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ORIGINAL PAPER

CBD at work: the impact of cannabidiol access on workplace health

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Abstract
This paper examines the causal impact of cannabidiol (CBD) product availability on workplace injuries, exploiting Italy's unintended liberalization of low-THC cannabis as a natural experiment. We use a staggered difference-in-differences approach, leveraging variation in the timing of CBD retailer entries across provinces. We find that CBD availability leads to a reduction in workplace injury rates by 2.5%, with larger effects among young and prime-age workers. Robustness checks confirm these findings, and placebo tests rule out confounding trends. These effects are stronger in provinces with higher pre-existing use of pharmaceuticals commonly prescribed for stress, anxiety, sleep disorders, and chronic therapies. We interpret this pattern as suggestive of a substitution-based channel in which CBD products may represent an additional source of pain and stress management.

Keywords CBD · Workplace safety · Cannabis liberalization · Occupational health · Workplace injuries

JEL Classification I12 · J28 · K32

1 Introduction

Institutional and regulatory changes shape economic and social outcomes in unexpected ways; the increasing availability of cannabis-derived products raises important questions about their impact on public health, labor markets, and workplace safety. In fact, cannabis access laws and increased cannabis consumption among workers have raised concerns about safety at work, but the current evidence remains ambiguous (Howard and Osborne 2020).

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The relationship between cannabis legalization (and use) and workplace injury risks is not clear *a priori*. From one angle, cannabis liberalization may lead to a reduced demand for pain management therapies and antidepressants (Carrieri et al. 2020; Drake et al. 2021; Raman and Bradford 2022). In this way, it can have a positive effect on occupational health through better pain and symptoms management that may prevent injuries at work, shorten the length of job separation due to work-related accidents or illness, and increase work capacity. Some studies support this substitution effect hypothesis. Evidence on medical marijuana laws (MMLs) in the USA suggests a reduction in self-reported absence from work caused by illness and medical issues, as well as declined work compensation claiming due to better symptoms management following the liberalization (Ullman 2017; Ghimire and Maclean 2020). Abouk et al. (2023) study the effects of recreational marijuana laws (RMLs) on the US population and find a decrease in the propensity to claim workers' compensation benefits after legalization, along with further improvements in other measures of labor supply and reductions in work-limiting disabilities. Furthermore, MMLs are also found to reduce alcohol and opioid consumption, leading to lower workplace fatalities (Anderson et al. 2018).[1]

On the other hand, marijuana use could affect workplace performance and increase the risk of injury due to its effects on cognitive and physical functioning (van Ours and Williams 2012; van Ours et al. 2013), and through reduced concentration, motivation, judgment, and attention (Hall and Degenhardt 2009; Hanson et al. 2010; Volkow et al. 2014; Winward et al. 2014; Hall 2015). In line with these hypotheses, Kaestner and Grossman (1998) find that males who use illicit drugs have a 25% higher probability of experiencing a workplace accident. Maclean et al. (2021) estimate an increase in disability applications following recreational marijuana laws; whereas Dong (2019) finds an increase in workplace injury rates of approximately 5–20% in counties that legalized recreational marijuana sales.

In this paper, we contribute to this debate and provide novel causal evidence by focusing, for the first time, on the availability of cannabidiol (CBD) products and their effects on workplace injuries. CBD is a cannabis-derived compound that has gained significant popularity in recent years and is known for its diverse range of effects. Unlike tetrahydrocannabinol (THC), CBD has no psychoactive effects but has been linked to various health benefits, including the treatment of anxiety, depression, epilepsy, insomnia, muscle disorders, and chronic pain (White 2019). Recognizing this, the WHO Expert Committee on Drug Dependence (ECDD) has exempted CBD products containing less than 0.3% THC from controlled drug classification (EMCDDA 2019). As regulatory barriers have loosened and consumer awareness has grown, the market for CBD-based products has expanded, reflecting broader shifts in demand for alternative therapeutic products.

In our contribution, we estimate the impact on workers' health outcomes in Italy by means of a staggered difference-in-differences (DiD) design, leveraging the unintended liberalization of light cannabis, which took place in December 2016 as a natural

[1] In fact, alcohol consumption increases serious industrial injuries (see, e.g., Ohsfeldt and Morrisey 1997). Policies aimed at reducing bar opening hours have proven to be effective in causally decreasing working accidents through lower alcohol consumption (Bassols and Vall Castello 2018).

experiment. Moreover, our analysis highlights the spillover effects of cannabis liberalization on work-related accidents within Europe by focusing on a policy that liberalized cannabis with very low THC levels and high CBD levels. This contrasts with previous studies from the USA, which examine cannabis strains with high THC content–a key distinction given the different psychoactive effects and potential implications for occupational health. A further contribution relates to the literature on the socioeconomic determinants of workplace health (see, e.g., Pouliakas and Theodossiou 2013; van Ours 2019) by estimating the causal effect of CBD products following light cannabis liberalization on work-related injuries through the use of province-month level data for the period from January 2016 to December 2017. Finally, our results could have relevant implications for public and health policies, leading to more informed decision-making for policymakers with respect to the trade-off between economic benefits and drawbacks that arise from the legalization of light cannabis and derived products. In doing so, they assess the safety- and health-related policy effects of liberalization.

Italy represents an ideal setting for this study from both a health and a socioeconomic perspective. In recent decades, the country has experienced high rates of both fatal and non-fatal workplace accidents, placing it above the EU-27 median in 2019. Furthermore, Italy is a country with a conservative view on cannabis, but "light cannabis shops" unexpectedly blossomed due to a loophole in the legislation; in December 2016, a legislative gap created the opportunity to legally sell cannabis with low levels of THC, and some start-ups (e.g., Easyjoint, Marymoonlight) entered the market and began selling light cannabis (C-light) and other CBD-based products. Liberalization occurred simultaneously in the entire territory, but the intensity of CBD availability varied according to the pre-liberalization presence of industrial cannabis retailers, also called grow shops.[2]

Exploiting this idiosyncratic availability of the products across provinces, our results show that access to CBD products in a province reduces workplace accident rates by 0.030 per 1000 workers, equivalent to an approximate 2.5% decrease compared to counterfactual provinces. These results are robust across a series of sensitivity checks and remain unchanged when using alternative DiD estimators that account for heterogeneity in treatment effects and the staggered availability of CBD products. To understand the possible mechanisms, we show that the positive impact on workplace safety is stronger in provinces with higher pre-existing levels of drug prescriptions. This may suggest that CBD products likely serve as substitutes for painkillers and pharmaceuticals commonly prescribed for anxiety, stress, sleep disorders, and chronic conditions, as well as for alcohol. Consistent with such evidence, at the intensive margin, we document a significant reduction in the severity of workplace injuries following the increased availability of CBD products. This effect manifests through a decline in doctor-prescribed sick leave days and a lower incidence of long-term impairments. These findings corroborate the idea that CBD products positively impact workplace health by improving pain management and mitigating injury-related symptoms, ultimately leading to faster recovery and a reduced burden of chronic impairments.

[2] A grow shop is a specialized store that provides equipment and supplies for cultivating industrial hemp and other plants. These shops offer essential products such as high-quality seeds (where legally permitted), fertilizers, growing mediums, lighting systems, ventilation, and irrigation solutions.

The remainder of the paper is organized as follows. Section 2 discusses the characteristics of CBD, details the policy reform in Italy, and presents the data. Section 3 outlines the identification strategy. Section 4 presents the main results and tests their robustness. Section 5 explores potential mechanisms. Section 6 discusses and concludes.

2 Institutional setting and data

2.1 CBD products and the Italian liberalization

Cannabis sativa has two main varieties: marijuana, the high-THC variety, and hemp, a variety characterized by low-THC and high-CBD levels. While THC is the psychoactive compound responsible for the "high" associated with cannabis, CBD does not have any psychoactive effects. Instead, it has been linked to numerous health benefits, including helping with anxiety, depression, epilepsy, insomnia, muscle disorders, and pain relief (White 2019). Products containing CBD with less than 0.3% THC are exempt from controlled drug classification by the WHO Expert Committee on Drug Dependence (ECDD) (EMCDDA 2019).

CBD products are available in various forms, including oils, capsules, gummies, topicals, and beverages, each offering different methods of consumption. These products are widely utilized for pain relief and anxiety management, highlighting its role in addressing both physical discomfort and mental health challenges. CBD is also used to improve sleep disorders, reducing stress, and alleviating symptoms of arthritis through its anti-inflammatory properties. Additionally, it is used to promote relaxation, aid post-exercise recovery, and support general health (Wheeler et al. 2020; Bhamra et al. 2021).

This regulatory clarity has contributed to the increasing availability of CBD products, such as food supplements and cosmetics, as consumers have become more familiar with and interested in the natural medicinal properties of CBD. The CBD market has grown rapidly, with sales reaching $5 billion USD in 2021 and continuing to rise as consumer demand expands. This growth reflects a strong market interest in CBD and CBD-containing products, ranging from health and wellness supplements to alternative medicine.

While many countries have responded to this rising demand with explicit regulatory changes, Italy's legal framework shifted unintentionally. Historically, Italy has a longstanding tradition of cannabis cultivation dating back to the 1st century A.D (Mercuri et al. 2002). Nowadays, its territory is characterized by a higher prevalence of cannabis cultivations and related shops in regions with proximity to waterways and humid soils. However, despite this historical backdrop, the cultivation, possession, and sale of marijuana remain illegal in Italy, with exceptions granted only for industrial and medical purposes. In December 2016, the government passed Law 242/2016, which was intended to remove some restrictions on the cultivation, transformation, and commercialization of industrial cannabis (also called *hemp*), which is widely used for textiles, clothing, and food, and is a strain of cannabis sativa. Due to this use, hemp

is not classified as a drug as it is almost free of THC, the main psychoactive cannabis compound.

The law did not explicitly intervene in the commercialization of cannabis flowers and, due to this legislative void, herbal cannabis was essentially liberalized. This (unintended) liberalization of C-light took place in May 2017, when grow shops began commercializing the flowers and selling light cannabis as a "technical product," formally not intended for human consumption. However, it is important to note that in May 2019, the new government adopted a restrictive policy and imposed a ban on these herbal cannabis sales. As a consequence, many companies and stores closed in June 2019. For these reasons, in this paper, we estimate the causal effect of the unintended liberalization by focusing on the period in which the market was entirely left unregulated.

2.2 The CBD market in Italy

Although unintended, the Italian liberalization rapidly generated a *de facto* legal retail market that reached economically meaningful scale within a short period. While administrative data on individual CBD consumption are not available for this period, several independent sources document a rapid and economically meaningful expansion of the Italian CBD and light-cannabis market following the unintended liberalization. Industry and press analyses indicate that the market expanded from roughly €40 million in 2017 to approximately €150 million in 2018 in annual revenue, corresponding to the first full year after liberalization.[3] More recent economic reports suggest that the broader cannabis light sector in Italy–including cultivation, processing, and distribution–has an estimated direct sales value approaching €1 billion and a total economic impact close to €2 billion by 2025, supporting over 20,000 full-time jobs.[4] In addition, market research focused specifically on cannabidiol products points to continued growth in CBD sales, with revenues on the order of tens of millions of euros in 2024 and further expansion expected in the coming years (Grand View Research 2024).

Moreover, broader epidemiological evidence indicates that cannabis use is relatively widespread in Italy, with between 8 and 32 percent of adults reporting use under different definitions, suggesting a large latent market for cannabinoid products (EMCDDA 2025). Complementary qualitative evidence from industry sources documents non-negligible consumer uptake, with regular cannabis light consumers reportedly spending on average around €50 per month on such products.[5] Additional evidence of consumer uptake comes from Carrieri et al. (2020), who document that

[3] See LegalWeed (2018) at https://www.legalweed.it/cannabis-light-le-cifre-di-un-mercato-che-potrebbe-cambiare-litalia and Canapa Industriale (2019) at https://www.canapaindustriale.it/2019/05/11/10mila-addetti-150-milioni-di-fatturato-e-1500-aziende-i-numeri-della-cannabis-light/.

[4] See Fuoriluogo (2019) at https://www.fuoriluogo.it/speciali/cannabis-light/canapa-il-ddl-sicurezza-relega-allillegalita-un-mercato-potenziale-di-2-miliardi/ and Quotidiano Nazionale (2025) at https://www.fuoriluogo.it/speciali/cannabis-light/canapa-il-ddl-sicurezza-relega-allillegalita-un-mercato-potenziale-di-2-miliardi/.

[5] See LegalWeed (2018) at https://www.legalweed.it/cannabis-light-le-cifre-di-un-mercato-che-potrebbe-cambiare-litalia.

exposure to light-cannabis availability led to a relevant reduction in sedative and anxiolytic prescriptions as well as a decline in several other chronic-therapy drugs. Taken together, these patterns indicate that the unintended liberalization generated a substantial increase in both access to and uptake of CBD products, providing an important context for the interpretation of our empirical results.

Importantly for identification, the unexpected liberalization generated uneven expansion of CBD availability across provinces. Areas with pre-existing grow shops were natural early adopters: these outlets were already specialized in cannabis-related goods and could introduce CBD flowers at minimal additional cost by exploiting economies of scope, existing infrastructure, and an established clientele. The short-run progression of CBD products availability across Italian provinces can be observed in Fig. A.1 in the online appendix. In our identification strategy, we leverage this variation to construct a quasi-natural experiment, comparing provinces where the CBD industry expanded rapidly following the law's introduction against those that have not yet gained access to these products. In the difference-in-differences specification, we do not classify provinces with grow shops as treated and others as controls. Instead, treatment is defined by the realized timing of CBD retailer entry. This distinction ensures that we exploit the policy-induced variation in the timing of CBD availability while measuring treatment based on the actual onset of local access.

2.3 Data and sample

Administrative microdata on work-related injuries are provided by the Italian Institute for Insurance against Occupational Accidents (INAIL), the Italian national agency monitoring work-related illness and injury and managing the mandatory insurance against work-related accidents. The mandatory enrollment in INAIL ensures that the universe of work-related injuries in Italy is recorded. In fact, employers must report all work-related accidents causing injuries which cannot be healed within 3 days and within 48 h of receiving the corresponding medical certificate.[6]

The INAIL dataset provides information such as the date of the accident,[7] the Italian province where the accident occurred, and details about the injured person, like gender and age. Moreover, the data include administrative and health-related characteristics of the injury, the degree of impairment, firms' sector of activity, and whether the accident took place at the workplace or while the worker was commuting to or from work (*in itinere*), which is compensated as if it had occurred at the workplace.

In this paper, we use data on all workplace accidents certified by INAIL that occurred in Italy during the period 2016–2017. After restricting our analysis to the working-age population (16–64), we aggregate the number of workplace injuries by province and month over the observed time window and merge it with provincial employment data from the National Institute of Statistics (ISTAT). This allows us to compute monthly provincial workplace accident rates per 1000 workers. Additionally, we calculate these

[6] Only some special categories of workers—such as firefighters, police officers, military personnel, and journalists—are covered by other insurers rather than INAIL and are therefore not represented in our dataset.

[7] Regardless of the time elapsed between the accident and the notification deadline, employers are required to report the accident date, which we use to compute monthly accident rates at the provincial level.

statistics by gender, age group, sector, and injury severity, measured by the number of days of absence of the injured worker and the degree of health impairment.[8]

To analyze the availability and expansion of retailer stores that sell CBD products at the province level, we construct a panel dataset covering 106 NUTS-3 provinces over the period from January 2016 to December 2017. Since no official registry of light cannabis retailers exists for this time frame, we rely on historical web data to reconstruct the market presence of dispensaries. Our primary data source is the Internet Archive Wayback Machine, a digital archive that captures and stores periodic snapshots of publicly available websites. Using this tool, we retrieve archived versions of the websites of the four largest producers of CBD products in 2017 (i.e., Easyjoint, Marymoonlight, RealHemp, XXXJoint), which listed the locations of their affiliated retailers. By systematically extracting and geocoding these addresses from multiple time-stamped website versions, we reconstruct the geographical distribution of light cannabis retailers and track their market entry at the provincial level. This approach enables us to document the spatial and temporal expansion of the CBD market.[9] Using the same archive, we also retrieve data on the number of grow shops in the pre-policy period (October 2016), obtained through web scraping techniques from a snapshot stored in the archive of www.growshopmaps.com. This website maps the grow shops operating in Italy before the unintended liberalization, as shown in Fig. A.2 in the online appendix.

After merging data on local CBD access with the ones on workplace injuries, the final sample is a balanced panel dataset made up of 2544 province-month-level observations, coming from 106 provinces observed from January 2016 to December 2017. Table 1 provides some descriptive statistics at the province-month level.

3 Identification strategy

To identify the causal effect of CBD products on workplace injuries, we set up a staggered DiD design relying on the staggered timing of the CBD products availability, and on the provinces without any CBD and cannabis light retailer as the control group. Two key features of our study help rule out the possibility of endogenous entry. First, the unintended and unannounced nature of the liberalization process, along with a local C-light availability that mainly depended on the geographical presence of grow shops before the policy, should exclude any anticipation effect. Second, our monthly data allow us to compare variations in a very small time window after the time during

[8] We use yearly provincial employment data separated by gender, by age group, and by sector of activity to compute the corresponding workplace injury rates.

[9] To the best of our knowledge, alternative and sufficiently strong validations are not available to this aim. Tax filing registries are not accessible and would not allow to document the monthly entries of retailers by province. As for archived news and social media posting, these source of information would be less precise than our approach to map the temporal and spatial distribution of CBD dealers, being media coverage or social interest likely to be influenced by other factors such as competing news, provinces' cultural background, or political orientations.

Table 1 Descriptive statistics

	2016-2017		2016		2017	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
A. Workplace accident rate (per 1000 workers)						
Overall	1.183	0.389	1.193	0.381	1.173	0.396
Males	1.440	0.537	1.448	0.527	1.432	0.546
Females	0.839	0.260	0.850	0.259	0.827	0.261
Ages 16–29	1.773	0.727	1.766	0.707	1.781	0.747
Ages 30–54	1.089	0.369	1.101	0.363	1.077	0.376
Ages 55–64	1.116	0.368	1.131	0.367	1.102	0.368
Primary sector	0.567	1.047	0.535	0.999	0.599	1.093
Secondary sector	1.341	0.609	1.348	0.598	1.344	0.620
Tertiary sector	0.858	0.274	0.867	0.269	0.850	0.278
Severe	0.376	0.132	0.378	0.132	0.375	0.133
Mild	0.806	0.295	0.815	0.289	0.798	0.300
Macro-permanent impairment	0.003	0.004	0.003	0.004	0.003	0.004
Micro impairment	1.180	0.388	1.190	0.381	1.170	0.395
B. Shops						
Grow shops	2.764	4.241	2.764	4.241	2.764	4.241
CBD dealers	0.522	1.680	-	-	1.044	2.260
Provinces	106		106		106	
Months	24		12		12	
Observations	2544		1272		1272	

Notes: workplace accident rates by sector exclude those injury episodes with missing information on the firm's sector of activity. Descriptive statistics on the outcome variables are weighted by the provincial employment in the baseline year (2016)

which the policy took place (less than 1 year), and the short-term focus of our analysis rules out endogeneity issues due to potential migration effects to/from the treated provinces. Formally, we aim at estimating the following empirical specification:

$$Y_{pt} = \sum_{k} \beta_k Entry_{pk} + \phi_p + \theta_t + \varepsilon_{pt} \tag{1}$$

where $p = 1, ..., 106$ indexes the 106 provinces and $t = 1, ..., 24$ refers to the different calendar months in our observed time window; Y_{pt} is the measure for the workplace accident rates; the treatment variable $Entry_{pk}$ is an indicator that takes value 1 if at least a CBD retailer has entered in all periods $k < t$ in province p; ϕ_p and θ_t are province and time (month × year) fixed effects, respectively; ε_{pt} is the idiosyncratic error term. While ϕ_p absorbs unobserved time-invariant characteristics of each province, θ_t allows us to control for monthly unobserved shocks common across provinces in a given year and flexibly captures seasonal trends in workplace injuries. We weight each regression by the provincial employment in the baseline year (2016) and cluster standard errors at the

province level. Our coefficient of interest is β_k, which captures the monthly change in workplace injury rates due to the local availability of CBD products. Since our treatment captures the local availability of CBD—proxied by the entry of a retailer—the parameter β_k should be interpreted as measuring an intention-to-treat (ITT) effect.

The main identifying assumption for interpreting the parameter estimates β_k from Eq. 1 as the causal effect of local availability of CBD products on workplace safety is that those provinces experiencing different timings in the local availability of these products (treatment group) and those provinces never served by CBD retailers in the period we consider (control group) should have observed the same pre-policy trends for the occupational health outcomes. In other words, it requires that in the absence of the unintended liberalization, provinces would have experienced parallel trends in occupational injuries independently from the presence of CBD dealers.

We formally assess the plausibility of the parallel trend assumption by mean of an event-study analysis, including in Eq. 1 n months pre-entry and post-entry dummies per each province. Then, we estimate the following model:

$$Y_{pt} = \sum_{\tau=2} \beta_{-\tau} Entry_{p,t-\tau} + \sum_{\tau=0} \beta_{+\tau} Entry_{p,t+\tau} + \phi_p + \theta_t + \varepsilon_{pt} \quad (2)$$

One-month pre-entry is the excluded dummy for each dimension and is set equal to 0 in our presentation of the results. In this framework, the placebo coefficients associated to pre-entry periods capture any differential trend between treatment and control groups. Our results are shown in Fig. 1 and provide evidence that all pre-treatment coefficients are not different from 0, confirming the assumption of parallel trends between the two groups of provinces in our setting. We find that reductions in the workplace injury rates occur since the first month after the entry of local retailers and becomes more pronounced from the third month onwards. Lastly, the average post-treatment coefficient is -0.033, that is very close to our main DiD specification presented in the next Section.[10]

4 Results

4.1 Main findings

Our results are reported in Table 2, where we present the estimated coefficients of Eq. 1 on the overall workplace accident rate along with heterogeneity analyses by gender, by age group, and by sector of activity. In column (1), we detect that the market availability of CBD products due to the entry of at least one retailer in a given province is associated with a decrease in injury rate by 0.030 per 1000 workers, that is approximately -2.5% with respect to the sample mean of the outcome.

[10] As shown in Fig. A.3, Rambachan and Roth (2023)'s sensitivity tests rule out a null effect on workplace injury rate after slightly stressing the relative magnitude or the smoothness of potential violations of the parallel trend possibly induced by different unobserved province-specific shocks or secular trends across provinces. In Subsection 4.2.2, we formally account for the potential existence of such confounding factors and examine whether they affect the main results.

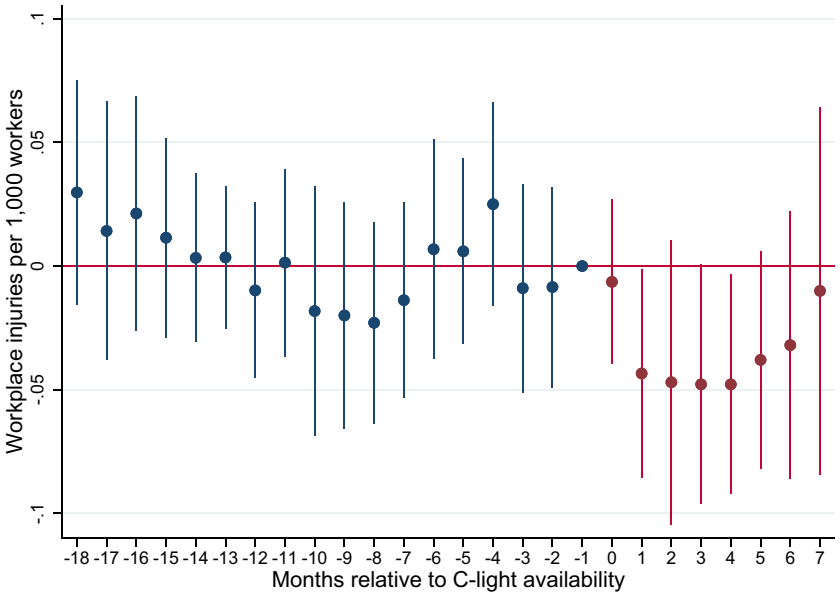

Fig. 1 Event study estimates. *Notes*: Workplace accident rates per 1000 workers before and after the CBD products availability. The graph plots event study coefficients estimated relative to the month before the entry. 95% intervals constructed using standard errors clustered at the provincial level. The regression is weighted by the provincial employment in the baseline year (2016)

While the effect is statistically significant and similar in magnitude for both male and female employees, the extent of the reduction in workplace accident rates reveals a considerable degree of heterogeneity across age groups. The reduction in workplace injuries due to CBD availability is most pronounced among younger (16–29) and prime-age (30–54) workers, who are also more likely to use light cannabis and related products. The former group experiences a reduction of about 6% in workplace injuries, whereas this effect is about −3% for the group of prime-age employees. Effect het-

Table 2 Baseline and heterogeneous effects

		Gender		Age group			Sector of activity		
	Total	Males	Females	Young	Prime-age	Senior	Primary	Secondary	Tertiary
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Entry_{pk}$	−0.030**	−0.033*	−0.029**	−0.111**	−0.030**	0.012	0.046	−0.042	−0.034**
	(0.012)	(0.017)	(0.012)	(0.048)	(0.013)	(0.019)	(0.180)	(0.027)	(0.014)
Mean outcome	1.183	1.440	0.839	1.773	1.089	1.116	0.567	1.341	0.858
R^2	0.537	0.518	0.321	0.324	0.498	0.274	0.020	0.449	0.295
Observations	2544	2544	2544	2544	2544	2544	2544	2544	2544

Notes: regressions include province and time fixed effects and are weighted by the provincial employment in the baseline year (2016). Clustered standard errors at the provincial level are in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$

erogeneity across age groups may derive from several aspects, such as different health behaviors towards CBD consumption or heterogeneous mental and physical stressors due to different life trajectories, working conditions, and exposure to occupational hazards (see, e.g., Kerndler et al. 2025).[11] Therefore, we shed light on the sector of activity as a further determinant of effect heterogeneity, dividing between primary, secondary, and service sectors. While it is difficult to derive conclusions from the primary sector due to the high share of informal employment, our point estimates reveal that the effect is very similar between services and secondary sector, although the latter is less precisely estimated. Overall, the finding that the impact of CBD availability is homogeneous between male and female employees as well as across manufacturing or construction industries and service sectors (namely workers and industries characterized by different physically-demanding occupations and risk profiles) but is concentrated among youth and prime-age workers, might suggest that the effect would be driven by the demand-side, that is CBD uptake, rather than by workplace conditions and job risks.

These results are in line with previous evidence on the effects of marijuana liberalization on lost days of work, work capacity, and workers' compensation claimings documented in the USA. Ghimire and Maclean (2020) detect a reduced propensity to claim workers' compensations by 6.7% post-MML, suggesting that workers use marijuana medically to treat symptoms associated with work-related injuries due to its effectiveness in reducing symptoms burden associated. Abouk et al. (2023) find similar results on post-RML on workers' compensation benefits and lost days of work. The reduced opioid prescriptions points out that patients substitute marijuana for prescription medications used to treat chronic pain, with improvements in pain management and in work capacity. Furthermore, the reduction in non-traumatic injuries such as low back disorders or infectious diseases suggests that the increased use of marijuana as a source of pain management may reduce the need of absence from work and, thereby, the injury rates.

4.2 Robustness checks

To test the robustness of our results, we run a series of sensitivity checks. We show that our results are robust to the use of alternative model specifications and identification strategy; are not biased by geographical spillovers or driven by either underlying trends across provinces with different baseline characteristics or unobserved province-specific shocks; and are confirmed by the use of alternative estimators accounting for the staggered nature of our treatment. Furthermore, we conduct falsification tests that help us in excluding spurious correlations and in strengthening the causal mechanisms.

[11] In line with this hypothesis, we estimate the effects of CBD access on the number of workplace injuries for different sub-categories within the young and prime-age groups using a count regression model. We find that the effect on prime-age workers is driven by the group aged 26–39 rather than 40–54. These results are available upon request.

4.2.1 Model specifications

First, we perform some exercises on the model specification aimed at (i) reducing the pre-policy period (May 2016–December 2017); (ii) reaching symmetrical time windows by considering 6 months before and after the unintended implementation of the policy (May 2017); and (iii) extending the pre-treatment period to 2015. The results are reported in columns (1)–(3) of Table 3 and are in line with our benchmark model.

Second, we test the robustness of our results by leveraging the variation in the physical availability of CBD products across provinces. To achieve this, we adopt an alternative identification strategy that uses a DiD model, incorporating the number of grow shops in each province prior to the unintended liberalization in May 2017 as a treatment intensity variable. This approach allows us to replicate the estimates over the same sample period (column 4), and extends the analysis to a longer pre-treatment period (column 5), and to December 2018, just before the restrictive policy introduced by the new government in 2019 (column 6). The negative coefficients indicate that provinces with higher pre-liberalization CBD infrastructure experienced a statistically significant reduction in workplace injuries, although with a smaller magnitude compared to the baseline DiD estimate. This smaller effect likely reflects the continuous nature of treatment intensity, which accounts for the incremental differences in CBD access.

Table 3 Alternative specifications

	Model specification			Treatment intensity		
	Reduced time window (1)	−6/+6 months (2)	Extended pre-treatment (3)	Same period (2016-2017) (4)	Extended pre-treatment (5)	Extended time window (6)
$Entry_{pk}$	−0.028**	−0.040**	−0.034**			
	(0.012)	(0.016)	(0.014)			
$Shops_{p2016} \times Post_t$				−0.011***	−0.011**	−0.006
				(0.004)	(0.004)	(0.003)
Mean outcome	1.228	1.222	1.233	1.183	1.233	1.217
R^2	0.556	0.573	0.545	0.537	0.545	0.546
Observations	2120	1272	3816	2544	3816	5088

Notes: the specification in column (1) reduces the analysis to the period May 2016–December 2017. The specification in column (2) reduces the analysis to 6 months before and after May 2017. The specifications in columns (3) and (5) extend the pre-treatment period including 2015. The specification in column (6) covers the period 2015–2018. The specifications in columns (4)–(6) use a treatment intensity variable based on the log number of pre-policy grow shops (October 2016) interacted with a dummy = 1 indicating the post-May 2017 period. Regressions include province and time fixed effects and are weighted by the provincial employment in the baseline year (2015 or 2016). Clustered standard errors at the provincial level are in parentheses. $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 4 Underlying trends and unobserved shocks

	Workplace hazards (1)	Industrial composition (2)	Economic development (3)	Demographic structure (4)	Irregular employment (5)	Regional trend (6)	Province shocks (7)	Past outcome (8)
$Entry_{pk}$	−0.025*	−0.028**	−0.034**	−0.033**	−0.032**	−0.031**	−0.032**	−0.007
	(0.013)	(0.013)	(0.013)	(0.013)	(0.012)	(0.013)	(0.013)	(0.016)
Mean outcome	1.183	1.183	1.183	1.183	1.183	1.183	1.183	1.246
R^2	0.554	0.577	0.574	0.562	0.583	0.699	0.581	0.604
Observations	2544	2544	2544	2544	2544	2544	2544	1272

Notes: regressions include province and time fixed effects and are weighted by the provincial employment in the baseline year (2016). The full set of time dummies is interacted with provincial characteristics measured in 2015; number of workplace injuries (column 1); share of employment in the secondary sector (column 2); log of per-capita GDP (column 3); share of inhabitants aged 16–29 on total population (column 4); regional share of irregular employment (column 5); regional dummies (column 6); quintile dummies for the change in workplace accident rate over the sample period (column 7). The specification in column (8) regresses workplace injury rate in 2015 on $Entry_{pk}$ in 2017. Clustered standard errors at the provincial level are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

4.2.2 Confounding factors and placebo tests

Identification threats in our setting arise if the observed effect is driven by provincial unobserved characteristics that are correlated with CBD access and injury rates. In Table 4, to formally assess the role played by underlying trends, we augment our model by including a full set of interactions between time dummies and the initial number of workplace injuries in each province (column 1). These interactions flexibly account for heterogeneous trends across provinces with different baseline occupational hazards. Similarly, in column (2), we account for provinces' industrial composition, a further determinant of workplace injury risk, by interacting the province p's share of employment in the secondary sector in 2015 with a full set of time dummies. In columns (3)–(4), we also consider province-specific trends based on log GDP per-capita and share of youth (16–29) over total population to account for economic development, urbanization, and demographic conditions. We find that these identification threats are unlikely to drive the results.

Moreover, we alleviate concerns about our estimates being driven by unobserved differential trends in workplace safety and occupational health across regions. In column (5), we account for labor market informality by interacting the time dummies with the regional share of irregular employment in 2015 provided by ISTAT, without affecting the main result. In column (6), we include region-specific time trends along with province fixed effects used in the benchmark specification. It is reassuring that the estimated coefficients are very similar to the baseline one, since this rules out the possibility that the key results are driven by some underlying region-specific time trends that may capture potential unobserved cross-region differences in occupational health over time.

Nonetheless, the results may reflect unobserved time-varying shocks affecting specific provinces. We start by performing a leave-one-out exercise in which we estimate our model by excluding one province at a time from the analysis. Figure A.4 in the online appendix plots the estimates of the DiD coefficient corresponding to each excluded province. The results are robust—when one province is omitted, the results remain unaffected in magnitude and statistical significance compared to the baseline specification. Furthermore, we assess the role of these shocks by dividing provinces into five bins corresponding to the quintiles of the change in workplace accident rate over the sample period. We then extend our model by adding a full set of interactions between each quintile bin and time dummies to absorb such unobserved shocks common to provinces with similar trends in workplace safety. Reassuringly, the results in column (7) are largely unchanged.

To strengthen causal mechanisms in our framework, we perform a falsification test by estimating the impact of CBD products availability on the workplace accident rate measured in 2015, namely two years before the liberalization. If treated and control groups experienced similar changes in occupational health in a period before the unintended liberalization, it would suggest that anticipation mechanisms are biasing our analysis and that the parallel trend assumption does not hold. The coefficient reported

in column (8) is not statistically significant and very close to 0, providing further support to our main results and mechanisms in terms of causality and confirming that our estimates are not biased by any anticipation effect.

Next, we conduct a permutation test by randomly assigning the treatment to provinces at different points in time in place of the real one, in order to generate a "fake" treatment based on a Monte Carlo simulation. This exercise allows us to test the robustness of the results to assumptions about the structure of the error distribution. Figure A.5 illustrates the non-parametric distribution of placebo treatment effects resulting from 5000 permutations regarding the impact of CBD products availability on workplace accidents. The distribution reveals that the mean is virtually zero, indicating an unbiased estimate of the effect.

4.2.3 Geographical spillovers

Cross-province travel to access CBD products may introduce spillover effects, potentially invalidating the Stable Unit Treatment Value Assumption (SUTVA) and bias our estimated coefficients. Although we cannot rule out cross-province movements to buy the products, the short period we consider limits possibilities that individuals managed to know about the local availability of CBD products in a different province and systematically move there just to buy the product. This leads to spillover effects from cross-province shopping being not a relevant issue in our setting. Nevertheless, we test the geographical reach of the effect of new shop entries to check for the presence of geographical spillovers in Table 5. In column (1), we formally address concerns on spillover effects by including in the treatment group also the provinces adjacent to the treated units. The estimated coefficient is very close to zero and not statistically significant, confirming that the SUTVA is not violated in our framework. Similar conclusions are obtained when we extend the treatment at the regional level in column (2). These robustness checks exclude the presence of downward bias coming from cross-province shopping in our setting, and confirm that endogeneity issues due to potential migration effects to/from the treated provinces are ruled out in our identification strategy.

Table 5 Geographical spillovers

	Adjacent provinces (1)	Regional treatment (2)
$Entry_{pk}$	0.009	0.037
	(0.035)	(0.037)
Mean outcome	1.183	1.183
R^2	0.536	0.536
Observations	2544	2544

Notes: the specification in column (1) extends the treatment to the adjacent provinces. The specification in column (2) extends the treatment at the regional level. Regressions include province and time fixed effects and are weighted by the provincial employment in the baseline year (2016). Clustered standard errors at the provincial level are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

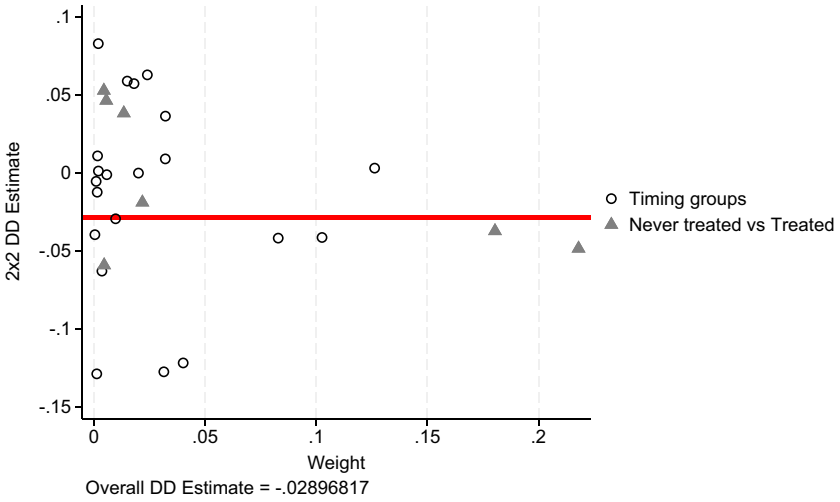

Fig. 2 The figure plots each 2×2 DiD estimates against their weights calculated following the decomposition proposed by Goodman-Bacon (2021). The red horizontal line refers to the weighted average DiD coefficient resulting from the decomposition. The "timing groups" (circles) refer to groups whose treatment started at different times and serve as each other's control group in two ways: late as a control group for an earlier treatment group and vice versa. The triangle refers to estimates where the never-treated provinces act as the control group

4.2.4 Alternative staggered DiD estimators

The two-way fixed effect DiD model is a weighted average of all possible 2 × 2 DiD estimators. Thus, we study the time-varying nature of the policy and the weights associated with its component following the decomposition proposed by Goodman-Bacon (2021). We plot all the 2×2 pairwise DiD estimates (on the vertical axis) against their weights (on the horizontal axis). The red line in Fig. 2 represents the weighted DiD coefficient once accounting for the different weights associated with its component. We note that the coefficient is negative and qualitatively similar to the benchmark one (−0.029).[12] Moreover, the treated vs. never treated are the 2 × 2 pairwise DiD with the largest weight, suggesting that this is the main source of identification in our framework. Finally, albeit some 2 × 2 pairwise comparisons are positive, their weights are very close to zero.

Finally, we employ alternative estimators to test the robustness of our findings by eliminating any residual concerns related to the staggered nature of our treatment (Borusyak et al. 2024; Callaway and Sant'Anna 2021). In DiD settings with staggered treatment adoption, standard estimation techniques can sometimes produce biased estimates if treatment effects are heterogeneous over time or across groups. This issue arises because later-treated units may serve as controls for earlier-treated units, potentially confounding the estimated effects. By using alternative estimators specifically designed to mitigate these biases, we ensure that our results are not driven by method-

[12] The original DiD accounts for the presence of time dummies, which are not implementable using the decomposition routine available in the Stata package "bacondecomp."

ological artifacts. As shown in Fig. A.6 in the online appendix, these estimators yield results that remain consistent with our main analysis.

5 Possible mechanisms

Previous evidence on the USA supports a substitution effect hypothesis behind the reduced self-reported absence from work caused by illness and medical issues, and the declined work compensation claiming due to better symptoms management following the liberalization of marijuana (Ullman 2017; Ghimire and Maclean 2020; Abouk et al. 2023). If workers use CBD products or light cannabis outside of work hours to manage stress and anxiety, it might contribute to better relaxation and sleep quality, leading to improved cognitive functions and alertness at work. For workers in high-stress environments, this could potentially improve focus and reduce mistakes due to stress or burnout. At the same time, better-managed pain through the use of CBD products might lead to improved physical functioning and alertness, reducing the likelihood of workplace accidents.

The substitution effect is also likely to be the main underlying mechanism for the Italian case we are focused on. As detected by Carrieri et al. (2020), the local availability of C-light in a given Italian province led to a significant and large reduction of dispensed boxes of several pharmaceuticals. First, anxiolytics and sedatives, i.e., the type of drugs for which C-light and CBD products are recognized as having a clinical effect to treat anxiety, psychosis, and sleep disorders due to their relaxant properties, are reduced by approximately 10%. Second, Carrieri et al. (2020) also document a 1–1.5% reduction in anti-epileptic, anti-depressant, opioid, and anti-migraine prescriptions, namely pharmaceuticals which appear to offer a more chronic therapy. Therefore, in our setting, the availability of C-light and other CBD products would operate both at the extensive margins by reducing workplace accidents through lower mental distress, improved sleep quality, and concentration at work, and at the intensive margins by offering better pain management that may shorten the length of absence from work and increase work capacity.

Table 6 Possible mechanisms

	Sleep disorders, stress, anxiety, and relaxation		Pain management and chronic therapies		Alcohol consumption	
	Below (1)	Above (2)	Below (3)	Above (4)	Below (5)	Above (6)
$Entry_{pk}$	−0.027*	−0.042**	−0.012	−0.052**	−0.013	−0.045**
	(0.015)	(0.021)	(0.014)	(0.021)	(0.012)	(0.019)
Mean outcome	1.184	1.182	1.066	1.352	1.019	1.323
R^2	0.577	0.499	0.580	0.515	0.516	0.595
Observations	1272	1272	1272	1272	1272	1272

Notes: regressions include province and time fixed effects and are weighted by the provincial employment in the baseline year (2016). Clustered standard errors at the provincial level are in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

In what follows, we explore these hypotheses and present the corresponding results in Table 6. We start by checking whether the positive effect of CBD products availability on workplace safety operates through the substitution of some pharmaceuticals used to face anxiety and stress, and to improve relaxation and sleep quality. In doing so, in columns (1)–(2), we split the sample in provinces below and above the median for total sedatives, anxiolytics, and anti-psychotics prescriptions measured in 2015. Second, in columns (3)–(4), we adopt the same strategy when considering pharmaceuticals that are mostly used as painkillers and for chronic therapies, such as opioids, anti-epileptics, anti-migraines, and anti-depressants. Third, in columns (5)–(6), we also check whether CBD products availability reduces alcohol consumption through substitution, exploiting Istat regional data on the percentage of people assuming alcohol not during the meals. Since cannabis and alcohol can be substitutes, increased cannabis-derived products availability may lead to a reduction in alcohol consumption resulting in fewer workplace injuries.

In columns (1) and (2), provinces with higher pre-liberalization levels of sedative, anxiolytic, and antipsychotic prescriptions exhibit a stronger reduction in workplace injuries (-0.042 compared to -0.027). We interpret this evidence as suggestive of a substitution relationship between CBD products and pharmaceuticals commonly used to manage stress, anxiety, and sleep disorders, improving workers' mental health and concentration. Similarly, columns (3) and (4) show that provinces with higher pre-liberalization use of painkillers and chronic therapy drugs experience a more pronounced decline in injuries (-0.052 *vs.* -0.012). This suggests that CBD's pain-relieving properties may reduce workplace accidents by enhancing workers' physical health and capacity to perform their tasks. Finally, in columns (5) and (6) we examine the link between CBD availability and alcohol consumption, a known risk factor for workplace accidents. Provinces with higher baseline alcohol use experience a greater reduction in injuries (-0.045 *vs.* -0.013). This finding aligns with the idea that CBD may substitute for alcohol consumption, thereby reducing accidents caused by impaired judgment or coordination.

However, we cannot interpret these findings purely as direct mediation pathways on occupational hazards, considering that our estimates capture intention-to-treat effects of CBD availability rather than individuals' CBD usage, and being Carrieri et al. (2020)'s substitution mechanism detected on prescription volumes reflecting also non-working population. Along with a direct substitution effect, also indirect underlying channels might play a role in determining the positive impact of CBD availability on workplace safety. For instance, social spillovers may influence a worker's well-being and reduce injury risks even without direct usage of CBD products but through improved interpersonal dynamics, workplace behaviors, and reduced household stress levels due to CBD uptake by family members or colleagues.

In Table 7, we test the impact at the intensive margin providing evidence on the effect of the availability of CBD products on the severity of workplace injuries both at the province and at the episode-level. As main outcomes, we analyze two measures of the severity of work-related accidents: (i) the number of days of sick leave assessed by a doctor; (ii) the degree of impairment established by the INAIL's scheme, re-scaled to range between 0 and 100, with 0 meaning absence of permanent impairments and 100 the maximum degree of permanent impairment. In the province-level analysis,

Table 7 Sick leave days and degree of health impairment

	Days of absence		Health impairment		Injury-level analysis	
	Mild (1)	Severe (2)	Micro (3)	Macro (4)	Sick leave days (5)	Health impairment (6)
$Entry_{pk}$	−0.025**	−0.005	−0.030**	−0.000*	−0.403*	−0.210**
	(0.010)	(0.005)	(0.012)	(0.000)	(0.230)	(0.087)
Mean outcome	0.806	0.376	1.180	0.003	29.598	6.295
R^2	0.543	0.230	0.537	0.013	0.039	0.038
Observations	2544	2544	2544	2544	569,852	103,470

Notes: in columns (5) and (6), the regressions include, along with province, month, and year fixed effects, also demographic characteristics such as age, age square, a dummy for being Italian, female, and industry fixed effects (Ateco 1-digit level). In column (5), we exclude top and bottom 1% outliers for days of absence. In column (6), we also drop injury episodes with a missing value (−1) in health impairment. Regressions are weighted by the provincial employment in the baseline year (2016). Clustered standard errors at the provincial level are in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$

we first distinguish the workplace injury rates according to sick leave days in severe and mild injury rates in columns (1)–(2). Then, we split the injuries into those with and without macro-permanent impairments in columns (3)–(4).[13] For the second type of analysis, which estimates the degree of severity among workers' injuries in terms of the degree of impairment and the number of prescribed sick leave days, the unit of analysis is the injury episode. The estimated coefficients are presented in columns (5)–(6).

The analysis at the province level shows that the main results are driven by less severe injuries, along with a less precise effect on workplace accidents implying macro-permanent impairments. The injury-level analysis confirms these results; on average, injured workers in a province with CBD products availability experience a lower degree of health impairment by 0.210, roughly 3.3% of the outcome mean, and a lower number of sick leave days by 0.4 day, that is a −1.4%. We can speculate that severe and more traumatic injuries are less responsive to pain management therapy availability, whereas mild injuries can potentially be managed medically. In this case, the access to CBD products as an additional source of pain management may reduce the need of absence from work and increase work capacity. These results are in line with Abouk et al. (2023), who find a very small reduction for traumatic injuries compared to non-traumatic ones.

6 Conclusions

In this paper, we examine the causal impact of CBD products availability on workplace injuries. We exploit Italy's unintended liberalization of low-THC cannabis as a natural experiment and adopt a staggered DiD approach, leveraging variation in the timing of CBD retailer entries across provinces.

[13] Severe (mild) injuries imply more (less) than 31 days of absence from work. Injuries with (without) macro-permanent impairments are those above (below) 50 in the INAIL's scheme.

We show that CBD products availability reduces workplace injury rates by 2.5%, with larger effects among young and prime-age workers. These estimates should be interpreted as intention-to-treat (ITT) effects, as our treatment captures the onset of local CBD availability rather than individual CBD usage. A battery of robustness checks confirms these findings, and placebo tests rule out confounding trends. This effect is stronger in provinces with higher pre-existing use of alcohol and pharmaceuticals commonly prescribed for stress, anxiety, sleep disorders, and chronic therapies. Overall, we interpret this pattern as suggestive of a substitution-based channel in which CBD products may serve as an additional source of improved pain management and mental health, operating both at the extensive and intensive margins.

These findings have important implications for public health, labor market policies, and the ongoing debate surrounding cannabis regulation. From a regulatory standpoint, these insights suggest that policies governing CBD and cannabis-related products should not be solely assessed through a lens of drug control but also through their broader implications for workforce well-being and economic efficiency. While much of the existing discourse around cannabis policy has focused on potential risks related to cognitive impairment and workplace productivity, our findings highlight the need for nuanced regulations that distinguish between THC-containing and non-psychoactive cannabis products, recognizing the potential occupational health benefits of the latter stemming from improved pain management and mitigated stress-related impairments.

However, our analysis primarily focuses on short-term effects due to the constraints of the empirical design. Future research should investigate the long-term impacts of CBD access on workplace injury trends, labor productivity, and healthcare expenditures, providing a more comprehensive understanding of how cannabis liberalization influences workforce dynamics and public health spillovers over time. In a similar vein, recent literature provides evidence on the effects of legalization on employment and earnings (Dave et al. 2025), as well as on the relationship between working conditions and substance use (Chen et al. 2026). Focusing on long-term health outcomes would also allow researchers to account for any potential side effects coming from prolonged use of these products (Hansen et al. 2021; Lichenstein 2022; Moore et al. 2024). As for the Italian case, where a first CBD ban took place in 2019, and more restrictive policies are expected to come, future work may derive complementary policy perspectives from evaluating the impact of these restrictions on occupational safety and prescription trends.

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Declarations

Competing interests The authors declare no competing interests.

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