examine the impacts of a health shock.

We also make a contribution from a policy perspective. Given the high prevalence of mTBI and the fact that mTBI can, unlike most other minor physical injuries, have long-lasting effects, we add to the understanding of the potential costs to individuals in terms of their future earnings, and to society in terms of lost productivity and the potential increased burden on health and social welfare systems.

The rest of the paper proceeds as follows. Section 2 reviews previous evidence on labour market outcomes and health shocks. Section 3 details our empirical strategy. Section 4 describes the data and population of interest. Section 5 presents and discusses our results. Section 6 concludes.

2 Literature review

This study relates to the economics literature on health shocks and subsequent labour market outcomes, as well as the health literature on the consequences of TBIs.

In terms of the economics literature on health shocks, numerous studies explore the links between health and labour market outcomes, whether investigating how unemployment and income can affect health or how health conditions alter labour market trajectories. There is previous evidence of a negative effect of job loss and unemployment on health (Eliason & Storrie, 2009; Sullivan & von Wachter, 2009). There is also a strong positive relationship between income and health, known as the "income gradient of health" (Case et al., 2002). However, these results may suffer from endogeneity and reverse causality issues. Therefore, more recent studies explored the reverse relationship, *i.e.* the effect of health on labour market outcomes.

Empirical studies investigating these effects examine various health shocks such as road accidents (Dano, 2005; Halla & Zweimüller, 2013) or sudden hospitalisations (García-Gómez et al., 2013; Lindeboom et al., 2016), as well as self-assessed health indicators (Contoyannis & Rice, 2001; Lenhart, 2019; Riphahn, 1999) and disability (Lechner & Vazquez-Alvarez, 2011). In general, these studies find negative effects of adverse health shocks on both employment and earnings (García-Gómez et al., 2013; Halla & Zweimüller, 2013). In general, studies have also found that whether the negative labour market effects persist over time depends on the severity of the injury. For example, Crichton et al. (2011) shows that more severe health shocks have stronger effects on labour market outcomes, and Pelkowski and Berger (2004) finds that temporary illnesses do not have any significant long-term effects on employment and income.

Findings also highlight differences between demographic groups in terms of the impact of health shocks. Riphahn (1999) and Pelkowski and Berger (2004) find a larger effect on income for women, but a stronger effect on employment for men. Similar effects on employment are found in Dano (2005), Lenhart (2019) and Zucchelli et al. (2010), and on earnings in Crichton et al. (2011). However, Contoyannis and Rice (2001) and Dano (2005) find that only men experience long-term effects on earnings. Many studies also find stronger effects on employment for older workers (Crichton et al., 2011; García-Gómez et al., 2013; Halla & Zweimüller, 2013), often related to the higher severity of the accidents and a lower ability of this population to recover from them. Part of the larger negative effect on employment with age can also be attributed to the opportunity of early retirement (Zucchelli et al., 2010). On the contrary, young workers seem to experience higher and more persistent income penalties (Halla & Zweimüller, 2013), maybe because of a negative effect on productivity but lower effects on employment. Finally, individuals with lower income prior to the shock suffer larger detrimental effects (Crichton et al., 2011; Dano, 2005; García-Gómez et al., 2013; Riphahn, 1999).

The institutional context also has an influence on labour market outcomes after health shocks. For example, Lechner and Vazquez-Alvarez (2011) show that while health shocks reduce the probability of being employed and decrease labour earnings, negative effects on income are (at least partially) compensated by disability benefits in countries with more protective social security systems. García-Gómez (2011) also show that the negative effect on employment can be reduced in the presence of quotas for disabled workers.

To our knowledge, there is no existing research in the economics literature specifically examining TBIs and subsequent labour market outcomes. However, there is health research on this topic. For example, using Danish hospital data, Graff et al. (2019) finds a strong negative effect on employment five years after the shock and Fallesen and Campos (2020) finds large income penalties. Using New Zealand data on 245 adults from the Brain Injury Incidence and Outcomes New Zealand in the Community longitudinal study, Theadom et al. (2017) shows that more than 15% of the individuals had exited the labour force four years after experiencing a mTBI, and those who remained in employment suffered work limitations and productivity losses.

An issue in this literature is the ability to attribute the outcomes to the TBI given that there may be a correlation between generally unobservable individual characteristics, such as risk preferences, and both the likelihood of suffering a TBI and labour market outcomes. As far as we are aware, there is only one existing study which addresses this issue using quasi-experimental methods. Fallesen and Campos (2020) uses a comparison group of those who suffer a mTBI at a future time point, following Fadlon and Nielsen (2019)'s approach. It finds that suffering a mTBI reduces average annual salary by 4.2%, mostly due to lower employment rates among those who suffered from a concussion. As discussed, we use a similar methodology, but are able to include all medically-diagnosed mTBIs, including those treated by primary healthcare providers and use monthly, rather than annual, employment and income data, allowing for a clearer differentiation between short-run and more persistent effects. Moreover, we use the method of Callaway and Sant'Anna (2021) to address the potential issue of bias in the application of standard two-way fixed effects regressions to staggered difference-in-differences analysis.

3 Empirical strategy

For causal estimates of the effects of mTBI on labour market outcomes, we need counterfactual outcomes of what would have happened to these individuals if they had not suffered from a mTBI. A simple comparison with those who have not suffered a mTBI would not enable any observed effect to be attributed to the mTBI. For instance, the (unobserved) characteristics of those who suffer from a mTBI are likely to be different from those who did not suffer from one (e.g. more likely to engage in risk-taking behaviour), and these characteristics are also likely to be correlated with labour market outcomes. This could lead to selection bias when comparing those who did and did not suffer from a mTBI and an overestimation of the mTBI's effects. To address this concern, we use a quasi-experimental design and construct counterfactuals using individuals who experienced the same mTBI shock but in the future (as per Fadlon & Nielsen, 2019). Therefore, our control group is not composed of individuals who will never be treated, but instead, of individuals who are not treated yet at each point in time.

Focusing on mTBIs is not an arbitrary choice. Indeed, this kind of accident is likely to be sudden and unpredictable, ensuring the randomness of the timing that we need in our strategy. Moreover, mTBIs are a very common injury and a major cause of disability and death according to the World Health Organization (WHO). They are, therefore, of particular interest in terms of public health policies and have consequences for other socio-economic outcomes. In addition, the high incidence of mTBI provides us with a large sample size which is likely to improve the robustness of our results.

One concern with our quasi-experimental design is that the individuals in our sample are not all treated at the same time, and that treatment effects are likely to vary over time. Therefore, results from a standard two-way fixed effects (TWFE) regression (i.e. a regression including both individual and time fixed effects) may be biased (Callaway & Sant'Anna, 2021; de Chaisemartin & D'Haultfœuille, 2020; Sun & Abraham, 2021) and cannot necessarily be interpreted as causal effects. To deal with this issue, we rely on the doubly-robust difference-in-differences estimator proposed by Callaway and Sant'Anna (2021).

3.1 Model

We estimate the following staggered difference-in-differences (DiD) model:

$$Y^{g,t} = \alpha_1^{g,t} + \alpha_2^{g,t}.G_g + \alpha_3^{g,t}.1\{T = t\} + \beta^{g,t}.(G_g \times 1\{T = t\}) + \gamma.X + \epsilon^{g,t} \tag{1}$$

where g denotes the groups, each group corresponding to all individuals starting to be treated at time G. $Y^{g,t}$ denotes the labour earnings of group g at time t, α_2 and α_3 are respectively group and time fixed effects, and X denotes the individual controls. To differentiate between the intensive and extensive margins, we also estimate the effects of mTBI on employment, using the same specification as in Equation 1, but with $Y^{g,t}$ the employment observed in group g at time t. Under limited anticipation and homogeneous treatment effects assumptions, the average treatment effects $ATT^{g,t}$ are given by $\beta^{g,t}$. However, they are not obtained through the standard $ATT^{g,t} = \mathbb{E}[Y_t(g) - Y_t(0)|G_g = 1]$, but are instead re-weighted using propensity scores. Following Callaway and Sant'Anna (2021), the average treatment effect of group g at time t can be written:

$$ATT(g;t;\delta) = \left[\left(\frac{G_g}{\mathbb{E}[G_g]} - \frac{\frac{p_{g,t+\delta}(X)(1-D_{t+\delta})(1-G_g)}{1-p_{g,t+\delta}(X)}}{\mathbb{E}\left[\frac{p_{g,t+\delta}(X)(1-D_{t+\delta})(1-G_g)}{1-p_{g,t+\delta}(X)}\right]} \right) \left(Y_t - Y_{g-\delta-1} - m^{ny}_{g,t,\delta}(X)\right) \right] \tag{2}$$

where $m^{ny}_{g,t,\delta}(X) = \mathbb{E}[Y_t - Y_{g-\delta-1}|X, D_{t+g}, G_g = 0]$ is the population outcome regression for the "not-yet treated" group at time $t+g$. Here, δ is the known duration of the anticipation period, and $p_{g,t+\delta}(X)$ is the probability of being first treated at time g conditional on covariates X and on either belonging to group g, so that $G_g = 1$, or belonging to the "not-yet treated" group at time $t + \delta$, so that $(1 - D_{t+\delta})(1 - G_g) = 1$.

Since we are interested in the monthly average effects of the mTBI and their dynamics, rather than the group-time ATT, we want to recover at each date the average effect of being treated for the group(s) that have been treated for exactly e time periods. This effect is given by:

$$\theta(e) = \sum_{g=1}^{\tau} 1\{g + e \leq \tau\} ATT(g, g + e) P(G = g|G + e \leq \tau) \tag{3}$$

where τ is the date of treatment of the last group.

We also compute the overall average treatment effects, which are analogous to the ATT in a standard two-period difference-in-differences model, and can be written:

$$\theta_\Delta = \frac{1}{\Delta + 1} \sum_{e=0}^{\Delta} \theta(e) \tag{4}$$

where Δ is the duration of the post-period. We compute these estimates for different values of Δ from 12 to 48 months. With $\Delta = 12$, we obtain the average treatment effect of the mTBI on labour market outcomes in the first year following the shock; with $\Delta = 24$, the average treatment effect of the mTBI in the first two years following the shock, etc.

3.2 Identification

This model is identified under five assumptions: (1) irreversibility of treatment, (2) limited anticipation, (3) random sampling, (4) parallel trends and (5) overlap (Callaway & Sant'Anna, 2021). Conditions (1) and (2) are verified by the sudden nature of the health shock we study. TBIs, by definition, cannot be unexperienced, and *a priori* cannot be anticipated. The random sampling assumption (3) is likely to be verified given the nature of our data. Indeed, we are able to observe all mTBI which have been treated by health services during the period (see Section 4 for more details).

The parallel trends assumption (4) is standard in DiD frameworks, although in this model, it should hold after conditioning on covariates. This allows for potential group-specific trends that would bias the estimates to be accounted for. Because we use not-yet treated individuals as counterfactuals to control for unobserved heterogeneity (Fadlon & Nielsen, 2019), and given the nature of the treatment, there is no reason to believe that individuals who experienced the TBI earlier are different from those who experienced it later. Therefore, this assumption is likely to hold even unconditionally (see the trends in Figure 1). Nevertheless, we control for a set of demographic characteristics that could affect the outcomes. As will be shown, the average ATT observed for the pre-period is sometimes statistically significant, but economically negligible (less than NZ$5, see Table 1), as well as the monthly ATT (Figure 2), which confirms the validity of this assumption.

The overlap assumption (5) states that a positive share of the sample starts being treated at each time period g, and that, for each t and g, there is at least a small probability of not being treated, ensuring common support between the treated group and their counterfactuals. In other words, the actual date of treatment has to be uncorrelated with the probability of being treated. We use not-yet treated individuals as the control group to limit the presence of unobservables that would affect the probability of treatment and, given the suddenness of TBIs, the timing of treatment for this population can be considered as good as random, ensuring the overlap assumption is met.

4 Data and population of interest

The Integrated Data Infrastructure (IDI) is a large research database managed by Stats NZ. It holds population-wide linked micro-data about life events, including health events, income and other labour market information, from various government agencies and Stats NZ surveys.[1]

We use multiple IDI data sources to conduct our analysis. We use information provided by the Accident Compensation Corporation (ACC) to identify individuals who experienced a mTBI between January 2012 and June 2022. For each of these individuals, we retrieve their wages and salaries for each month between January 2010 and December 2019 from the Inland Revenue (IR) data. Individual characteristics, such as age, gender and ethnicity come from Stats NZ's personal details table, which collates this information from across different IDI data sources.

NZ's ACC system is unique internationally and has some advantages over hospital and/or emergency room, or worker compensation data that has been used in previous studies. ACC is a compulsory, universal, no-fault compensation system that encompasses all accidents that occur in New Zealand. Compensation covers medical treatment costs and, for those in employment, income compensation of up to 80% of their pre-injury earnings for as long as the injury impacts on their ability to work. Treatment claims are lodged by medical providers rather than the injured individual, mitigating underreporting issues, and meaning coverage extends beyond hospital and emergency room treatment to, for example, primary health services. While unreported mTBIs are likely to still be an issue, the inclusion of mTBIs treated by primary health services means that ACC data are likely to capture more mTBIs than hospital data, particularly those of milder severity.

Our sample is comprised of individuals who experienced a mTBI between January 2012 and June 2022, identified using ICD-9 diagnosis code of 850, ICD-10 of S06.0 and/or ACC READ code of S6 (which is an ACC-specific code used to indicate the diagnosis of a concussion by a medical practitioner). Ideally, we would restrict attention to concussions with a short period or no loss of consciousness. While the ICD-9, ICD-10 and ACC READ codes include

[1]See https://www.stats.govt.nz/integrated-data/integrated-data-infrastructure/ for more detailed information about the IDI.

sub-categories of concussions which allow for these to be coded according to how long the loss of consciousness was, medical practitioners generally do not code the diagnosis beyond the higher-level 'concussion' classification. However, consistent with previous research (Feigin et al., 2013), ACC notes that the vast majority (95%) of TBIs are mild (Accident Compensation Corporation, 2017). Our data also indicates that the majority are initially treated by a primary care physician (79%) or other non-specialist medical practitioner, such as a nurse (83%), which further suggests that the majority are mild in nature.

We restrict our sample to individuals aged at least 25 years old at the beginning of the pre-treatment period (i.e. 24 months before they experience the mTBI), and younger than 65 at the time of the mTBI. We exclude from our analysis individuals who had experienced a prior TBI of any severity from 1994 (when ACC records begin) onwards. We also exclude individuals who experience multiple TBI during the study's period. We, thus, are examining the effect of just one medically-diagnosed mTBI on labour market outcomes. Further, we exclude individuals who die before 2020 and those who lived overseas during the period (identified via Customs border movement data).

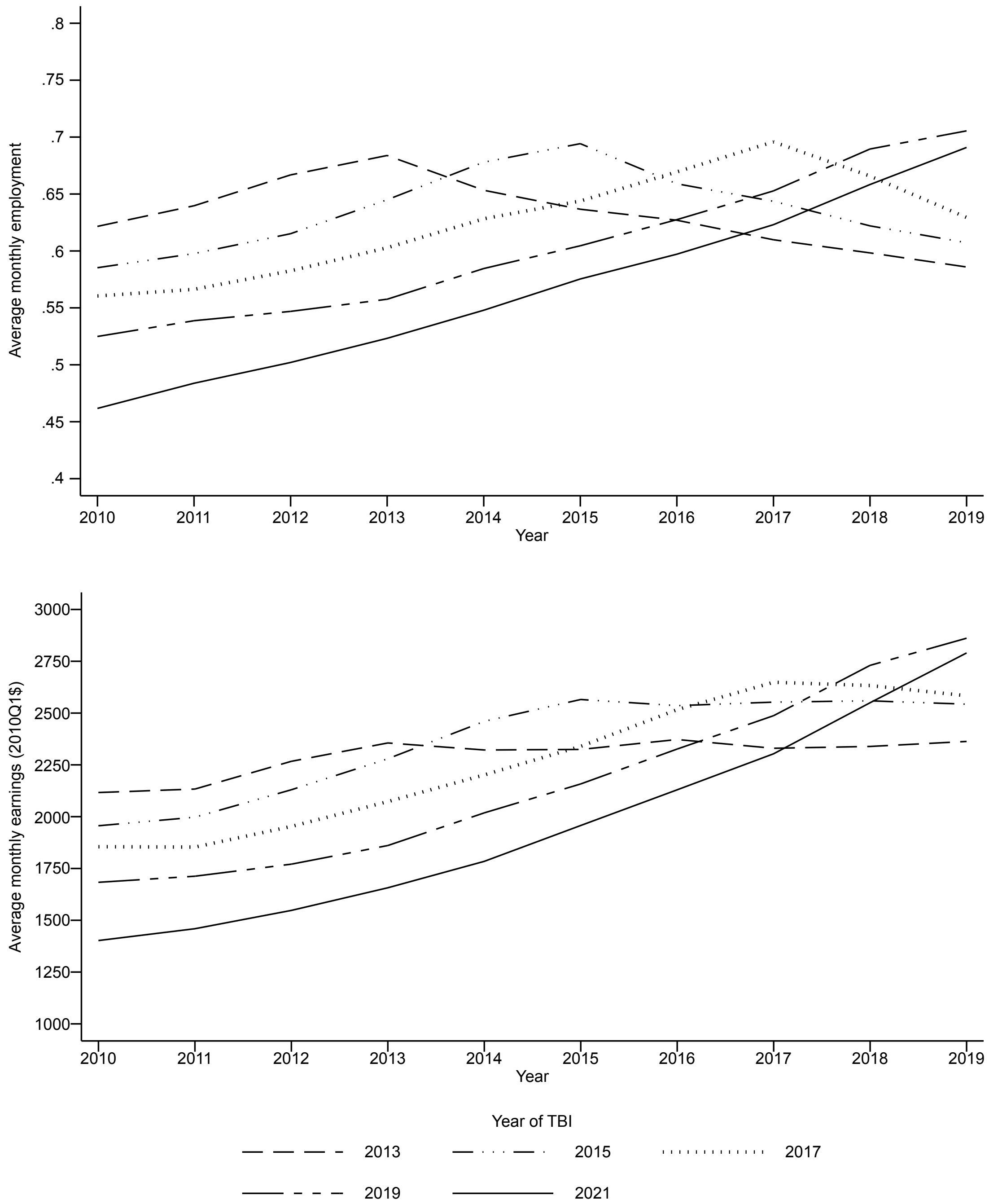
Most individuals in our sample are included in both the control and treatment groups, but at different points in time. This reduces the risk of unobserved differences between the treatment and control ("not-yet treated") groups. However, individuals who suffered the shock after December 2019 are only in the control ("not-yet treated") group. Although we observe the employment and earnings from January 2010, nobody in the sample is treated before January 2012, ensuring that we observe a pre-period of at least 24 months for each individual.

We include controls for gender, age at the time of the mTBI, ethnicity and fixed effects for region of residence at the time of the shock. Indeed, the inclusion of individual covariates should further reduce any remaining risk of unobservable differences between the treated and not-yet treated groups, which would result in important biases of our estimates if not taken into account (Callaway & Sant'Anna, 2021; Heckman et al., 1997). To avoid any reverse effect, we only include time-invariant demographics and pre-treatment covariates (Wooldridge, 2005).

We measure employment and earnings outcome variables using IR monthly tax records. Monthly earnings are expressed in New Zealand dollars (NZ$), deflated to the prices of the first quarter of 2010 (2010Q1) using the consumer price index. One limitation of the data is that we cannot observe hours of employment. Therefore, we cannot assess how much of any change in the intensive margin is due to reduced hours versus reduced earnings per hour.

Figure 1 displays the trends in earnings and employment for the different cohorts (aggregated

Figure 1: Annual average of monthly earnings and employment, by year of treatment



Note: These figures display the annual average of monthly earnings and employment for individuals experiencing a mTBI in years 2013, 2015, 2017, 2019 and 2021. For sake of clarity and since the pattern is similar, we do not report the average earnings and employment for individuals experiencing a mTBI in years 2012, 2014, 2016, 2018, 2020 and 2022.
Source: Authors' calculations using IDI.

by year of treatment). Regardless of the year of treatment, we observe that both outcomes are increasing before the mTBI, supporting the parallel trends assumption. The absolute differences in values between cohorts might be related to demographic variation between cohorts (especially in terms of age), which argues for the inclusion of the individual covariates in our model. After the shock, we show a clear decrease in employment, while wages stagnate rather than decrease. This suggests that we should find a stronger effect of mTBI on employment than on earnings.

5 Results

We analyse the effects of suffering from a mTBI on future earnings and employment. Table 1 presents the overall average treatment effects for different post-shock horizons (θ_Δ in Equation 4). We find a clear negative effect of the health shock on employment and earnings (Columns 1a and 1b). In the first year following the mTBI, the average monthly employment effect is -6.2 percentage points. In the four years following the shock, the average employment effect is -13.1 percentage points. The average monthly earnings penalty is around NZ$250 (NZ$500) in the first year (the first four years) after the shock, which is about 10% (20%) of pre-treatment average earnings.

Table 1: Effects of mTBI on earnings and employment

	(1) Whole sample		**(2) Employed at time e**	**(3) Always employed**
	(a) Monthly earnings	(b) Employ-ment	Monthly earnings	Monthly earnings
Pre-effect	4.63***	0.00***	-0.52	-1.39
	(0.55)	(0.00)	(0.79)	(0.95)
<u>*ATT*</u>				
$\Delta = 12$	-255.58***	-0.06***	-108.72***	-67.62***
	(9.11)	(0.00)	(8.84)	(17.75)
$\Delta = 24$	-346.55***	-0.09***	-114.66***	-67.38***
	(10.72)	(0.00)	(9.67)	(18.33)
$\Delta = 36$	-428.09***	-0.11***	132.22***	-75.43***
	(12.33)	(0.00)	(10.80)	(19.46)
$\Delta = 48$	-505.74***	-0.13***	-155.88***	-89.23***
	(13.97)	(0.00)	(12.10)	(20.95)
N individuals	35,301	35,301	35,301	5,454

Note: Staggered difference-in-differences estimates are obtained using Equation 1. The effects reported in this table are calculated using Equation 4. Effects in Columns (1a) and (1b) are calculated for all individuals in the sample. Effects in Column (2) are calculated conditional on being employed at time e. Effects in column (3) are calculated on the subsample of individuals employed in all of the 120 periods of our data. Standard errors are clustered at the individual level.
*** indicates significance at the 1% level, ** at the 5% level and * at the 10% level.
Source: Authors' calculations using IDI.

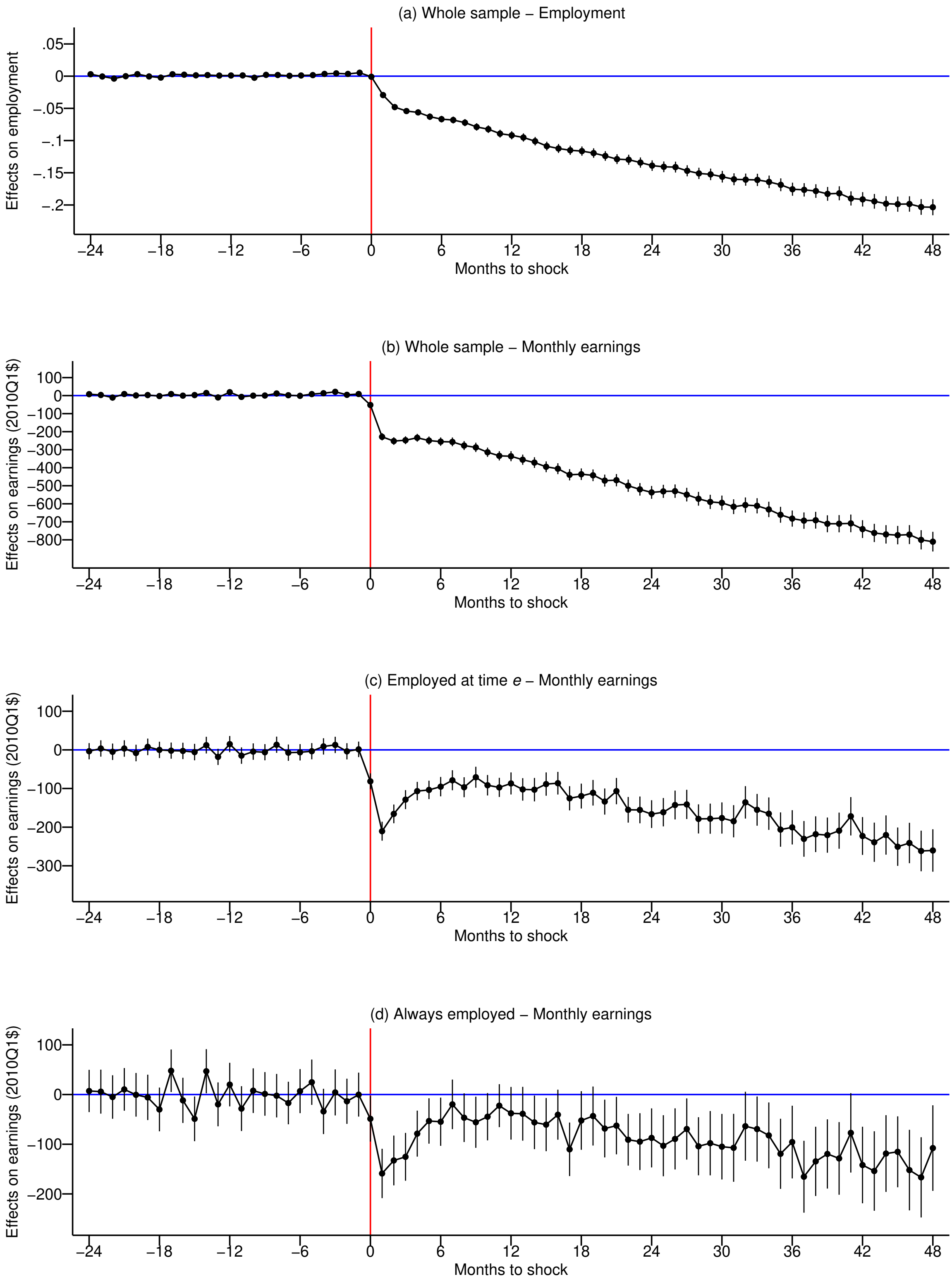
Since we are interested in distinguishing between the intensive and extensive margins, we also estimate the effects on earnings conditional on employment. Column 2 in Table 1 reports the θ_Δ obtained by including only individuals in employment at time e in the calculation of $\theta(e)$. By comparison, column 3 reports the results obtained by restricting our sample to individuals who were employed in all of the 120 periods of our data (every month between January 2010 and December 2019). These results confirm the negative effect of mTBI on earnings. However, the magnitude of the penalties are lower than for the whole sample. Conditional on being employed at time e (always being employed), the penalty is around NZ$110 (NZ$70) in the year following the TBI, against NZ$250 for the whole sample. Moreover, looking at longer time horizons, the average monthly penalty seems to increase slower for individuals who remain in employment. Therefore, most of the effect on earnings seems to be driven by a drop in employment. In order to confirm this, we next analyse how these labour market effects evolve on a monthly basis.

5.1 Monthly treatment effects

Figure 2 displays the average monthly effects calculated using Equation 3. We find a negative and significant effect of the health shock on both employment and earnings (Figures 2a and 2b) starting immediately after the mTBI. Employment falls by three percentage points and earnings fall by NZ$230 in the first month after the shock. The wage penalty remains reasonably stable during the first six months following the shock, before increasing strongly and continuously to reach NZ$330 a month after one year and more than NZ$800 after four years (Figure 2b).

Therefore, even though these injuries are considered to be minor and temporary in nature, mTBIs appear to have strong and persistent effects on earnings. This contradicts findings by Pelkowski and Berger (2004), who found that in general, temporary illnesses only have limited impact on labour market outcomes. However, it is in line with the medical literature about TBIs, which evidences long-term (and sometimes hidden) health and cognitive effects, as well as employment effects, of mTBI (Dean & Sterr, 2013; Ribbers, 2007; Theadom et al., 2017).

Figure 2: Monthly effects of mTBI on earnings and employment



Note: These figures display the average monthly effects calculated using Equation 3 along with the 95% confidence intervals. Effects in (a) and (b) are calculated for all individuals in the sample. Effects in (c) are calculated conditional on being employed at time *e*. Effects in (d) are calculated on the subsample of individuals employed in all of the 120 periods of our data. Standard errors are clustered at the individual level.
Source: Authors' calculations using IDI.

The results for earnings conditional on employment (Figures 2c and 2d) confirm that the negative effect on earnings is mostly (but not entirely) due to a decrease in employment. This is illustrated by the muted effects on earnings in Figure 2c (conditional on being employed at time e) and Figure 2d (conditional on being always employed) relative to the impact on earnings evident for the full sample in Figure 2b.

These results confirm that the strong long-term effects on earnings for the full sample are mostly driven by transitions out of employment. For individuals able to remain in employment, there seem to be smaller effects of mTBI, resulting in only small decreases in either hours of work or productivity and thus lower wage penalties. These smaller effects are likely to be due to temporary part-time employment during the recovery period.

Another noteworthy feature of Figure 2c is that for those employed at time e, earnings initially drop after the injury, then recover somewhat, before gradually falling again. We observe a similar pattern for individuals employed in each time period (Figure 2d), with a sudden decrease in earnings right after the TBI, then a temporary recovery and finally a slow decrease after 18 to 24 months.This suggests that the wages of people who experienced a mTBI but remain more attached to the labour market and manage to stay employed, start stagnating in the longer term.

While there are few studies examining the longer-term effects of mTBI on labour market outcomes, our results accord with the limited research in this area. In particular, previous health research has found that while many of those who suffer mTBIs return to their previous work duties within a short timeframe, they often struggle to meet the demands of their employment in the longer term and may go on to exit employment or reduce their work intensity (Theadom et al., 2017). This further highlights how mTBI may be different from other forms of minor injuries in terms of having more long-lasting effects.

An important caveat of our analysis is that our focus is on medically-diagnosed mTBI. As mentioned, this is an improvement on existing research that only examines hospital-treated mTBI. However, it must be recognised that there are likely to also be undiagnosed and untreated mTBIs in addition to the medically-diagnosed mTBI that we examine. The expected labour market impacts if the analysis included undiagnosed mTBIs is not clear. The impacts may be smaller on average if we assume that the undiagnosed mTBIs are less severe in nature. The impacts could also be larger on average if the diagnosed mTBIs receive more appropriate medical guidance and treatment relative to the undiagnosed mTBIs and thus have relatively better labour market outcomes in the longer term.

5.2 Heterogeneity analysis

We estimate the heterogeneous effects on earnings and employment across gender, age and occupational skill level[2] at the time of the shock. Results (θ_Δ) obtained through Equation 4 are reported in Table 2 for the different demographic subgroups.

Results by gender (Panel 1 of Table 2) show that the penalty is slightly higher for men than for women. Regarding income, this might partly reflect that women earn lower wages on average than men. The year before they experienced the mTBI, women earned on average NZ$2,130 a month, versus NZ$2,790 a month for men. The average monthly penalty during the first year after the shock thus corresponds to a relative loss of 9% for women and 11% for men. However, while employment is similar for both genders the year before the shock (67.6% for women, 67.9% for men), men suffer from slightly higher employment penalties (around one percentage point higher) both in the short and longer terms. This could be because women have less consistent labour market attachment in general than men due to, for example, being more likely to spend time out of the labour force to raise children, thus leading to smaller differences between the treatment and comparison groups.

There is a strong heterogeneity in the effect of mTBI depending on the age of the individuals (Panel 2 of Table 2). Wage penalties are higher for younger workers (under 40) than for older ones (aged 40+). In the first year following the shock, the average monthly income loss is around NZ$300 for younger workers, compared with NZ$230 for older ones. This absolute magnitude difference is also more stark in percentage terms given older workers have higher average pre-shock earnings than younger workers. This difference grows over time, with an income loss of around NZ$650 in the fourth year after the mTBI for younger workers and NZ$420 for older workers. Our results thus contradict those of Charles (2003), who found stronger negative effects of health shocks (transition to disability) on the earnings of older workers, which he associated with a destruction of the accumulated human capital and a shorter time horizon to recover from the shock. Our results show an even higher gap between age groups for employment, with a eight percentage point decrease in employment in the first year for younger workers compared with a five percentage point decrease for older workers. This employment effect grows to 18 percentage points in the first four years after the shock for younger workers, versus 10 percentage points for older workers.

[2]We use the Australian and New Zealand Standard Classification of Occupations (ANZSCO) classification to define our two skill groups. High skilled corresponds to ANZSCO skill levels 1 and 2, low to middle skilled corresponds to ANZSCO skill levels 3, 4 and 5.

Similar to the case of gender, the differences between younger and older workers might be explained by differences in the employment and earnings trajectories of the comparison group. For example, the earnings of younger workers tend to grow more strongly than those of older workers, who are more likely to have already entered their prime earning years. Thus, younger workers who experience a mTBI may lose an increasing amount of ground against the comparison group of other younger workers whose earnings are rising at a quicker pace.

It may also be that younger workers have a lower opportunity cost of exiting employment, at least in the short-term, due to lower average pay rates and potentially having lower financial responsibilities (e.g. less likely to have dependents, a mortgage etc.). A counterargument to this possibility is that the lifetime opportunity cost of time out of the workforce is likely to be higher for younger workers due to the greater potential that this will have a scarring effect. However, individuals may discount the future heavily or be myopic and therefore not fully factor in this consideration.

Another possible explanation is that younger people have lower labour market attachment in general, and lower attachment to their employer in particular. For example, older workers are likely to have higher longer job tenure than their younger counterparts. Thus, in the event of an accident that impacts their ability to undertake their job, older workers may have more support from their employer to return to work (e.g. more options to take on lighter duties for a time). Younger people may also be in more precarious work situations. For example, they may be less likely to be on permanent contracts and more likely to be on fixed-term or casual contracts. Therefore, more than an effect on the ability to keep one's job, mTBIs might have a negative effect on the probability of finding a subsequent job, whether because of reduced productivity (Theadom et al., 2017) or because of a scarring effect of having experienced such a health shock or having experienced a period of non-employment.[3] Unfortunately, our data do not contain information on whether individuals are employed on fixed-term or permanent contracts, preventing us from verifying this possibility.

In terms of occupational skill level, mTBIs are more detrimental for workers in high-skilled jobs than for those in low-to-middle-skilled ones (Panel 3 of Table 2). Wage penalties in the longer term are about twice as high for the former in comparison with the latter (respectively -NZ$330 against -NZ$220 in the first year, -NZ$750 against -NZ$380 with a four years time horizon). Similar to what is observed by gender, the smaller effect on wages for low-to-middle

[3]To the best of our knowledge, there is no existing work about such an effect due to TBI. However, there is previous evidence of adverse effects of other health conditions on future employability, see e.g. Ameri et al. (2018), Drydakis (2010), and Hipes et al. (2016).

skilled workers may (at least partly) be explained by lower pre-shock earnings on average. Indeed, with respective average earnings of NZ$3,300 and NZ$2,100 the year before the shock, the relative wage losses are similar at around 10% for both groups in the year following the mTBI. Nevertheless, in the longer term, the relative penalties increase more for high-skilled workers (around 36% against 29% after 48 months). Contrary to what we observe for age, this could be related to a destruction of human capital (Charles, 2003). Our results differ from the economics of health shocks literature which finds that those with lower income prior to the shock suffer larger detrimental effects (Crichton et al., 2011; Dano, 2005; García-Gómez et al., 2013; Riphahn, 1999). However, higher skilled occupations are often more reliant on cognitive functions, which are the most affected by TBIs (Dean & Sterr, 2013). Indeed, our results align with those of Theadom et al. (2017), which finds that productivity losses following a mTBI are greater for mental and interpersonal tasks than for physical tasks.

It is expected that those who received the initial treatment for their mTBI in a hospital would have a more severe injury on average than those who were initially treated in a non-hospital setting (e.g. a primary healthcare practice) and, therefore, more negative employment and earnings outcomes. However, there is little difference in the employment consequences of the hospital-treated and non-hospital-treated (Panel 4 of Table 2). Employment fell by seven percentage points over the first 12 months for the hospital-treated group, and six percentage points for the non-hospital-treated group. These employment losses had grown to 13 percentage points and 11 percentage points over the 48 months since the injury for the hospital and non-hospital treated respectively. The hospital-treated had larger earnings losses, although the magnitude of the differences are not large. The hospital-treated had earnings losses of about NZ$300 a month over the first 12 months, increasing to just over NZ$500 over the first 48 month. The non-hospital-treated had earnings losses of about NZ$250 over the first 12 months, increasing to NZ$500 over the first 48 months.

These smaller-than-expected differences may be because the difference in injury severity between hospital- and non-hospital-treated injuries is not great. For example, if hospital-treated mTBI is largely due to the timing of the injury - for example, if it is mainly those who were injured after hours or on the weekend when primary healthcare practices are generally closed. However, it could also be the case that the characteristics of those who are treated in the hospital are different. In particular, hospital treatment for accidents is free in New Zealand, while primary healthcare treatment is in general partially subsidised, with patients being required to make a co-payment towards their treatment costs. Moreover, some individuals do not have a primary care physician and may, therefore, have little choice but to go to a hospital emergency department. Since differences in primary healthcare access tend to be related to socioeconomic status, it is perhaps unsurprising that those who receive hospital treatment are less likely to be in high-skilled occupations (25% versus 36% for those receiving non-hospital treatment). They are also a little less likely to be employed in the year before the mTBI (60% were employed for at least one month of the year, versus 63% for those receiving non-hospital treatment), and had lower earnings (NZ$2,014 average monthly earnings in the year before the mTBI, versus NZ$2,220 for those receiving non-hospital treatment). Another possible explanation is that those who are initially treated in a hospital setting have more severe mTBIs, but are provided with more specialised treatment and better follow-up care and guidance, thus leading to similar outcomes as those treated in non-hospital settings.

Table 2: Heterogeneous effects of mTBI on earnings and employment

Gender	**(1) Women** ($N = 17,385$)		**(2) Men** ($N = 17,916$)	
	(a) Monthly earnings	(b) Employment	(a) Monthly earnings	(b) Employment
Pre-effect	3.47***	0.00***	5.73***	0.00***
	(0.70)	(0.00)	(0.84)	(0.00)
ATT				
$\Delta = 12$	-192.47***	-0.05***	-313.65***	-0.07***
	(11.43)	(0.00)	(14.03)	(0.00)
$\Delta = 24$	-278.79***	-0.08***	-408.56***	-0.09***
	(13.60)	(0.00)	(16.36)	(0.00)
$\Delta = 36$	-356.29***	-0.11***	-493.84***	-0.12***
	(15.90)	(0.00)	(18.62)	(0.00)
$\Delta = 48$	-424.41***	-0.13***	-579.63***	-0.13***
	(18.12)	(0.01)	(20.96)	(0.00)
Age	**(3) Under 40** ($N = 14,952$)		**(4) 40+** ($N = 20,349$)	
	(a) Monthly earnings	(b) Employment	(a) Monthly earnings	(b) Employment
Pre-effect	9.65***	0.00***	1.11	0.00***
	(0.93)	(0.00)	(0.68)	(0.00)
ATT				
$\Delta = 12$	-299.52***	-0.08***	-226.11***	-0.05***
	(15.30)	(0.00)	(11.26)	(0.00)
$\Delta = 24$	-437.26***	-0.12***	-287.00***	-0.07***
	(18.26)	(0.00)	(13.10)	(0.00)
$\Delta = 36$	-548.33***	-0.15***	-350.21***	-0.08***
	(21.07)	(0.00)	(15.07)	(0.00)
$\Delta = 48$	-646.44***	-0.18***	-415.74***	-0.10***
	(23.88)	(0.01)	(17.12)	(0.00)
Skill level	**(5) Low- to mid-skilled** ($N = 23,505$)		**(6) High-skilled** ($N = 11,796$)	
	(a) Monthly earnings	(b) Employment	(a) Monthly earnings	(b) Employment
Pre-effect	3.90***	0.00***	6.65***	0.00***
	(0.63)	(0.00)	(1.07)	(0.00)
ATT				
$\Delta = 12$	-217.62***	-0.06***	-328.78***	-0.07***
	(10.60)	(0.00)	(17.36)	(0.00)
$\Delta = 24$	-274.18***	-0.08***	-486.88***	-0.11***
	(12.43)	(0.00)	(20.50)	(0.00)
$\Delta = 36$	-325.85***	-0.10***	-626.25***	-0.14***
	(14.15)	(0.00)	(24.03)	(0.01)
$\Delta = 48$	-380.95***	-0.11***	-748.34***	-0.16***
	(15.98)	(0.00)	(27.41)	(0.01)
Hospital	**(7) Hospital-treated** ($N = 7,890$)		**(8) Non-hospital treated** ($N = 27,411$)	
	(a) Monthly earnings	(b) Employment	(a) Monthly earnings	(b) Employment
Pre-effect	6.62***	0.00***	4.12***	0.00***
	(1.15)	(0.00)	(0.63)	(0.00)
ATT				
$\Delta = 12$	-291.13***	-0.07***	-245.40***	-0.06***
	(20.10)	(0.00)	(10.22)	(0.00)
$\Delta = 24$	-365.73***	-0.09***	-340.10***	-0.09***
	(23.26)	(0.01)	(12.06)	
$\Delta = 36$	-437.03***	-0.11***	-423.25***	-0.11***
	(26.53)	(0.01)	(13.91)	(0.00)
$\Delta = 48$	-512.16***	-0.13***	-500.01***	-0.11***
	(29.81)	(0.01)	(15.78)	(0.00)

Note: Staggered difference-in-differences estimates are obtained using Equation 1. The effects reported in this table are calculated using Equation 4. Standard errors are clustered at the individual level.
*** indicates significance at the 1% level, ** at the 5% level and * at the 10% level.
Source: Authors' calculations using IDI.

5.3 Effects of mTBIs on accident compensation payments

In addition to the effects of mTBIs on labour market outcomes, we also examine to what extent the ACC system can mitigate the earning losses we observe. To this end, we estimate the effects of mTBIs on accident compensation payments using the same methodology. Table 3 shows the accident compensation payment results, alongside the monthly earnings results from Table 1 for reference.

As expected, individuals who experienced a mTBI receive accident compensation payments following the shock, the average monthly treatment effect for over the first 12 months after the mTBI being around NZ$100. However, this amounts to only about 40% of earning losses. As the earning losses grow over time, the accident compensation payments actually shrink in relative terms, reaching just 11% of average earning pre-injury losses by the fourth year.

Table 3: Effects of mTBI on accident compensation payments

	(1) Monthly ACC payments	(2) Monthly earnings	(3) -ACC/Earning losses
Pre-effect	-0.42***	4.63***	0.09
	(0.12)	(0.55)	
ATT			
$\Delta = 12$	101.92***	-255.58***	0.40
	(3.79)	(9.11)	
$\Delta = 24$	77.80***	-346.55***	0.22
	(3.62)	(10.72)	
$\Delta = 36$	63.75***	428.09***	0.15
	(3.64)	(12.33)	
$\Delta = 48$	54.98***	-505.74***	0.11
	(3.84)	(13.97)	
N individuals	35,301	35,301	35,301

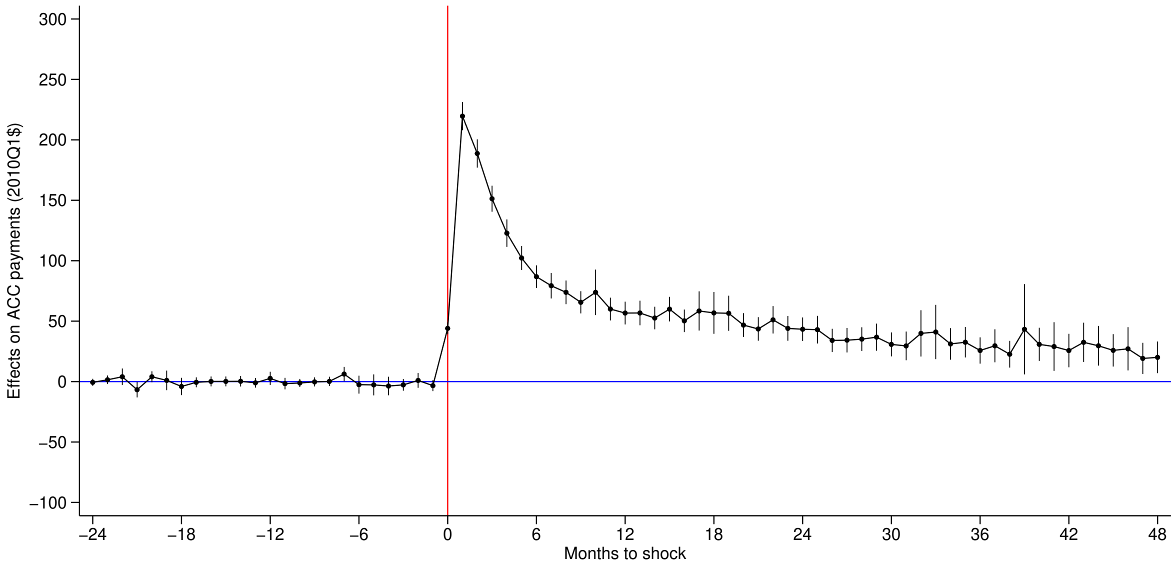
Note: Staggered difference-in-differences estimates are obtained using Equation 1. The effects reported in this table are calculated using Equation 4. Effects are calculated for all individuals in the sample. Standard errors are clustered at the individual level. For comparison, earnings effects from Table 1 are repeated here.
*** indicates significance at the 1% level, ** at the 5% level and * at the 10% level.
Source: Authors' calculations using IDI.

To examine this in more detail, Figure 3 provides monthly estimates. In the first month following the mTBI, the average amount received is NZ$220, which covers almost entirely the loss in labour earnings (-NZ$230, see Figure 2b).[4] After that initial payment, the compensation gradually decreases, not exceeding NZ$100 after one year and NZ$50 after two years. Given that, at the same time, labour earnings penalties are strongly and continuously increasing, individuals who experienced a mTBI suffer strong income losses. The average monthly ACC

[4]ACC will pay up to 80% of pre-injury earnings as compensation. It is, therefore, unclear why the average ACC payments equate to more than 80% of earnings losses in the first month after the injury. However, it may be due to payment timing. For example, if there is an initial delay in the payment of ACC in the month of the accident that is then made up in the next month, or because ACC payments are made weekly while most employees are paid fortnightly, which may mean payments are more likely to fall in the earlier month than wage/salary earnings.

payment over the four years is NZ$55, while the average wage loss is almost ten times higher (NZ$505, see Table 1).

Figure 3: Monthly effects of mTBI on ACC payments



Note: This figure displays the average monthly effects calculated using Equation 3 along with the 95% confidence intervals. Standard errors are clustered at the individual level.
Source: Authors' calculations using IDI.

Heterogeneity analysis

We observe similar patterns in accident compensation payments for all the demographic subgroups (Table 4). The main differences concern the amount received due to the fact that the ACC system calculates the compensation payments based on previous earnings. Therefore, ACC payments are slightly higher for men, those in high-skilled occupations and older workers. However, in terms of ACC payments as a proportion of earning losses, there are some differences particularly for younger versus older workers. ACC payments account for just over a quarter of earning losses for those under 40 years old in the first 12 months after the mTBI, falling to 7% over a 48 month period. ACC payments as a share of earning losses are almost twice as high for those aged 40 and over, accounting for just over half of earning losses over the first 12 months after the mTBI, falling to 15% over a 48 month period. Although we cannot say definitively why this is the case, it could be because ACC payments are based on pre-injury earnings, and for younger workers, the earnings of the comparison group continue to go up as their careers progress and they enter their prime earning years, while ACC payments are only adjusted to increase in line with the Labour Cost Index. In contrast, for those aged 40 and over, earnings of the comparison group are rising at a slower pace due to these individuals already being in their prime earning years and, therefore, experiencing slower earnings growth. However, there may also be other explanations. For example, ACC may more strongly encourage younger mTBI sufferers to return to work given their potential lifetime earnings compensation liability is higher, or because they are perceived to be more able to recover from their injury and return to work.

There are also some differences between those treated in a hospital versus those treated in a non-hospital setting such as a primary healthcare practice. Those treated in a hospital have higher monthly ACC payments in both absolute terms, and as a share of lost earnings. The difference in absolute terms could be related to injury severity if those treated in hospitals have a more severe TBI on average. For example, someone with a more severe injury may not be able to work at all and would, therefore, receive the maximum amount of income compensation. Someone with with a less severe injury may be able to work but only at reduced hours and, therefore, may receive only partial income compensation. However, this would not explain the difference in terms of the share of lost earnings. A potential reason for the difference in terms of share of lost earnings could be that those treated in a hospital were better able to access ACC services, including income compensation. Perhaps, for example, because they were more likely to have been treated by medical practitioners who were more specialised in TBI and gave additional guidance.

Table 4: Heterogeneous effects of mTBI on ACC payments

Gender	**(1) Women** ($N = 17,386$)		**(2) Men** ($N = 17,915$)	
	(a) Monthly ACC payments	(b) ACC/ Earning losses	(a) Monthly ACC payments	(b) ACC/ Earning losses
Pre-effect	-0.21	0.06	-0.61***	0.11
	(0.13)		(0.19)	
ATT				
$\Delta = 12$	78.75***	0.41	123.81***	0.39
	(4.56)		(5.97)	
$\Delta = 24$	57.98***	0.21	96.43***	0.24
	(4.34)		(5.72)	
$\Delta = 36$	46.19***	0.13	80.09***	0.16
	(4.39)		(5.72)	
$\Delta = 48$	40.13***	0.09	68.78***	0.12
	(4.81)		(5.90)	
Age	**(3) Under 40** ($N = 14,950$)		**(4) 40+** ($N = 20,351$)	
	(a) Monthly ACC payments	(b) ACC/ Earning losses	(a) Monthly ACC payments	(b) ACC/ Earning losses
Pre-effect	-0.36**	0.04	-0.46***	0.42
	(0.16)		(0.16)	
ATT				
$\Delta = 12$	80.68***	0.27	116.06***	0.51
	(4.89)		(5.41)	
$\Delta = 24$	59.49***	0.14	89.91***	0.31
	(4.63)		(5.19)	
$\Delta = 36$	49.91***	0.09	72.67***	0.21
	(4.70)		(5.19)	
$\Delta = 48$	44.24***	0.07	61.76***	0.15
	(5.06)		(5.43)	
Skill level	**(5) Low- to mid-skilled** ($N = 23,505$)		**(6) High-skilled** ($N = 11,796$)	
	(a) Monthly ACC payments	(b) ACC/ Earning losses	(a) Monthly ACC payments	(b) ACC/ Earning losses
Pre-effect	-0.43***	0.11	-0.38**	0.06
	(0.15)		(0.18)	
ATT				
$\Delta = 12$	89.63***	0.41	127.16***	0.39
	(4.39)		(7.26)	
$\Delta = 24$	69.58***	0.25	94.76***	0.19
	(4.21)		(6.93)	
$\Delta = 36$	56.92***	0.17	77.86***	0.12
	(4.22)		(7.01)	
$\Delta = 48$	49.42***	0.13	66.41***	0.09
	(4.40)		(7.55)	
Hospital	(7) Hospital-treated ($N = 7,890$)		(8) Non-hospital treated ($N = 27,411$)	
	(a) Monthly ACC payments	(b) ACC/ Earning losses	(a) Monthly ACC payments	(b) ACC/ Earning losses
Pre-effect	-0.84***	0.13	-0.31***	0.08
	(0.26)		(0.13)	
ATT				
$\Delta = 12$	146.71***	0.50	89.09***	0.36
	(8.88)		(4.16)	
$\Delta = 24$	110.54***	0.30	68.33***	0.20
	(8.10)		(4.05)	
$\Delta = 36$	88.92***	0.20	56.43***	0.13
	(7.84)		(4.12)	
$\Delta = 48$	76.23***	(0.15)	48.68***	(0.10)
	(7.84)		(4.41)	

Note: Staggered difference-in-differences estimates are obtained using Equation 1. The effects reported in this table are calculated using Equation 4. Standard errors are clustered at the individual level.
*** indicates significance at the 1% level, ** at the 5% level and * at the 10% level.
Source: Authors' calculations using IDI.

6 Conclusion

This study investigates the effects of mild traumatic brain injuries (mTBIs) on future labour market outcomes. It is important to understand the effects of mTBIs as they are a common injury with a high incidence rate. Indeed, the health literature on mTBIs is growing, with a recognition that our understanding of brain injuries and their effects is lagging behind our understanding of other physical injuries. Despite the growing body of economic research on health shocks, this is the first study to examine TBIs specifically. Past economics literature highlights that minor / temporary injuries have only a short term effect on labour market outcomes. However, the health literature suggests mTBI could have more lasting effects despite their seemingly minor nature due to the possibility of ongoing cognitive impairment. This paper therefore fills a clear gap in the literature by examining the causal effect of suffering a mTBI on subsequent employment and earnings outcomes.

We use population-wide administrative data on all medically-diagnosed mTBIs linked to employment and earnings data from tax records. To account for possible endogeneity, we construct comparison groups of those who suffer from a mTBI but at a future date and apply a doubly-robust staggered difference-in-differences estimator. We examine the effect of suffering just one mTBI by excluding those who had previously been diagnosed with a TBI or who suffered a subsequent TBI (of any severity).

We find that individuals who experience a mTBI suffer adverse effects on employment and large earning losses. A large part of the effect is at the extensive margin (i.e. an employment effect), although the intensive margin is also important in explaining the earning losses. Indeed, for individuals who manage to stay employed after a mTBI, we observe an initial drop in earnings, followed by a recovery, before earnings gradually decrease again in the longer term. This is in line with the medical literature on mTBIs, which finds that individuals often return to work after an initial recovery period and may manage adequately for a time. However, they often struggle to function at their previous level, with gradually emerging impairments which result in medium-to-longer term adverse effects.

There is some difference in the magnitude of the adverse effects across groups. The largest difference is between younger and older workers, with younger workers experiencing greater adverse effects on employment and earnings. Additional smaller differences are evident by gender and occupational level. The negative labour market effects are larger for men than women, and for those in high-skilled occupations relative to those in low-to-middle skilled occupations.

We also investigate the accident compensation payments following a mTBI. We find that earning losses are largely offset by accident compensation payments immediately following the shock. However, while earnings continue to fall over the four years after the mTBI, accident compensation payments decrease over time. This raises questions about whether the current income replacement scheme recognises and provides adequate assistance for the potential long-term consequences of mTBIs.

Overall, our results show that, despite being classified as minor injuries, suffering a mTBIs can have important and long-lasting detrimental effects on individuals' labour market outcomes. Our findings highlight the need for timely diagnosis and treatment to mitigate the effects of mTBIs and reduce the burden on the individual, in terms of not only health costs, but also economic and social costs experienced in the labour market. Early intervention would reduce the likelihood of these negative effects, particularly longer-term effects, from occurring. Given the richness of linked administrative data used in this study, future work could explore the broader effects of mTBI. This includes the potential impact on educational outcomes of young people; other health outcomes (such as mental health); and relationship outcomes, for example, through an examination of family formation/dissolution patterns.

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