



The causal effect of mental health on labor market outcomes: The case of stress-related mental disorders following a human-made disaster

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As disasters increase due to climate change, population density, epidemics, and technology, information is needed about postdisaster consequences for people's mental health and how stress-related mental disorders affect multiple spheres of life, including labor-market attachment. We tested the causal hypothesis that individuals who developed stress-related mental disorders as a consequence of their disaster exposure experienced subsequent weak labor-market attachment and poor work-related outcomes. We leveraged a natural experiment in an instrumental variables model, studying a 2004 fireworks factory explosion disaster that precipitated the onset of stress-related disorders (posttraumatic stress disorder, anxiety, and depression) among individuals in the local community (N = 86,726). We measured labor-market outcomes using longitudinal population-level administrative data: sick leave, unemployment benefits, early retirement pension, and income from wages from 2007 to 2010. We found that individuals who developed a stress-related disorder after the disaster were likely to go on sickness benefit, both in the short- and long-term, were likely to use unemployment benefits and to lose wage income in the long term. Stress-related disorders did not increase the likelihood of early retirement. The natural experiment design minimized the possibility that omitted confounders biased these effects of mental health on work outcomes. Addressing the mental health and employment needs of survivors after a traumatic experience may improve their labor-market outcomes and their nations' economic outputs.

mental health | natural disasters | labor market outcomes | causal effects | natural experiment

Working adults who experience mental disorders also have more difficulties in the workplace and in the labor force. As a consequence, individuals with mental disorders may experience downward occupational mobility (1), driven by poor job performance, absenteeism, low wages, unemployment, and early exit (2–4). These associations could reflect a causal effect of mental disorders on labor-market outcomes. For instance, low motivation, fatigue, social withdrawal, and self-regulation difficulties may impair individuals' ability to engage in and maintain employment. Alternatively, these associations may stem from reverse causation, in which problems in the labor market trigger mental health problems. Or, these associations could emerge from common causes. Cognitive abilities, personality characteristics, and environmental stressors could simultaneously shape risk for both mental disorders and labor-market detachment. Establishing a causal effect of mental disorders on labor-market outcomes requires study designs that can address these alternative explanations (5).

Prior work has utilized diverse approaches, including longitudinal designs in which mental health problems precede labor-market outcomes (6–8); propensity-score methods that control for measured confounders (9, 10); sibling fixed-effects approaches that control for unmeasured confounders (11–14); natural experiments that leverage naturally occurring variation in the treatment of mental health problems [e.g., changes in policies concerning mental-health treatment access (15)]; and randomized controlled trials (primarily in lower- and middle-income countries) that track labor-market outcomes following behavioral and pharmacologic interventions to improve mental health (16, 17). Collectively, this body of research provides evidence that mental health problems are linked to unemployment, reduced earnings, receipt of work disability, and take-up of disability pension (though associations with earnings are somewhat variable) and that treatment of these problems may reduce these negative labor-market outcomes. While there is increasing causal evidence that treatment of mental disorders improves labor market outcomes, less is known about the causal effect of developing a mental health

Significance

We leveraged a natural experiment—a fireworks factory disaster which occurred in 2004—in an instrumental variables model to test whether developing a stress-related mental disorder negatively impacts labor-market outcomes among working-aged individuals (N = 86,726). Our results showed that individuals who developed a stress-related disorder after the disaster were likely to go on sickness benefit, both in the short- and long-term, to use unemployment benefits, and to lose wage income in the long term. Stress-related disorders did not increase the likelihood of early retirement. Addressing the mental health and employment needs of survivors after a traumatic experience may improve labor-market attachment. Such supports may become increasingly important as disasters increase due to climate change, population density, epidemics, and technology.

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disorder on subsequent labor market outcomes, and natural experiments have seldom been leveraged for this purpose. Triangulation of results across study designs with complementary strengths and limitations can help to improve the quality of evidence that is needed to establish the presence of causal associations (18).

Here, we leverage a natural experiment and longitudinal population-level administrative data to test the causal hypothesis that developing stress-related mental disorders—posttraumatic stress disorder, anxiety, and depression—decreases labor-market attachment and leads to poorer work-related outcomes. Specifically, we used a natural experiment to obtain exogenous variation in the risk of developing stress-related mental disorders. The natural experiment comes from one of the largest disasters in recent times in Denmark: a factory explosion that occurred on November 4, 2004, whose seismic waves rocked an entire community. Previous studies have documented that this event substantially increased the risk of developing stress-related disorders in the exposed population (19). In the present study, we relied on 43,363 individuals aged 25 to 50 who lived in the impact area at the time of the disaster and a matched sample of 43,363 comparable individuals living elsewhere in Denmark at the time of the disaster, to test whether these mental disorders affected labor-market outcomes in an instrumental variables (IV) model. To test the hypothesis that developing stress-related mental disorders decreases attachment to the labor market, we focus on four outcomes: sick leave, unemployment benefits, early retirement pension (a pension granted to individuals who are unable to work for physical or mental health reasons), and income from wages. We tracked these four indicators from 2007 through 2010 following the 2004 fireworks factory explosion, hypothesizing that sick leave would rise, followed by unemployment benefits, then disability pension status. We hypothesized that during this period, income from wages would fall.

Methods

Study Population. We used population-level administrative data from Denmark. All Danish residents are assigned a unique personal number through the Danish Civil Registration System that identifies them in interactions with the government and private institutions. These personal numbers help to determine where individuals live and enable the linkage of administrative databases at the individual level.

We based our study population on $N = 5,391,853$ individuals who were living in Denmark at the time of the explosion. Due to our focus on labor market outcomes, we further restricted our study population to only include individuals of working age and who were not so old that they would naturally retire in the years following the explosion. We thus restricted our study population to $N = 1,987,023$ individuals aged 25 to 50 y at the time of the explosion (see *SI Appendix* for further details about the work behavior of working-age Danes).

Because individuals living in the impact area are not representative of all Danes, we used nearest-neighbor propensity score matching (1:1, no replacement) to match each of the working-age individuals who lived in the impact area at the time of the explosion with one other same-sex Dane on the following characteristics: 1) lagged information on the outcome variables (sick leave benefits, unemployment, early retirement benefits, and income) from the two years leading up to the 2004 explosion (2002 and 2003), 2) demographic characteristics including age, immigrant status, marital status, and level of education (measured in the beginning of 2004), and 3) lagged information on mental health measured in 2002 and 2003. We matched on these characteristics given evidence that vulnerable groups respond more strongly to stressors (20–22). The strategy of combining propensity score matching and IV models is well described in the literature (23–25).

Our final study population consisted of 86,726 individuals, of which half ($N = 43,363$; 21,435 women and 21,928 men) lived in the impact area between January 2004 and January 2005, and the other half, our control group, did not. The upper part of Table 1 shows the postmatching distribution of the variables that were used for matching. Table 1 documents that the matching procedure ensured that the individuals in the impact area were sufficiently similar to the

individuals from the control area in the period leading up to the explosion so that the estimated effect of the instrument would not just reflect initial differences.

Because the data for this study came from deidentified administrative registers that Statistics Denmark makes available for research purposes for approved institutions, institutional review board approval was not required to carry out the research. This research was conducted as part of project #705830 approved by Statistics Denmark.

The Endogenous Regressor: Stress-Related Mental Disorder. From the register on psychiatric hospitalizations (which includes both inpatient and outpatient contact), we constructed an indicator which measures whether the individual had been diagnosed with post-traumatic stress disorder (PTSD) (ICD-10 codes F43, F430, F4300, F4301, F4302, F431, F438, and F430), anxiety (ICD-10 codes F40, F400, F4000, F4001, F401, F402, F402A, F41, F410, F4100, F4202, and F411), or depression (ICD-10 codes F32, F320, F3200, F3201, F321, F3210, F3211, F322, F323, F3230, F3231, F328, F329, and F329A) at a psychiatric hospital between November 2004 and October 2006. PTSD, anxiety, and depression are not qualitatively different conditions. The literature on the classification of mental disorders provides evidence and consensus that these three conditions belong to a syndrome called “internalizing disorders” (26). The three disorders are known to share similar genetic and environmental etiological factors. People who meet diagnostic criteria for one of these conditions are likely to meet criteria for the other two conditions, simultaneously or later. For this reason, the three are often studied together as a syndrome of distress-related diagnoses.

We used a collated measure of mental disorders for the two years following the explosion (November 2004 to October 2006) rather than focusing on 1 y, as the three conditions often take time to develop and be diagnosed. In our sample, 990 individuals (657 women and 333 men) were diagnosed—either through inpatient or outpatient hospital contact—with PTSD, anxiety, or depression during those 2 y: 401 women and 211 men in the impact area and 256 women and 122 men in the control group.

Outcome Variables in the Labor Force. Our analysis focuses on whether and how stress-related mental disorders affect labor market affiliation, identified through four outcomes measured in each of the 4 y 2007 to 2010: 1) sick leave, 2) unemployment, 3) transitioning into early retirement pension, and 4) income. With this setup, we analyze a total of 16 outcome variable (4 y for each of the four outcome areas).

In Denmark, the benefit system is organized such that the entitlement to sick leave benefits is exhausted after 22 wk, and unemployment benefits for insured unemployed are exhausted after 2 y, while early retirement pension does not have a fixed duration and can continue indefinitely. When sick leave benefits are exhausted, the individual who is not ready to transition back into work transitions instead into unemployment benefits and/or into a process that could eventually lead to early retirement pension (although granting of formal disability status is costly and thus relatively rare). The system implies that our four outcomes are mutually exclusive: an individual can receive wage income from employment or can receive only one benefit at a time (on a weekly or monthly basis). During a week in which the individual receives sick leave benefits, he or she cannot also receive unemployment benefits.

We defined sick leave as weeks within a year with this type of benefit, which is granted to individuals who are sick for more than 2 wk, and who would otherwise rely on wage income or unemployment benefits. This information about sick leave was obtained from the DREAM database, which is compiled by the Danish Agency for Labour Market and Recruitment. We defined unemployment as reliance on unemployment benefits for both insured and uninsured unemployed for more than 50 percent of the time in a year. This information was obtained from the Central Labor Market Register. We defined early-retirement pension as weeks within a year with this type of benefit, which is granted to individuals who are unable to support themselves for physical or psychological health reasons. This information on early retirement pension was also obtained from the DREAM database. We defined income as all pretax income in thousands DKK. This information was obtained from the Income Register which is collected by the Danish Tax Authorities.

Statistical Methods. This study used a natural experiment to obtain exogenous variation in the risk of developing stress-related mental disorders. The natural experiment comes from one of the largest disasters in recent times in Denmark: On November 3, 2004, two employees of N. P. Johnsen's Fireworks Factory in Seest dropped a box of fireworks, which caught fire and exploded. The fire spread to the rest

Table 1. Postmatching distribution of background characteristics and outcome variables, for the control group and treatment group

	Control group Mean or share (95% CI)	Treatment group Mean or share (95% CI)
<i>Covariates</i>		
Sick leave, 2002 (mean, weeks)	1.43 [1.38; 1.49]	1.50 [1.44; 1.55]
Sick leave, 2003 (mean, weeks)	1.52 [1.46; 1.58]	1.59 [1.52; 1.65]
Unemployment, 2002 (share with >50%)	3.11 [2.95; 3.27]	3.00 [2.84; 3.04]
Unemployment, 2003 (share with >50%)	4.25 [4.06; 4.44]	4.31 [4.12; 4.50]
Early retirement, 2002 (mean, weeks)	2.68 [2.58; 2.79]	2.65 [2.55; 2.76]
Early retirement, 2003 (mean, weeks)	2.93 [2.82; 3.04]	2.93 [2.82; 3.04]
Gross income, 2002 (mean, in 1,000 DKK)	258.05 [256.48; 259.60]	255.64 [254.28; 257.00]**
Gross income, 2003 (mean, in 1,000 DKK)	268.25 [266.71; 269.80]	265.41 [264.01; 266.82]**
Age, 2004 (mean)	38.05 [37.98; 38.11]	37.89 [37.82; 37.96]***
Immigrant (share)	7.04 [6.80; 7.28]	7.16 [6.92; 7.71]
Early school leaver (share)	29.08 [28.65; 29.51]	29.40 [28.97; 29.82]
Married (share)	49.81 [49.33; 50.27]	49.60 [49.12; 50.07]
Stress-related diagnosis, 2002 (share)	0.44 [0.38; 0.50]	0.44 [0.37; 0.50]
Stress-related diagnosis, 2003 (share)	0.61 [0.54; 0.68]	0.57 [0.50; 0.64]
<i>Endogenous regressor</i>		
Stress-related diagnosis, November 2004–October 2006 (share)	0.87 [0.78; 0.96]	1.41 [1.30; 1.52]***
<i>Outcome variables</i>		
Sick leave, 2007 (mean, weeks)	1.79 [1.73; 1.86]	1.95 [1.88; 2.02]**
Sick leave, 2008 (mean, weeks)	1.78 [1.72; 1.85]	1.90 [1.83; 1.96]
Sick leave, 2009 (mean, weeks)	1.73 [1.67; 1.80]	1.90 [1.84; 1.97]*
Sick leave, 2010 (mean, weeks)	1.80 [1.73; 1.86]	1.96 [1.89; 2.03]*
Unemployment, 2007 (share with >50%)	1.74 [1.62; 1.86]	1.30 [1.19; 1.40]***
Unemployment, 2008 (share with >50%)	0.59 [0.51; 0.66]	0.32 [0.26; 0.37]***
Unemployment, 2009 (share with >50%)	1.90 [1.77; 2.03]	2.19 [2.05; 2.32]
Unemployment, 2010 (share with >50%)	2.47 [2.32; 2.62]	2.99 [2.83; 3.15]
Early retirement, 2007 (mean, weeks)	4.08 [3.95; 4.21]	4.02 [3.89; 4.15]
Early retirement, 2008 (mean, weeks)	4.35 [4.22; 4.49]	4.31 [4.18; 4.44]
Early retirement, 2009 (mean, weeks)	4.66 [4.52; 4.80]	4.64 [4.51; 4.78]
Early retirement, 2010 (mean, weeks)	4.91 [4.77; 5.05]	4.89 [4.75; 5.03]
Gross income, 2007 (mean, in 1,000 DKK)	319.32 [317.23; 321.41]	318.81 [316.92; 320.71]
Gross income, 2008 (mean, in 1,000 DKK)	333.28 [330.97; 335.58]	333.13 [331.18; 335.08]
Gross income, 2009 (mean, in 1,000 DKK)	332.82 [330.83; 334.81]	330.31 [328.40; 332.23]**
Gross income, 2010 (mean, in 1,000 DKK)	346.09 [343.65; 348.53]	340.51 [338.36; 342.66]***
Number of observations	43,363	43,363

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$ (two-tailed test).

Note: The distributions of covariates and outcome variables in the table reflect distributions among all individuals in the control group and all individuals in the treatment group (i.e., those living in the impact area). The findings presented in the four panels of Fig. 2 only reflect outcomes among the compliers (i.e., individuals in the impact area that responded to the explosion by developing and being diagnosed with a stress-related mental disorder).

of the factory, causing two major explosions. The last explosion was the largest and caused seismic waves comparable to a magnitude 2.2 earthquake (like the seismic waves measured when the south tower of the World Trade Center collapsed on 9/11). The explosion threw large pieces of concrete, bricks, roof tiles, and iron carriers several hundred meters away from the factory area. Before the explosion, the police had evacuated 760 houses housing a total of 2,000 individuals. The explosion severely damaged 355 houses, of which half were subsequently uninhabitable. A total of 85 people had to receive medical treatment, and one person—a firefighter—lost his life in the first explosion. The disaster is perceived to be the largest in Denmark since WW2, and both residents of the evacuated area as well as the larger local community surrounding the fireworks factory were affected by the catastrophe (Fig. 1).

Aside from the material damage, reports show both short- and long-term mental health deterioration among individuals living close to the factory (19, 27). This includes a significant rise in the proportion of individuals diagnosed with

stress-related disorders around the factory in the years following the explosion (28). Relying on this knowledge about how the fireworks disaster affected the likelihood of developing stress-related disorders, we used a binary indicator for whether the individual lived in the impact area affected by the explosion in November 2004 as an instrument for mental health in an IV-model (29). Eqs. 1 and 2 show the model:

$$SD_i = \alpha_i + \delta_1 x_i + \theta \text{impact area}_i + r_i, \quad [1]$$

$$\text{labor market outcomes}_i = \alpha_2 + \delta_2 x_i + \beta \widehat{SD}_i + u_i, \quad [2]$$

In both equations, SD represents stress-related disorders and i represents the individual ($i = 1, \dots, N$). Eq. 1 forms the first stage, in which the endogenous variable (SD) is regressed on the vector of exogenous controls x_i (as specified in Table 1), and the instrument, which reflects whether the individual lived in the



Fig. 1. Pictures showing the explosion and its consequences. Sources (clockwise order of appearance starting from *Top Left*): Claus Fisker/Ritzau Scanpix, Claus Fisker/Ritzau Scanpix, Bax Lindhardt/Ritzau Scanpix, Jan Laursen/ABC Luftfoto.

impact area at the time of the explosion. Eq. 2 uses the predicted value of the endogenous variable to predict each of the labor market outcomes, along with the vector of controls, x_i . Random error terms are r_i and u_i . The numerical value of the prediction expresses how much a one-unit change in the risk of developing a stress-related disorder because of the explosion affects the outcome in focus. The estimated effect is termed the local average treatment effect (LATE) and captures the treatment effect on the subgroup of treated individuals who responded to the instrument by experiencing an increased risk of developing a stress-related disorder. This group is termed the compliers.

The validity of the IV model rests on four key assumptions. First is the relevance assumption, which implies that the instrument has a causal effect on the endogenous regressor. Second is the exclusion restriction, which means that the instrument affects the outcome only through the endogenous regressor. Third is the exchangeability assumption, which implies that the instrument is random and thus uncorrelated with individual-level characteristics. Fourth is the monotonicity assumption, according to which there is a monotonic relationship between the instrument and the treatment; i.e., the instrument cannot increase the risk of stress-related mental disorders in some individuals but decrease this risk in others (30). In *SI Appendix*, we provide evidence to support that these assumptions are justifiable in the present study.

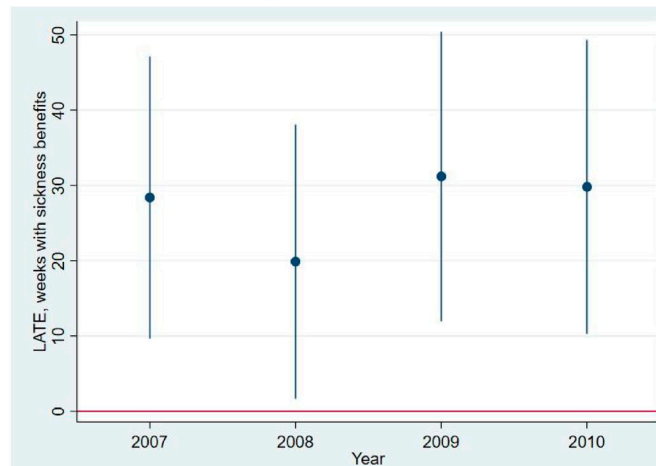
Defining the Instrument. Our instrument is a binary indicator, which takes the value 1 if the individual lived in the impact area at the time of the catastrophe, and 0 otherwise. This information about place of residence was obtained from the Central Person Register. We defined the population of the impact area as individuals living in municipalities a) that contained or were geographically adjacent to the evacuated area, and b) which contributed to the disaster relief, according to the Danish Emergency Management Agency (31). Thus, the instrument takes the value 1 for individuals who lived in the municipalities of Kolding, Lunderskov, Vamdrup, and Christiansfeld at the time of the explosion, according to the municipal borders as they were defined in 2005 (see *SI Appendix* for further details about the delimitation of the impact area).

Results

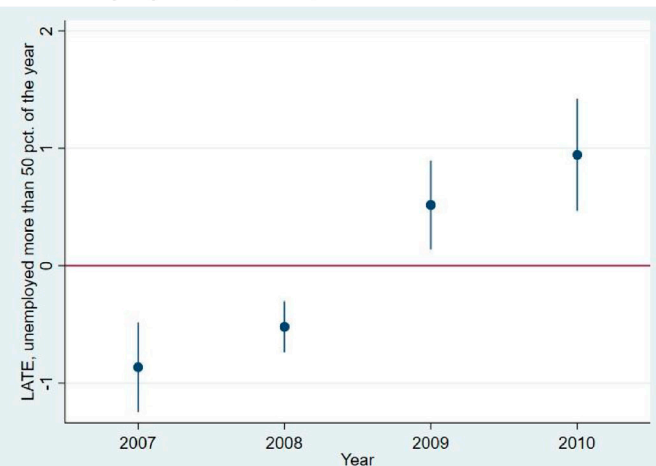
Table 1 (upper part) shows the postmatching distribution of background characteristics in the disaster-exposed (treatment) group and the control group. *SI Appendix, Table S1* shows the prematching distribution of the same variables. After matching, there were three small, but statistically significant differences between the two groups across the 14 total covariates: on wages in 2002 and 2003 and on age. However, the pseudo R^2 and χ^2 -test of the joint significance of the covariates both suggest that the treatment and control group are sufficiently balanced (pseudo $R^2 = 0.000$; $\chi^2 = 22.09$, $P = 0.109$). Thus, the matching procedure successfully produced balanced samples. Furthermore, there was a statistically significant difference between the treatment and control groups on the endogenous regressor, i.e., in the share of individuals who were diagnosed with a stress-related disorder between November 2004 and October 2006. In the treatment group, 1.41% of individuals were diagnosed with PTSD, anxiety, or depression between November 2004 and October 2006 (1.87% of women and 0.96% of men), versus 0.87% of individuals in the control group who were so diagnosed (1.19% of women and 0.56% of men).

The lower part of Table 1 compares the four labor-market outcomes from 2007 to 2010 for individuals who lived in the area impacted by the explosion against their matched controls. Fig. 2 *A–D* shows the second-stage results from the IV models in which we estimated the association between stress-related disorders and the four measures of labor-market marginalization for each of the years 2007 to 2010. The results from the IV model, presented in Fig. 2, rely on the assumption that these differences are attributable to the larger share of individuals in the impact area who were

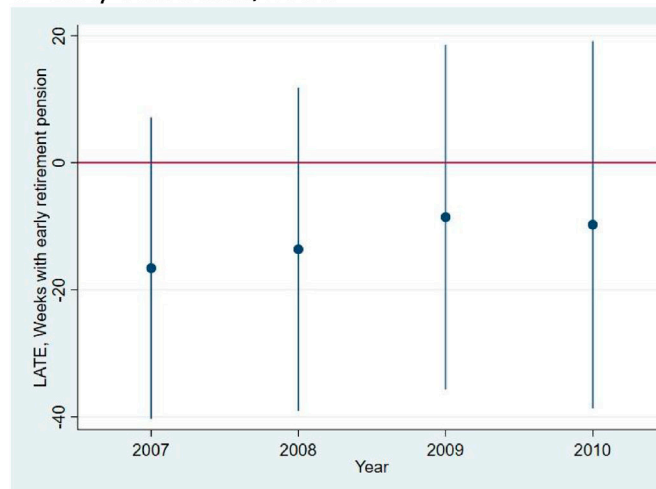
A Sick leave benefits, weeks



B Unemployment (>50%)



C Early retirement, weeks



D Wage income (1,000 DKK)

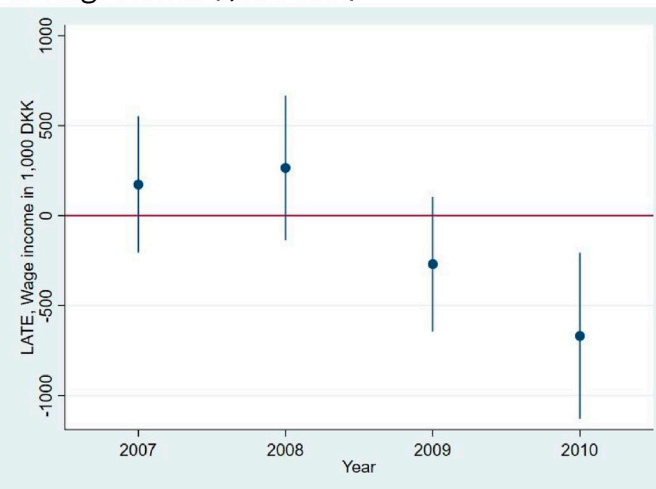


Fig. 2. The effect of postdisaster stress-related disorders on the four measures of labor-market marginalization for each of the years 2007 to 2010 (N = 86,726). Panel (A) reports results on the number of weeks with sick leave benefits, Panel (B) on the share who experienced unemployment more than 50% of the year, Panel (C) on number of weeks with retirement benefits, and Panel (D) on wage income measured in 1,000 DKK. Dots indicate point estimates and vertical lines indicate the 95% CI. LATE = local average treatment effect; i.e., how much the outcome would change for an individual who developed a stress-related disorder due to the explosion, the complier.

diagnosed with a stress-related disorder after the explosion. The y axis shows the LATE; i.e., how much the outcome would change for an individual who developed a stress-related disorder due to the explosion, the complier. Fig. 2A shows that compliers experienced more weeks on sickness benefit, throughout the period from 2007 to 2010. The size of the estimated coefficient indicates that this group received approximately 30 more weeks of sick leave benefits in 2007, 2009, and 2010, and approximately 20 wk more in 2008. Fig. 2B shows that during the first 2 y following the explosion, compliers experienced a reduction in their risk of being unemployed for at least half the year (nearly 100% for 2007 and approximately 50% for 2008). The risk of unemployment increased in subsequent years, and in 2010, compliers had an almost 100 percent increase in the risk of being unemployed for more than 50 percent of the year. Fig. 2C shows no association for compliers between developing a stress-related disorder following the explosion and the risk of receiving early retirement pension. Finally, Fig. 2D shows that compliers experienced a reduced wage income of approximately 600,000 DKK in the long run.

Evidence presented in *SI Appendix* suggests that the key assumptions of the IV model have most likely been met in the present

study. The relevance assumption is supported through significant differences in the share of individuals in the treatment and control groups who were diagnosed with stress-related mental disorders after the explosion (*SI Appendix, Fig. S1*) and through the F-test of the excluded instrument in the first-stage regression. As further support for the relevance assumption, placebo tests documented that other comparable areas in Denmark did not experience the same increase in stress-related disorders as observed in the impact area following the disaster (*SI Appendix, Fig. S2*), and individuals in the impact area did not differ on indicators of stress-related disorders prior to the disaster (*SI Appendix, Fig. S3*). As support for the exclusion restriction, we suggest that it is unlikely that the instrument affected the outcomes through routes other than stress-related disorders (e.g., through destruction of places of employment, through physical injuries, or through relocation). As support for the exchangeability assumption, we documented that the treatment and control groups were balanced on a range of background characteristics (Table 1) and that the predictive value of these background characteristics did not differ between individuals in the treatment and control groups (*SI Appendix, Fig. S4*). As support for the monotonicity assumption, we analyzed

pharmaceutical records and documented that the share of individuals who *stopped* taking SSRIs (which are used to treat stress-related disorders) did not differ between the treatment and control group, suggesting that it is unlikely that individuals responded in a way opposite to what we would expect given the mechanism activated by the instrument.

Discussion

Mental health disorders are thought to reduce a nation's economic outputs because of nonemployment, absenteeism, and presenteeism while ill (32). Establishing the causal effect of mental disorders on labor-market outcomes is challenging due to difficulties in finding a suitable empirical design that enables causal inference (33). However, with increasing awareness of the pervasiveness of mental disorders in the population (34, 35), this knowledge gap is problematic: providing help to those suffering from mental disorders—as well as to the family members, friends, coworkers, and employers of those affected by mental disorders—requires a thorough understanding not only of the causes but also of the *consequences* of mental disorders. Furthermore, a key component in seeking to integrate vulnerable groups into the labor market is to understand whether their marginalization is rooted in mental health problems.

To minimize the possibility that omitted confounders bias the association between stress-related mental disorders and labor market outcomes, we used an IV model and obtained exogenous variation in mental health by exploiting a traumatizing event that happened in Denmark in 2004, when a fireworks factory exploded. Previous studies documented that this event increased the risk of developing stress-related disorders (19), which accords with studies of other disasters showing a link to increased risk of stress-related mental disorders (36–39). Here, we document that these mental disorders further affected workers' labor-market attachment over the next several years. For those who responded to the explosion by developing stress-related disorders, the consequences were substantial. Developing a stress-related disorder increased the likelihood of going on sickness benefit, both in the short- and long-term. The point estimates varied between 20 and 31 wk, suggesting that those affected were likely to spend approximately half the year on sickness benefits. We also observed an increase in the risk of unemployment in the long-term, where those affected were likely to spend half the year on unemployment benefits by the end of the observation period. Interestingly, the short-term effect on unemployment indicated a reduced unemployment risk. We speculate that this may be attributable to different groups of individuals transitioning between sickness and unemployment benefits in different ways across time, due to the mutually exclusive nature of the two benefit types. It may be that the most vulnerable individuals (those with the highest risk of unemployment in a normal situation) responded first to the explosion and became sick rather than unemployed in the short run. This group may have then transitioned into unemployment in the longer run, due to the exhaustion of sickness benefit entitlements, which explains the positive long-term effect on unemployment. Less vulnerable individuals may have developed stress-related disorders somewhat later or sought sickness benefits at a later point. Possibly due to stigma around mental disorders, some survivors may have postponed seeking sickness benefits as long as possible. Furthermore, the negative long-run effect on wage income might be an indication of a delayed effect among the less vulnerable, who may have developed stress-related disorders later, gotten diagnosed later, moved into sickness benefits later, and lost income as a result. Thus, the patterns we see in our results may reflect dynamics in two different groups who developed stress-related disorders at different points in time.

This study offers several strengths in seeking to test the causal effect of mental disorders on labor-market outcomes. First, extending cognate studies (15, 16, 40), we utilized a credible source of exogenous variation in the independent variable in an IV model, which effectively randomized individuals into stress-related mental disorders. Because our study design plausibly satisfies the four critical assumptions of the IV model, it may be possible to interpret the estimated effect of developing a stress-related mental disorder on labor market outcomes as a causal effect. Second, in studies of disasters, it is often difficult to obtain a representative population of all affected persons. Here, we were able to use residential information from a national registry to identify all residents of the impact area, ensuring no selection bias. Third, a concern with studies that focus on outcomes associated with disasters is that disasters often lead to residential relocation. Relocation can have its own untoward effects, and it can also lead to biases, because relocated individuals are often lost to follow-up and because nonrelocated exposed individuals may not be representative of the exposed population (41). This concern was obviated in the present study both because relocation was minimal and because we used longitudinal nationwide registry data to make accurate linkages and obtain information about all exposed individuals irrespective of residential changes. Fourth, rather than a single point-in-time outcome, we measured labor-market outcomes over time to test how mental disorders affect multiple dimensions of labor-force attachment.

Our findings advance causal inference in research about mental health and labor market affiliation. However, they cannot adjudicate between the possible mechanisms that bring about these effects. Over time, stress-related disorders involving impaired mood, thinking, and behavior may lead to shifts or drift to marginal part-time work, either by choice or circumstance; may affect job-search behavior; and may interfere with job performance. These are not mutually exclusive possibilities, and they may compound labor-market difficulties. While the present study offers a methodology for advancing causal inference, alternative designs will be needed to unravel causal mechanisms. For example, tests of mechanisms by which postdisaster mental disorders affect labor-market outcomes could use diary studies to investigate everyday behaviors and processes in work settings (42), longitudinal surveys could be used to investigate changes in attitudes toward work, and mixed-methods could be used to understand the labor-market challenges of postdisaster stress-related disorders.

This study has limitations. First, the study was carried out in one country (Denmark) during a circumscribed period of time (early 21st century). Studies of stress-related mental disorders in other places and time are needed to confirm the findings reported here and also to assess whether stress-related mental disorders have an even greater effect on marginalized groups (43). Second, the Danes studied here came from one region of the country, and as is clear from *SI Appendix, Table S1*, these individuals differ from the average Dane on several dimensions—there are more early school leavers, fewer immigrants, and a higher share have a history of mental health problems. However, as we account for these differences by only including individuals in the control group who are identical to individuals from the impact area, it is unlikely that regional differences in background characteristics can account for the observed associations between poor mental health and labor-market outcomes. Third, we assessed mental disorders using hospital records. On the one hand, this ensured that we studied cases who were impaired. On the other hand, we are unable to comment on less severe forms of mental distress that followed the explosion. Fourth, we focused on a limited set of disorders (PTSD, depression, and anxiety), and it is possible that other conditions

(e.g., substance dependence) may have increased following the explosion and affected labor-market outcomes. Fifth, we focused on mental disorders that followed a disaster, but it is not clear whether mental disorders that follow interpersonal traumas have similar or different effects on labor-market outcomes, both in terms of the strength and reach of their impact.

The latter point flags a more general observation about the study of stress-related disorders. Historically, the study of trauma has concentrated on interpersonal trauma. Through the dogged efforts of many researchers, it has become apparent that natural, human-made, and intentional disasters are associated with lingering mental health conditions (36, 44–48). As disasters increase due to climate change, population density, epidemics, and technology, more information is needed about the course of postdisaster psychopathology and about how it affects multiple spheres of life, including labor-market attachment (49).

Our study detected stress-related mental disorders following a disaster and identified causal effects of stress-related disorders on multiple labor-market outcomes over time. Jointly, these findings suggest that strategies are needed to help prevent the development of mental disorders in the immediate aftermath of disaster and that strategies are also needed to help mitigate the sequelae of postdisaster mental disorders. Complementary public-health approaches may be required at different stages of the course of disaster-related psychopathology. First, to build resilience during a crisis, a premium may be placed on psychological first-aid readiness to address mental health distress during disasters (50, 51). Second, there is a need to increase both the availability and awareness of mental health services. Health-care utilization following disasters is low (52–54), despite promising treatments (55). Third, apart from mental health services, helping disaster victims address

social and employment needs may serve to mitigate the effects of disaster-related psychopathology on labor-market outcomes. Coordinated services between social welfare and healthcare providers may be increasingly needed to promote recovery and prevent decline as disasters increase in frequency and scope. In our study, the patients were seen and diagnosed in an outpatient clinic or hospital. We do not know how much treatment patients received or its efficacy or whether the labor market outcomes of people who developed mental disorders after the disaster but were untreated may have been worse than outcomes of treated patients. However, it is useful to consider that in nations less well-resourced than Denmark, many of which cannot afford to treat mental disorders, the labor-market outcomes of disasters might be poorer than we observed.

Data, Materials, and Software Availability. Anonymized data analysis scripts have been archived with GitHub at <https://github.com/leahrr-umich/MentalHealth-LaborMarket.git> and are available on request from the corresponding author (56). The data are not publicly available and cannot be shared by the authors. Researchers who wish to use the data may request permission through Statistics Denmark.

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