The Effect of Smoking on Mental Health: Evidence from a Randomized Trial*

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Abstract

This paper estimates the causal effects of a smoking cessation intervention on mental health using data from the Lung Health Study, a randomized trial with five years of follow-up interviews. In the short-run, cessation worsens mental health, likely reflecting the effects of nicotine withdrawal. Long-run effects on mental health are small overall, but mask heterogeneity by gender. For women, cessation leads to improved mental health, driven by decreases in insomnia and nervousness. Men do not experience these improvements, due in part to a small increase in severe disturbances.

JEL Codes: I1, I12, I18

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1 Introduction

Smoking cigarettes has significant negative effects on the physical health of both the smoker and those in close proximity. As such, the government aims to reduce smoking take up and encourage smoking cessation through a wide variety of policies. Such policies may have unintended consequences on smokers' mental health. Given the extensive social and economic costs of mental illness, optimal smoking policy should take into account potential mental health effects.[1]

There is a well-documented correlation between smoking and mental illness. Individuals with mental illness are two to three times more likely to be current smokers than individuals without mental illness and consume nearly half of the cigarettes sold nationwide (McClave et al. 2010; Lasser et al. 2000). Despite this correlation, the causal mechanisms underlying the relationship are not well-understood (Fluharty et al. 2016). Prior research generally advances three hypotheses for the relationship between smoking and mental health: (1) smoking causes a decline in mental health; (2) poor mental health causes take up of smoking; and (3) smoking and mental illness are not causally related but coincide in the population due to third factors such as socioeconomic status or genetics.[2] The first hypothesis is supported by evidence that, in some settings, nicotine may exacerbate symptoms of anxiety and depression. The second hypothesis posits that nicotine provides *relief* from symptoms of depression and anxiety and is therefore used as a coping mechanism by individuals with untreated mood disorders.[3] Evidence for this theory includes the fact that smokers report using cigarettes to improve their mood as well as the fact that teenagers start smoking following traumatic

[1] Mental illness is widespread, affecting 1 in 5 adults in the U.S. in 2019, and generates substantial social costs (SAMHSA 2020). Estimates suggest that mental illness accounts for over half of the rise in disability receipt among men in recent decades (Duggan and Imberman 2009). In addition, recent work finds that treating mental illness increases labor supply and earnings, improves physical health, and increases parental investments in children (Ridley et al. 2020).

[2] Note, these hypotheses are not necessarily mutually exclusive. I.e., smoking and mental health may be related through multiple channels.

[3] Nicotine is a psychoactive drug that can act as both a stimulant and depressant (Ashton et al. 1973). While nicotine can relieve the symptoms of depression and anxiety in some settings, in others it acts to exacerbate them (Picciotto, Brunzell, and Caldarone 2002).

events (Friedman 2020).[4] Note, however, that smokers who report that smoking improves their mood may be conflating these effects with relief from nicotine withdrawal.

In addition to the effects of nicotine on the nervous system, smoking may affect mental health by causing behavioral changes. For example, cigarettes may serve as a complement to other substances, such as alcohol, which could independently affect mood (Dee 1999). Smoking may be a social activity, in which case quitting could reduce one's social network. The extensively-documented negative *physical* effects of smoking may also lead to declines in mental health (CDC 2014).

Given the many different ways in which smoking and mental illness may be related, it is crucial to use exogenous variation in smoking to study its effects on mental health. Simple comparisons of mental health between smokers and non-smokers may result in biased estimates due to factors that are correlated with both smoking status and mental state — e.g., a history of mental illness.

In this paper, we analyze data from a randomized controlled trial called the Lung Health Study (LHS). The LHS randomly assigned approximately 6,000 smokers to receive an intensive cessation intervention and followed them for the next five years. Random assignment ensures characteristics that are correlated with smoking status, such as baseline mental health, are unrelated to quitting behavior in the treatment group, allowing us to cleanly identify the causal effects of smoking cessation. As part of annual followup interviews, participants were asked several questions about their mental well-being, which we combine into a single "distress scale." These measures, along with data on prescription use of anxiolytics and anti-depressants, have never been studied as outcomes of the treatment. Importantly for a study of smoking and mental health, the long follow-up gives us the opportunity to differentiate between short-term effects (i.e. due to nicotine withdrawal) and long-term effects of

[4]For example, participants in the Lung Health Study, which we analyze in this article, were asked whether they smoke to improve their mood. A majority replied "usually" or "always," as opposed to "sometimes" or "never," in response to the following prompts: "I light up a cigarette when I feel angry about something"; "When I get blue or want to take my mind off my cares and worries, I smoke cigarettes"; "When I feel uncomfortable or upset about something, I light up a cigarette".

cessation.

We find that assignment to the smoking cessation program causes a large increase in quitting, driven by sustained, rather than temporary, quits. The treatment effect on sustaining cessation across all five annual follow-up interviews is 17 percentage points, a 309% increase over the sustained quit rate in the control group. A benefit of the LHS data is that smoking cessation is medically validated, mitigating concerns about measurement error that can arise when variables are self-reported.

Our primary contribution is to study effects on mental health. We find that in the first annual interview, conducted shortly after the end of the cessation program, there is a 13% increase in the distress scale. Reports of severe disturbances, while rare, also increase. These results likely reflect initial withdrawal effects. To examine the long-run effect of smoking cessation on mental health, we calculate the average of our distress scale and prescription drug indicators over interview years 2 through 5. We find small and statistically insignificant effects of the cessation program on these outcomes.

Although we find little evidence of effects on long-run mental health in the full sample, prior evidence suggests there may be important heterogeneity by gender. Smoking behavior differs across men and women, perhaps due to differing effects of nicotine on the brain across gender. For example, smoking rates among men have historically exceeded those among women (Holford et al. 2014). Medical studies reveal that smoking activates male smokers' reward pathways more than those of women (Cosgrove et al. 2014). Other research suggests that this difference in satisfaction from smoking is tied to nicotine specifically, rather than other aspects of smoking. Perkins and Karelitz (2015) find that cigarettes with and without nicotine act similarly to alleviate the effects of withdrawal among female smokers, but only the cigarettes with nicotine provide relief to male smokers. Motivated by these facts, we study effects separately by gender.

Indeed, overall mental health effects mask considerable heterogeneity by gender. For women, assignment to the treatment leads to a 10% decrease in the distress scale in inter-

view years 2 through 5, driven by sizable reductions in insomnia and nervousness. These results are consistent with hypothesis (1) above–that is, smoking causes declines in mental health. Conversely, for men, there is a small increase in long-run distress which, although statistically indistinguishable from 0, is statistically distinguishable from the effect for women. In addition, the smoking cessation program leads to a small increase in severe disturbances for men, and possibly an increase in the use of anti-anxiety medication. These results are most consistent with hypothesis (2) above–that is, men may use smoking as self-medication for underlying mental health issues. Given the small and somewhat noisy effect sizes for men, we cannot rule out hypothesis (3), i.e. that smoking and mental health are not causally related in this group.

Our results provide new evidence on the relationship between smoking and mental health that can be used to inform anti-tobacco policy. The LHS treatment involves a cessation program, making our results most relevant to policies that increase quitting among current smokers. For example, under the Affordable Care Act, health insurance expansions to low-income Americans increased utilization of smoking cessation aids and reduced cigarette consumption (Cotti, Nesson, and Tefft 2019; Maclean and Saloner 2019).[5] Our findings suggest that welfare benefits from such policies include long-run mental health gains, in particular for women. Our findings also suggest that mental health supports and anti-smoking policies may be complementary public health interventions, as anti-smoking efforts alone can have unintended adverse consequences on mental health outcomes, in particular for men. Finally, these results may have implications for the regulation of e-cigarettes. In particular, although e-cigarettes are generally viewed as a healthier option than traditional cigarettes, they may have the same mental health effects.

However, our findings should be generalized to the broader policy context with some caution. The LHS sample is not demographically representative — for example, participants are

[5]Anti-tobacco policy includes a range of measures such as taxes, smoke-free laws, advertising restrictions, and public education campaigns. A recent review concludes that taxes have little effect on adult smoking; that evidence on the effects of bans on cessation is mixed; and that there is relatively little evidence on the effects of advertising and education campaigns (DeCicca, Kenkel, and Lovenheim 2020).

more likely to be white and college-educated than the true population of smokers (Courtemanche, Tchernis, and Ukert 2018). Second, participants signed up to be part of a smoking cessation program, implying that they all have some interest in quitting, which is not true of all smokers.[6] Another concern is that the treatment program, which emphasized behavioral and cognitive strategies for quitting, could independently affect mood. While we cannot rule this out, we expect that such effects would dissipate in the years following the program.

The paper proceeds as follows. Section 2 provides background on the Lung Health Study. Section 3 describes our treatment of the data. Section 4 describes our empirical methods. Section 5 presents our results. Section 6 concludes.

2 Background

The Lung Health Study (LHS) was a clinical trial which randomly induced smoking cessation among its participants.[7] The study aimed to identify ways of delaying the onset of chronic obstructive pulmonary disease (COPD) among at-risk smokers. In particular, the authors were interested in the efficacy of pairing smoking cessation with regular, long-term use of a prescription inhaler.

Study participants included 5,887 smokers who were identified as at-risk for COPD. The recruitment process occurred from October 1986-January 1989 at 10 clinical centers in the U.S. and Canada. To be eligible, participants had to be at-risk for COPD, have no other serious illnesses or medical conditions, and have no plans to move away from the clinic area during the study. Note, the study sample is not representative of the general population of smokers. For example, participants are aged 35-65, are almost exclusively white, and live in urban areas (i.e. where the clinical centers were located).

Participants were randomly assigned to one of three equally-sized groups: two treatment arms and one control arm. The treatment groups underwent an intensive smoking cessation program in the first few months of 1989. In addition, one of the treatment groups received

[6] In 2015, 68% of smokers in the U.S. said they wanted to quit (Babb et al. 2017).

[7] O'Hara et al. (1993) provide a detailed description of the LHS. Additional information is here: https://clinicaltrials.gov/ct2/show/NCT00000568.

a bronchodilator (a prescription inhaler), whereas the other treatment group received a placebo inhaler. All participants were then followed for five years (1990-1994), returning once a year to the clinic for interviews and lung tests. Participants in the treatment groups were instructed to use their inhalers regularly during the five years.

The smoking cessation program combined several elements thought to promote quitting, including: (1) a physician's message regarding current lung impairment and disease risk; (2) a 10 week, 12-session group program emphasizing cognitive and behavioral strategies for cessation; (3) encouragement and support from family members; and (4) provision of nicotine gum for up to 6 months. The group sessions initially focused on quitting and later emphasized relapse prevention, stress management, and tapering gum use.

During the five years following the smoking cessation program, individuals in the treatment group returned to the clinic every 4 months. The purpose of these meetings was to promote inhaler usage and prevent smoking relapse. Extended intervention options were provided to individuals who relapsed, including restart and stay-quit support groups, and LHS physician visits.

Once a year, participants in both the treatment and control groups returned to the clinic for interviews that covered a wide variety of topics, including health outcomes and healthcare utilization over the past year.[8] Individuals also underwent pulmonary testing to validate cessation. All measures of cessation we analyze are therefore medically validated. Attrition is relatively low, as 5,627 individuals (96%) remain in the sample in the final wave.

The cessation program was quite successful: 22.0% of individuals in pooled treatment arms (i.e., with or without the prescription inhaler) quit smoking cigarettes and sustained cessation for all five years, compared to 5.5% of the control arm. Ultimately, however, the prescribed inhaler was found to have little added benefit for lung health and, as a result, many felt the study was a "failure" (Anthonisen et al. 1994).

[8]The first annual interview took place about 8 months after the initial, 4-month smoking cessation program ended. Nicotine gum was provided during the program and for up to 2 months afterwards (6 months total). Questions asked about participants' mental health reference the individual's state of mind over the four months before the annual interview.

Perhaps as a consequence of the "failure" of the trial, some of the measures collected by the investigators during the annual follow-up interviews have not yet been analyzed. Our paper constitutes the first analysis of treatment effects on mental health outcomes collected during the follow-up interviews.

2.1 Prior Research Using the LHS to Estimate Causal Effects

In this section, we provide a brief overview of studies which use data from the LHS to estimate causal effects of smoking cessation.[9]

As discussed above, assignment to the smoking cessation program increased the likelihood of quitting smoking and improved lung function. These effects were observed to persist at five years (Kanner and Group 1996; Anthonisen et al. 1994) and 11 years (Anthonisen, Connett, and Murray 2002) after the initial cessation program. Assignment to the treatment also resulted in fewer respiratory symptoms (Kanner et al. 1999) and lower rates of lower respiratory illness (Kanner, Anthonisen, and Connett 2001) after five years. Anthonisen et al. (2002) and Anthonisen et al. (2005) examine effects on all-cause mortality, finding it is significantly lower in the treatment group after 14.5 years.

Several studies examine outcomes that, like mental health, were not a focus of the original study. For example, Murray, Istvan, and Voelker (1996) looks at effects on alcohol use at one year, finding no differences between the treatment and control group, despite large differences in smoking. Courtemanche, Tchernis, and Ukert (2018) use the LHS to estimate the relationship between smoking and body mass index (BMI), finding that quitting leads to an increase in BMI by 1.8 to 1.9 points, or 11-12 lbs for a male of average height. Lastly, Fletcher and Marksteiner (2017) find that spouses of treated individuals were also more likely

[9]To identify these studies, we reviewed publications from three sources. First is a list of publications on the Study Record page for the LHS published by ClinicalTrials.gov: https://clinicaltrials.gov/ct2/show/NCT00000568. These publications were provided by study investigators or added from automatic searches of ClinicalTrials.gov's database. Second, we reviewed publications listed on BioLincc's study page for the LHS https://biolincc.nhlbi.nih.gov/publications/?studies.raw=Lung+Health+Study+%28LHS%29&acronym=LHS&sort=citation&page_size=100. This list includes research conducted by individuals who, like us, obtained LHS data through an agreement with Biolincc. Third, we conducted a Google Scholar search for the phrases "Lung Health Study" and "causal."

to quit smoking.

Other works analyzing the LHS data are primarily descriptive, reporting on the study's design and implementation or identifying predictors of various outcomes, such as lung health or smoking cessation. Finally, a few studies use data from the two treatment arms to isolate the causal effects of the bronchodilator.

3 Data

We first generate several different outcomes describing smoking behavior during the follow-up interviews. The first, "sustained quit," is an indicator equal to one if a participant is a medically validated quitter across all five follow-up interviews. For the second measure,"current quit," we use information on whether an individual has quit at the time of a given follow-up interview. Unlike those with a sustained quit, these individuals may have relapsed in the years since the cessation program, or may have quit sometime after the initial intervention. Specifically, we first create an indicator equal to one for a given individual-year if the participant has quit smoking at the time of the interview. We then take the average of this indicator over interview years 2-5.[10]

Our third measure of smoking behavior is the average number of cigarettes smoked per day over the 12 months before a given follow-up interview. This outcome is self-reported and may be subject to measurement error. Participants are asked to provide the number of cigarettes smoked per day for each of the previous 12 months separately, and we calculate the mean of these 12 numbers. We then take the average value of this outcome over interview years 2-5.

Each measure of smoking behavior has distinct advantages and disadvantages. The two measures of cessation are medically validated, and thus less prone to measurement error. However, quitting only captures the extensive margin of smoking behavior and is measured at

[10]We omit year 1 from all averages to avoid conflating short term withdrawal symptoms with longer term mental health effects. Participants were provided with nicotine gum at the start of the smoking cessation program and expected to stop using it after 6 months (i.e., 2 months after the intervention ended). Nicotine withdrawal can impact mood for several months, and may thus have impacted responses at the first interview. See: https://www.insider.com/nicotine-withdrawal-symptoms. We also report results separately for year 1.

the time of the interview (potentially missing quits or relapses that occur between interviews). The number of cigarettes smoked over the past year instead captures the intensity of smoking. If the smoking cessation program causes some individuals to smoke less (but not quit), and smoking intensity affects mental health, it is important to consider intensive margin as well as extensive margin measures.[11]

Next, we generate several outcomes pertaining to mental health. The LHS asks about the interviewee's mental and physical state in each annual survey, via the following questions: "Indicate the extent to which you have been troubled in the last four months by any of the following. Please indicate Severe, Moderate, Mild, or Not at all." A list of 26 physical and mental conditions is provided (e.g., "Chest Discomfort," "Dry Mouth," "Excessive Salivation," etc.). The mental conditions are as follows: "Irritability," "Insomnia," "Mood Changes," "Nervousness," "Psychological Illness." We construct an overall measure of mental health by assigning each response a number from 0 through 3, where 0 corresponds to an answer of "Not at all" and 3 corresponds to an answer of "Severe", and summing the resulting scores across the five reported mental conditions for each respondent-year to create a "distress scale."[12] An increase in this distress scale indicates worsening mental health, while a decrease indicates an improvement in mental health. We also create a variable to isolate severe distress. Specifically, we first create an indicator variable equal to one for a respondent-year-condition if the interviewee states that they have been severely troubled by that condition, and zero otherwise. Next, for each respondent-year, we take the average of this indicator across the five mental health conditions. For example, if a respondent indicates in a given interview that they suffer from severe insomnia only, they would receive a value

[11] Courtemanche, Tchernis, and Ukert (2018) use assignment to the cessation program in the LHS to instrument for cigarettes per day and another measure of smoking – exhaled CO. While exhaled CO does not suffer from reporting error because it is clinically measured, it only reflects smoking in the few days before the follow-up interview, so may not be representative of usual behavior over the prior year (like the measure of cigarettes).

[12] The construction of this variable is similar to other measures of mental health such as the Kessler-6 and Kessler-10 Distress scores. These scores are calculated as the sum across a set of questions about emotional states with a five-level response scale.

of 1/5 for that year.[13] Finally, we again take the average of the distress scale and severity measure over interview years 2-5.

Next, we define indicators for prescription medications for mood disorders (anxiolytics and anti-depressants), and take the average of these indicators over years 2-5. At each annual interview, participants are asked to provide information on prescription drugs they have taken over the previous 12 months — first, within 11 medication categories related to lung and heart health and then by listing up to three additional drugs outside of these categories. Participants are instructed to bring in pill bottles or drug containers for medications they are taking for this purpose. The drug names are not cleaned and contain some inaccuracies such as spelling mistakes.

To match the drug names to their therapeutic categories, we performed the following steps. We first Googled each of the 1244 distinct drug names, as written.[14] For 629 of these, the search results in a sidebar Google creates that lists the drug's medication class, which we record.[15] For the remaining 615 drugs for which Google does not produce the automatic description, we use a database of drug name-to-drug class matches that is provided as part of the Medical Expenditure Panel Survey (MEPS) for the years 2002-2016.[16] These two steps allow us to match 97% of the reported drug names to therapeutic categories, from which we can identify anti-depressants and anxiolytics.[17]

[13] In unreported results, we created an alternative version of this measure in which we first calculated z-scores for each "severe" indicator and then calculated the average of the z-scores across the five mental health conditions in each year (following Kling, Liebman, and Katz 2007). Doing so addresses the issue that some conditions are more likely to be reported as "severe" than others. Our findings using the index measure are similar to those using the averaged measure.

[14] A Google search is helpful because it autocorrects spelling errors and produces partial matches.

[15] E.g., a Google search for "Venlafaxine," an anti-depressant, produces a sidebar that describes it as a "Nerve pain medication and antidepressant."

[16] Data files are available here: https://meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp MEPS lists as the source for its therapeutic class assignment "Multum Lexicon variables from Cerner Multum, Inc." Matching for each drug is done by hand, as some modification of the handwritten LHS entry is typically needed to match it to the MEPS name, which may involve translation between generic and brand name, or vice versa.

[17] Specifically, anti-depressants are identified as follows: the Google sidebar description includes the words "ANTIDEPRESSANT" and/or "SELECTIVE SEROTONIN" (in reference to a selective serotonin re-uptake inhibitor), or the MEPS therapeutic class codes are: 208, 209, 249 or 76. Anxiolytics are identified as follows: Google sidebar description includes the words: "ANXIOLYTIC", or the MEPS codes are: 67 or 69.

Between 5 and 8% of individuals per year do not answer the prescription drug and mental health questions, either due to attrition or failure to answer the question, and are assigned missing values for that year. In this case, we calculate the average for years 2 through 5 using the remaining non-missing values. Our main analysis sample consists of individuals with non-missing values of the year 2 to 5 average distress scale and prescription drug outcomes. This sample includes 97% of individuals enrolled in the trial. While prior studies using the LHS have established that the full sample (5,887) is balanced on observables, we verify that our main sample (5,705) is also balanced. In Table A1, we compare mean pre-treatment characteristics across the treatment and control groups. These characteristics include age, education, BMI, smoking behavior, and our mental health outcomes, measured during screening interviews.[18] Reassuringly, there is very little difference in means across the two samples and none of the differences are statistically significant.

Table A1 also reveals that the average study participant is 48 years of age and that men make up about 2/3 of the study population. On intake, participants smoke about 31 cigarettes (1.5 packs) per day, and started smoking around age 17 or 18. When asked to rate the extent to which irritability, insomnia, mood changes or nervousness have troubled them over the past 4 months from 0 (Not at all) to 3 (Severe), individuals indicate an average of 0.4 to 0.5. The average for psychological problems is approximately 0 (Not at all). Around 1 to 3% of individuals have taken anti-anxiety medications or anti-depressants in the past month.

4 Empirical Method

To estimate the effects of the smoking cessation program on smoking behavior and mental health, we estimate the following equation, for all individuals and separately for men and women:

[18] During the screening interview, participants were only given the option to indicate "Not at all", "Mild", or "Severe" in response to the questions about mood. In this case, we assign values 0, 1.5, and 3 to these responses, respectively, so the scale is comparable to that in follow-up interviews.

$$Y_i = \alpha + \beta \text{Treatment}_i + \epsilon_i \tag{1}$$

Where $Treatment_i$ is an indicator for whether individual i is assigned to one of the two treatment arms.[19] Randomized assignment to the treatment group implies that $Treatment_i$ is independent of the error term, ϵ_i, in which case β measures the causal effect of the smoking intervention on outcome Y_i. We estimate robust standard errors to adjust for heterogeneity across individuals.

Our aim is to understand how quitting smoking affects mental health. Therefore, it may seem preferable to estimate an instrumental variables (IV) specification for our mental health outcomes. In an IV specification, we would instrument for smoking using assignment to the treatment group. We choose not to present IV estimates as our preferred specification because each of our smoking variables is an imperfect measure of smoking intensity. As discussed above, our measures of quitting are medically validated and thus highly accurate, but only capture the extensive margin of smoking. Our intensive margin measure of smoking — number of cigarettes smoked per day over the past year — is based on recall and likely contains measurement error. Thus, for enhanced transparency and interpretability, we choose to present reduced form estimates of the effect of the treatment program on our measures of mental health.

Still, in order to compare the effects of quitting smoking on mental health between men and women, it is necessary to scale the reduced form coefficients to the change in smoking for each group. Therefore we also estimate the following two-stage least squares (2SLS) model:

$$\text{Cigarettes}_i = \gamma + \rho \text{Treatment}_i + \nu_i \tag{2}$$

$$M_i = \psi + \phi \text{Cigarettes}_i + \xi_i \tag{3}$$

[19] Note, for our purposes, we do not distinguish between treatment groups given the placebo vs. prescription inhaler.

where the second-stage outcome, M_i, is a mental health outcome for individual i. The endogenous regressor in Eq. 3, Cigarettes_i, is equal to cigarettes/day in year 1 or averaged over years 2-5, as indicated. The excluded instrument is the treatment group indicator, Treatment_i. We assume that assignment to the treatment group affects long-run mental health only through its direct effects on smoking. Given this assumption, ϕ can be interpreted as the average effect on mental health of smoking an additional cigarette. We estimate the 2SLS model separately for men and women and test whether the resulting estimates of ϕ differ.

5 Results

5.1 Smoking Behavior

First, we estimate treatment effects on smoking outcomes recorded during the follow-up interviews.[20] Table 1 reports estimates of β from Eq. 1, along with robust standard errors in parentheses and p-values in brackets. Panel A reports effects for the full sample and Panels B and C report effects for men and women, respectively. At the bottom of the table, we report the p-value from a test of whether the effects for men and women are equal.

In Column (1), we find that the smoking cessation program raises the probability of a sustained quit by 16.9 percentage points. This effect is a 307% increase with respect to the sustained quit rate in the control group of 5.5%. The treatment effect is larger for men than women (337% vs. 262%), implying that men are more responsive to the cessation program.

In Column (2), we report effects on the current quit rate, averaged over years 2 to 5. The treatment effect in the pooled sample is 18.9 percentage points, or 110% of the control mean. The fact that the effect on sustained quitting is nearly as large as the effect on the current quit rate ($16.9/18.9 = 90\%$) implies that the treatment works primarily to increase sustained quits.[21] The treatment effects are similar in magnitude for women and men, implying that

[20] These results replicate findings from prior LHS studies that also estimate treatment effects on smoking behavior. See Section 2.1 for a review of this prior literature.

[21] Sustained quits are a subset of current quits in a given year. Therefore, the difference between the current and sustained quit rate gives us the share of individuals who are not smoking in that year but relapsed during

women are somewhat more likely to quit temporarily (relapse) in response to the treatment than men.

In Column (3), we report effects on the number of cigarettes per day, averaged over years 2 to 5. Overall, the effect is -8.1 cigarettes, or a 38% decrease relative to the control mean. The treatment effect is larger for men than women (-8.6 vs. -7.0, respectively). However, men smoke more cigarettes per day than women (22.5 vs. 19.8), so the percentage declines are more similar (39% vs. 35%).

Note that the magnitude of the decrease in cigarettes, 8.1, suggests that the treatment program reduces cigarette consumption among individuals who continue smoking. The average daily cigarette consumption in the control group is 21.5. The treatment program increases the likelihood of quitting by by 19 percentage points, which implies a decrease in daily cigarettes by 19%*21.5 = 4.1 due to quits alone. Therefore, given that the total decline is 8.1, the treatment program likely works to reduce nicotine intake through both extensive (quitting) and intensive (number of cigarettes smoked) margins.

5.2 Mental Health Outcomes

In Table 2, we report the results of estimating Eq. 1 on mental health and prescription drug indicators averaged over annual followup interviews in years 2 to 5. As in Table 1, Panel A reports effects for the full sample and Panels B and C report effects for men and women, respectively.

At the bottom of Table 2, we report statistics derived from the 2SLS model (Eqs. 2 and 3). Specifically, we first estimate the 2SLS model separately by gender, setting M_i equal to the outcome indicated in the column heading. We then calculate the difference between the second stage estimates of ϕ for men and women ("Diff, Men-Women: b/cigs"). "P-Value" is the p-value from a test of whether the difference in coefficients is equal to zero.[22]

In the full sample (Panel A), effects are small and imprecise, but mask heterogeneity

another year.

[22]Table A2 reports the full set of results from these 2SLS regressions.

by gender. Treatment effects on the distress scale are positive but insignificant for men and negative and statistically significant for women (Column 1, Panels B and C). Specifically, assignment to the treatment group reduces women's distress scale by 0.25, or 10% of the control mean, an estimate that is statistically significant at the 5% level. The difference between the 2SLS estimates for men and women, -0.04 per additional cigarette, is significant at the 5% level.

Figure 1 displays treatment effects on each component score of the distress scale, averaged over years 2 to 5, along with 95% confidence intervals. Table A3 reports the corresponding coefficients, standard errors and p-values. The effects for men are generally positive, but small in magnitude and statistically insignificant. For women, the smoking cessation program reduces the average insomnia and nervousness scores by 18% and 13% of the control group means, respectively. In addition, the difference between the 2SLS estimates for insomnia and nervousness for men and women are statistically significant at the 5% level.

In Column 2 of Table 2, we estimate effects on the indicator for severe distress, averaged over years 2 to 5. In this case, assignment to the treatment increases the likelihood that men report severe distress by 0.48 percentage points relative to the control group (37% of the control mean). The effect for women is negative but noisy, and the difference between the 2SLS effects for men and women is statistically significant at the 5% level.

In Columns 3 and 4 of Table 2, we estimate effects on the average likelihood individuals take anti-anxiety or anti-depressant drugs in years 2-5. For men, the likelihood of taking an anxi-anxiety drug increases by 0.7 percentage points, or 33%, but this effect is only marginally significant at the 10% level. For women, the coefficients are both negative (suggesting less prescription drug use), but imprecisely estimated, and the difference between the 2SLS effects for men and women is not statistically different from zero.

In sum, we find that assignment to the treatment improves mental health for women, in particular through reductions in insomnia and nervousness. We do not find evidence that these reductions are accomplished through the use of prescription drugs. Men experience dif-

ferent (worse) effects on mental health than women. While we do not find evidence of declines in their overall mental health score, our results suggest an increase in severe disturbances.

Finally, we estimate the short-run effects of assignment to the smoking cessation program on smoking and mental health. Table 3 reports results from estimating Equation 1 on our outcomes measured during the first annual follow-up survey. As discussed above, the first annual follow-up occurred shortly after the conclusion of the smoking cessation program and therefore these effects may reflect nicotine withdrawal.

At the time of the first annual survey, 26.0% of the treatment sample has quit smoking, compared to 9.3% of the control group. The treatment sample smokes 12.4 fewer cigarettes per day over the past 12 months, or 47.9 percent fewer than the control group mean. The declines in smoking and number of cigarettes are somewhat larger for men than women. The fact that these treatment effects are larger in magnitude than those in Columns (1) and (2) of Table 1 reflects the fact that some individuals that quit initially due to the intervention do not sustain cessation.

As for the mental health effects, there are statistically significant increases in both distress measures in the pooled sample (Panel A). Effects are positive (indicating more distress) for both men and women, and the difference between the 2SLS effects for men and women is not statistically significant.[23] These results suggest that withdrawal causes distress in the short term that is different from longer-run effects. The coefficients on use of anxiolytics and anti-depressants are mostly small and uniformly statistically insignificant.

Finally, we consider the effects of the cessation program on mental health in each individual interview year (rather than averaging across interviews). These results are shown in Section A1. While we are somewhat limited in our ability to detect differences across years, the estimates provide some additional insights, suggesting that the short-run increase in distress is concentrated in year 1 and the improvement in mental health for women occurs gradually over time.

[23]Table A4 reports the 2SLS estimates.

6 Conclusion

The causal relationship between smoking and mental health is not well-understood. Prior work identifies three primary hypotheses for this relationship: (1) smoking worsens mental health; (2) poor mental health increases the likelihood of smoking; and (3) the two are not causally related, but coincide due to a third factor. We use previously un-analyzed variables from the Lung Health Study to examine the long-run mental health effects of smoking cessation, aiming to shed light on these potential causal pathways.

Previous work shows differences across gender in the physiological effects of smoking, motivating us to separately analyze men and women. We find that the long-run effects of smoking cessation on mental health differs across gender. While women experience improvements in mental health, men do not. In fact, we find evidence of an *increase* in severe distress among men, although this increase affects a very small share of the sample. The effects for women are consistent with hypothesis (1), i.e. that smoking was causing worse mental health for this group. For men, the effects are mixed. In particular, some men facing severe mental health issues may select into smoking to help manage severe symptoms (i.e., in line with hypothesis (2)). For others, smoking cessation seems to have little to no effect on reported mental health, in line with hypothesis (3).

Our results suggest that policies which aim to reduce consumption of cigarettes may have both un-accounted for benefits for some groups and unintended mental health consequences for others. Pairing such policies with mental health supports may reduce these consequences, potentially making cessation efforts and mental health supports a complementary set of public health interventions.

References

Abuse, Substance, and Mental Health Services Administration. 2020. *Key Substance Use and Mental Health Indicators in the United States: Results from the 2019 National Survey on Drug Use and Health.* HHS Publication, NSDUH Series H-55 PEP20-07-01-001. Center for Behavioral Health Statistics, Quality, Substance Abuse, and Mental Health Services Administration.

Anthonisen, Nicholas R, John E Connett, Paul L Enright, and Jure Manfreda. 2002. "Hospitalizations and Mortality in the Lung Health Study." *American Journal of Respiratory and Critical Care Medicine* 166 (3): 333–339.

Anthonisen, Nicholas R, John E Connett, James P Kiley, Murray D Altose, William C Bailey, A Sonia Buist, William A Conway, Paul L Enright, Richard E Kanner, Peggy O'Hara, et al. 1994. "Effects of Smoking Intervention and the Use of an Inhaled Anticholinergic Bronchodilator on the Rate of Decline of FEV1: the Lung Health Study." *JAMA* 272 (19): 1497–1505.

Anthonisen, Nicholas R, John E Connett, and Robert P Murray. 2002. "Smoking and Lung function of Lung Health Study Participants After 11 Years." *American Journal of Respiratory and Critical Care medicine* 166 (5): 675–679.

Anthonisen, Nicholas R, Melissa A Skeans, Robert A Wise, Jure Manfreda, Richard E Kanner, John E Connett, and Lung Health Study Research Group. 2005. "The Effects of a Smoking Cessation Intervention on 14.5-year Mortality: a Randomized Clinical Trial." *Annals of Internal Medicine* 142 (4): 233–239.

Ashton, Heather, JE Millman, Rosemary Telford, and JW Thompson. 1973. "Stimulant and Depressant Effects of Cigarette Smoking on Brain Activity in Man." *British Journal of Pharmacology* 48 (4): 715.

Babb, Stephen, Ann Malarcher, Gillian Schauer, Kat Asman, and Ahmed Jamal. 2017. "Quitting Smoking Among Adults—United States, 2000–2015." *Morbidity and Mortality Weekly Report* 65 (52): 1457–1464.

Centers for Disease Control and Prevention, Office on Smoking and Health. 2014. *The Health Consequences of Smoking: 50 Years of Progress. A Report of the Surgeon General.* Technical report. Atlanta, GA, January.

Cosgrove, Kelly P, Shuo Wang, Su-Jin Kim, Erin McGovern, Nabeel Nabulsi, Hong Gao, David Labaree, Hemant D Tagare, Jenna M Sullivan, and Evan D Morris. 2014. "Sex Differences in the Brain's Dopamine Signature of Cigarette Smoking." *Journal of Neuroscience* 34 (50): 16851–16855.

Cotti, Chad, Erik Nesson, and Nathan Tefft. 2019. "Impacts of the ACA Medicaid Expansion on Health Behaviors: Evidence from Household Panel Data." *Health Economics* 28 (2): 219–244.

Courtemanche, Charles, Rusty Tchernis, and Benjamin Ukert. 2018. "The Effect of Smoking on Obesity: Evidence from a Randomized Trial." *Journal of Health Economics* 57:31–44.

DeCicca, Philip, Donald S Kenkel, and Michael F Lovenheim. 2020. *The Economics of Tobacco Regulation: A Comprehensive Review.* Working Paper, Working Paper Series 26923. National Bureau of Economic Research, April.

Dee, Thomas S. 1999. "The Complementarity of Teen Smoking and Drinking." *Journal of Health Economics* 18 (6): 769–793.

Duggan, Mark, and Scott A Imberman. 2009. "Why are the disability rolls skyrocketing? The contribution of population characteristics, economic conditions, and program generosity." In *Health at older ages: The causes and consequences of declining disability among the elderly,* 337–379. University of Chicago Press.

Fletcher, Jason, and Ryne Marksteiner. 2017. "Causal Spousal Health Spillover Effects and Implications for Program Evaluation." *American Economic Journal: Economic Policy* 9 (4): 144–66.

Fluharty, Meg, Amy E. Taylor, Meryem Grabski, and Marcus R. Munafa. 2016. "The Association of Cigarette Smoking With Depression and Anxiety: A Systematic Review." *Nicotine & Tobacco Research* 19, no. 1 (May): 3–13.

Friedman, Abigail S. 2020. "Smoking to cope: Addictive behavior as a response to mental distress." *Journal of Health Economics* 72:102323.

Holford, Theodore R, David T Levy, Lisa A McKay, Lauren Clarke, Ben Racine, Rafael Meza, Stephanie Land, Jihyoun Jeon, and Eric J Feuer. 2014. "Patterns of Birth cohort–Specific Smoking Histories, 1965–2009." *American Journal of Preventive medicine* 46 (2): 31–37.

Kanner, Richard E, Nicholas R Anthonisen, and John E Connett. 2001. "Lower Respiratory Illnesses Promote FEV1 Decline in Current Smokers but not Ex-Smokers with Mild Chronic Obstructive Pulmonary Disease: Results from the Lung Health Study." *American Journal of Respiratory and Critical Care Medicine* 164 (3): 358–364.

Kanner, Richard E, John E Connett, David E Williams, and A. Sonia Buist. 1999. "Effects of Randomized Assignment to a Smoking Cessation Intervention and Changes in Smoking Habits on Respiratory Symptoms in Smokers with Early Chronic Obstructive Pulmonary Disease: the Lung Health Study." *The American Journal of Medicine* 106 (4): 410–416.

Kanner, Richard E, and Lung Health Study Research Group. 1996. "Early Intervention in Chronic Obstructive Pulmonary Disease: a Review of the Lung Health Study Results." *Medical Clinics* 80 (3): 523–547.

Kling, Jeffrey R., Jeffrey B. Liebman, and Lawrence F. Katz. 2007. "Experimental Analysis of Neighborhood Effects." *Econometrica* 75 (1): 83–119.

Lasser, Karen, J Wesley Boyd, Steffie Woolhandler, David U Himmelstein, Danny McCormick, and David H Bor. 2000. "Smoking and Mental illness: a Population-Based Prevalence Study." *JAMA* 284 (20): 2606–2610.

Maclean, Johanna Catherine, and Brendan Saloner. 2019. "The Effect of Public Insurance Expansions on Substance Use Disorder Treatment: Evidence from the Affordable Care Act." *Journal of Policy Analysis and Management* 38 (2): 366–393.

McClave, Annette K, Lela R McKnight-Eily, Shane P Davis, and Shanta R Dube. 2010. "Smoking Characteristics of Adults with Selected Lifetime Mental Illnesses: Results from the 2007 National Health Interview Survey." *American Journal of Public Health* 100 (12): 2464–2472.

Murray, Robert P, Joseph A Istvan, and Helen T Voelker. 1996. "Does Cessation of Smoking Cause a Change in Alcohol consumption? Evidence from the Lung Health Study." *Substance Use & Misuse* 31 (2): 141–156.

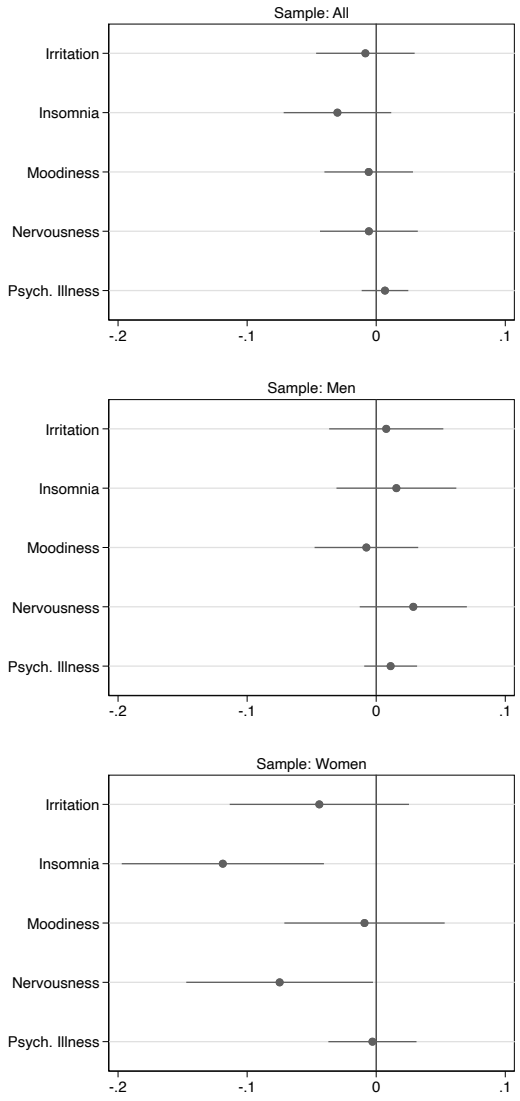
O'Hara, Peggy, Joseph Grill, Michael A Rigdon, John E Connett, Gary A Lauger, and Janet J Johnston. 1993. "Design and Results of the Initial Intervention Program for the Lung Health Study." *Preventive Medicine* 22 (3): 304–315.

Perkins, Kenneth A, and Joshua L Karelitz. 2015. "Sex Differences in Acute Relief of Abstinence-Induced Withdrawal and Negative Affect Due to Nicotine Content in Cigarettes." *Nicotine & Tobacco Research* 17 (4): 443–448.

Picciotto, Marina R, Darlene H Brunzell, and Barbara J Caldarone. 2002. "Effect of Nicotine and Nicotinic Receptors on Anxiety and Depression." *Neuroreport* 13 (9): 1097–1106.

Ridley, Matthew, Gautam Rao, Frank Schilbach, and Vikram Patel. 2020. "Poverty, depression, and anxiety: Causal evidence and mechanisms." *Science* 370 (6522): eaay0214.

Figure 1: Long-Run Effects of Cessation Program on Distress Score Components



Notes: Displayed above are point estimates and 95% confidence intervals corresponding to β from Eq. (1). The dependent variable is a numeric score corresponding to the severity of the indicated mental health condition, averaged over years 2 through 5. Participants are asked: "Indicate the extent to which you have been troubled in the last four months by any of the following. Please indicate Severe, Moderate, Mild, or Not at all." We translate these answers to a numeric score from 0 through 3, where 0 corresponds to "Not at all" and 3 corresponds to "Severe." Thus an increase in the score indicates an increase in distress. Table A3 reports the point estimates, standard errors, and p-values from these regressions. Standard errors are adjusted for heteroskedasticity. See the notes to Table 1 for more information on the sample.

Table 1: Long-Run Effects of the Cessation Program on Smoking

	(1) Sustained Quit	(2) Current Quit	(3) Cigs per Day
Panel A: All			
Treatment	0.1689	0.1894	-8.0687
	(0.0086)	(0.0101)	(0.3674)
	[0.0000]	[0.0000]	[0.0000]
Obs.	5,627	5,705	5,705
Control Mean	0.0546	0.1724	21.4838
Panel B: Men			
Treatment	0.1843	0.1922	-8.6535
	(0.0110)	(0.0129)	(0.4880)
	[0.0000]	[0.0000]	[0.0000]
Obs.	3,519	3,575	3,575
Control Mean	0.0546	0.1779	22.4267
Panel C: Women			
Treatment	0.1438	0.1854	-6.9925
	(0.0137)	(0.0163)	(0.5374)
	[0.0000]	[0.0000]	[0.0000]
Obs.	2,108	2,130	2,130
Control Mean	0.0547	0.1627	19.8210
P-Value, Men-Women	0.0214	0.7420	0.0221

Notes: The dataset is the Lung Health Study, limited to individuals with non-missing values of the dependent variable and the long-run distress score. Each point estimate, heteroskedasticity-robust standard error (in parentheses) and p-value (in brackets) is from a separate regression estimating Eq. 1. The dependent variable in Column (1) is an indicator for whether the participant sustained cessation through all 5 follow-up interviews. The dependent variable in Column (2) is an indicator for current cessation, averaged over interview years 2 through 5. Cessation is clinically validated. The dependent variable in Column (3) is average cigarettes per day over the last year, averaged over interview years 2 through 5. At the bottom of the table, we report p-values from a Chi-squared test of whether the difference in coefficients for men and women is equal to 0.

Table 2: Long-Run Effects of Cessation Program on Mental Health

	(1) Distress Scale	(2) Distress: Severe	(3) Anxiolytic	(4) Anti-Depressant
Panel A: All				
Treatment	-0.0436	0.0016	0.0082	-0.0024
	(0.0671)	(0.0020)	(0.0072)	(0.0074)
	[0.5165]	[0.4187]	[0.2563]	[0.7514]
Obs.	5,705	5,705	5,705	5,705
Control Mean	1.7719	0.0204	0.0681	0.0766
Panel B: Men				
Treatment	0.0558	0.0048	0.0068	-0.0026
	(0.0762)	(0.0022)	(0.0039)	(0.0044)
	[0.4644]	[0.0259]	[0.0824]	[0.5557]
Obs.	3,575	3,575	3,575	3,575
Control Mean	1.4151	0.0131	0.0206	0.0266
Panel C: Women				
Treatment	-0.2510	-0.0046	-0.0020	-0.0055
	(0.1231)	(0.0038)	(0.0071)	(0.0076)
	[0.0416]	[0.2307]	[0.7747]	[0.4714]
Obs.	2,130	2,130	2,130	2,130
Control Mean	2.4010	0.0334	0.0448	0.0523
Diff, Men-Women: b/cigs	-0.0423	-0.0012	-0.0011	-0.0005
P-Value	0.0309	0.0438	0.3326	0.6897

Notes: Each point estimate, heteroskedasticity-robust standard error (in parentheses) and p-value (in brackets) is from a separate regression estimating Eq. 1. The dependent variable in Column (1) is equal to the sum of the distress scores across the five mental health conditions, averaged across years 2 through 5. The dependent variable in Column (2) is equal to an indicator for severe distress, averaged across the five mental health conditions and interview years 2 through 5. The dependent variables for Columns (3) and (4) are equal to indicators for whether the participant took anti-anxiety drugs or anti-depressants over the past 12 months, averaged over interview years 2 through 5. We estimate IV regressions of the effects of smoking cigarettes on these outcomes (Eq. 3) separately for men and women. At the bottom of the table, we report the difference between these estimates and the p-value from a Chi-squared test of whether the difference in coefficients is equal to 0. See the notes to Table 1 for more information on the LHS sample.

Table 3: Short-Run Effects of Cessation Program on Smoking and Mental Health

	(1) Quit	(2) Cigs/Day	(3) Distress Scale	(4) Distress: Severe	(5) Anxiolytic	(6) Anti-Depressant
Panel A: All						
Treatment	0.2604	-12.3920	0.2113	0.0051	0.0010	0.0035
	(0.0102)	(0.3649)	(0.0704)	(0.0025)	(0.0044)	(0.0038)
	[0.0000]	[0.0000]	[0.0027]	[0.0388]	[0.8272]	[0.3585]
Obs.	5,705	5,484	5,474	5,497	5,497	5,497
Control Mean	0.0930	25.9182	1.6778	0.0181	0.0241	0.0164
Panel B: Men						
Treatment	0.2735	-13.7460	0.2286	0.0056	0.0013	0.0025
	(0.0129)	(0.4766)	(0.0813)	(0.0026)	(0.0050)	(0.0039)
	[0.0000]	[0.0000]	[0.0050]	[0.0334]	[0.7942]	[0.5338]
Obs.	3,575	3,418	3,410	3,427	3,427	3,427
Control Mean	0.0911	27.4547	1.3804	0.0117	0.0190	0.0112
Panel C: Women						
Treatment	0.2386	-10.0173	0.1470	0.0036	-0.0002	0.0044
	(0.0168)	(0.5450)	(0.1272)	(0.0049)	(0.0084)	(0.0076)
	[0.0000]	[0.0000]	[0.2482]	[0.4700]	[0.9813]	[0.5592]
Obs.	2,130	2,066	2,064	2,070	2,070	2,070
Control Mean	0.0964	23.2489	2.1940	0.0291	0.0330	0.0255
Diff, Men-Women: b/cigs			-0.0033	0.0000	-0.0001	0.0003
P-Value	0.0987	0.0000	0.7927	0.9376	0.9026	0.7383

Notes: Each point estimate, heteroskedasticity-robust standard error (in parentheses) and p-value (in brackets) is from a separate regression estimating Eq. 1. The dependent variable in Column (1) is an indicator for whether the participant had quit smoking at the time of the first annual interview. The dependent variable in Column (2) is the average number of cigarettes smoked per day in the 12 months before the first interview. The dependent variable in Column (3) is the sum of the distress scores across the five mental health conditions, as reported in the first interview. At the bottom of Columns (2) and (3), we report the p-value from a Chi-squared test of whether the coefficient estimates for men and women are equal. The dependent variable in Column (4) is an indicator for severe distress, averaged across the five mental health conditions, from the first interview. The dependent variables for Columns (5) and (6) are indicators for whether the participant took anti-anxiety drugs or anti-depressants in the 12 months prior to the first interview. We estimate IV regressions of the effects of smoking cigarettes on these outcomes (Eq. 3) separately for men and women. At the bottom of Columns (3)-(5), we report the difference between these estimates and the p-value from a test of whether they are equal. See the notes to Table 1 for more information on the LHS sample.

Table A1: Pre-Treatment Characteristics, Analysis Sample

	Treatment	Control	Diff	P-Val
Age	48.4460	48.4791	0.0332	0.8626
Male	0.6209	0.6381	0.0172	0.2059
no HS Diploma	0.1225	0.1199	-0.0026	0.7779
HS Diploma	0.3025	0.2916	-0.0109	0.3987
College or Trade School	0.5750	0.5885	0.0135	0.3323
Body Mass Index	25.5643	25.5679	0.0036	0.9740
Cigs. per Day	31.2933	30.9857	-0.3075	0.3944
Age, First Cigarette	17.4303	17.5695	0.1391	0.1975
Total Distress Score	1.8915	1.8147	-0.0768	0.2469
Distress: Severe	0.0233	0.0225	-0.0008	0.7608
Irritability, Past 4 Mos.	0.5450	0.5206	-0.0244	0.2814
Insomnia, Past 4 Mos.	0.3970	0.3899	-0.0072	0.7403
Mood Changes, Past 4 Mos.	0.4049	0.3980	-0.0069	0.7357
Nervous, Past 4 Mos.	0.4923	0.4596	-0.0327	0.1392
Psych. Problems, Past 4 Mos.	0.0523	0.0468	-0.0056	0.5037
Anti-Depress., Past Month	0.0147	0.0174	0.0027	0.4314
Anxiolytic, Past Month	0.0252	0.0243	-0.0009	0.8402
Observations	3,812	1,893	5,705	5,705

Table A2: Long-Run Effects of Cessation Program on Mental Health, 2SLS Estimates

	(1) Distress Scale	(2) Distress: Severe	(3) Anxiolytic	(4) Anti-Depressant
Panel A: Men				
Avg. Cigarettes per Day, Years 2-5	-0.0064	-0.0006	-0.0008	0.0003
	(0.0089)	(0.0003)	(0.0005)	(0.0005)
	[0.4666]	[0.0285]	[0.0836]	[0.5560]
Obs.	3,575	3,575	3,575	3,575
Control Mean, Men	1.4151	0.0131	0.0206	0.0266
F-Statistic	315	315	315	315
Panel B: Women				
Avg. Cigarettes per Day, Years 2-5	0.0359	0.0007	0.0003	0.0008
	(0.0175)	(0.0005)	(0.0010)	(0.0011)
	[0.0403]	[0.2284]	[0.7749]	[0.4726]
Obs.	2,130	2,130	2,130	2,130
Control Mean, Women	2.4010	0.0334	0.0448	0.0523
F-Statistic	169	169	169	169

Each point estimate, heteroskedasticity-robust standard error (in parentheses) and p-value (in brackets) is from a separate 2SLS regression estimating Eq. 3. The dependent variable in Column (1) is equal to the sum of the distress scores across the five mental health conditions, averaged across years two through five. The dependent variable in Column (2) is equal to an indicator for severe distress, averaged across the five mental health conditions and interview years 2 through 5. The dependent variables for Columns (3) and (4) are indicators for whether the participant took anti-anxiety drugs or anti-depressants over the past 12 months, averaged over interview years 2 through 5. At the bottom of the table, we report the F-Statistic from the first stage regression (Eq. 2). See the notes to Table 1 for more information on the LHS sample.

Table A3: Long-Run Effects of Cessation Program on on Distress Score Components

	(1) Irritation	(2) Insomnia	(3) Moodiness	(4) Nervousness	(5) Psych. Illness
Panel A: All					
Treatment	-0.0084	-0.0300	-0.0058	-0.0057	0.0068
	(0.0195)	(0.0212)	(0.0175)	(0.0193)	(0.0092)
	[0.6674]	[0.1578]	[0.7398]	[0.7699]	[0.4598]
Obs.	5,705	5,705	5,705	5,705	5,705
Control Mean	0.4697	0.4526	0.3589	0.4057	0.0850
Panel B: Men					
Treatment	0.0078	0.0157	-0.0076	0.0287	0.0112
	(0.0226)	(0.0237)	(0.0205)	(0.0212)	(0.0104)
	[0.7303]	[0.5086]	[0.7104]	[0.1744]	[0.2835]
Obs.	3,575	3,575	3,575	3,575	3,575
Control Mean	0.3960	0.3411	0.3096	0.3037	0.0648
Panel C: Women					
Treatment	-0.0440	-0.1188	-0.0091	-0.0748	-0.0029
	(0.0354)	(0.0399)	(0.0317)	(0.0369)	(0.0174)
	[0.2137]	[0.0030]	[0.7747]	[0.0427]	[0.8674]
Obs.	2,130	2,130	2,130	2,130	2,130
Control Mean	0.5998	0.6494	0.4457	0.5856	0.1204
Diff, Men-Women: b/cigs	-0.0072	-0.0188	-0.0004	-0.0140	-0.0017
P-Value	0.2057	0.0030	0.9348	0.0153	0.5363

Each point estimate, heteroskedasticity-robust standard error (in parentheses) and p-value (in brackets) is from a separate regression estimating Eq. 1. The dependent variable in each column is the severity score for the given mental health condition, averaged across interview years 2 through 5. We estimate IV regressions of the effects of smoking cigarettes on these outcomes (Eq. 3) separately for men and women. At the bottom of the table, we report the difference between these estimates and the p-value from a test of whether they are equal. See the notes to Table 1 for more information on the LHS sample.

Table A4: Short-Run Effects of Cessation Program on Mental Health, 2SLS Estimates

	(1) Distress Scale	(2) Distress: Severe	(3) Anxiolytic	(4) Anti-Depressant
Panel A: Men				
Avg. Cigarettes per Day, Year 1	-0.0161	-0.0004	-0.0001	-0.0002
	(0.0058)	(0.0002)	(0.0003)	(0.0003)
	[0.0054]	[0.0388]	[0.7941]	[0.5351]
Obs.	3,575	3,575	3,575	3,575
Control Mean, Men	1.3804	0.0117	0.0190	0.0112
F-Statistic	71	71	71	71
Panel B: Women				
Avg. Cigarettes per Day, Year 1	-0.0128	-0.0003	0.0000	-0.0004
	(0.0112)	(0.0005)	(0.0008)	(0.0007)
	[0.2514]	[0.4736]	[0.9813]	[0.5608]
Obs.	2,130	2,130	2,130	2,130
Control Mean, Women	2.1940	0.0291	0.0330	0.0255
F-Statistic	27	27	27	27

Each point estimate, heteroskedasticity-robust standard error (in parentheses) and p-value (in brackets) is from a separate 2SLS regression estimating Eq. 3. The dependent variable in Column (1) is the sum of the distress scores across the five mental health conditions, as reported in the first interview. The dependent variable in Column (2) is an indicator for severe distress, averaged across the five mental health conditions, from the first interview. The dependent variables for Columns (3) and (4) are indicators for whether the participant took anti-anxiety drugs or anti-depressants in the 12 months prior to the first interview. At the bottom of the table, we report the F-Statistic from the first stage regression (Eq. 2). See the notes to Table 1 for more information on the LHS sample.

A1 Effects on Mental Health in Each Interview Year

In our main results, we study outcomes in interview year 1 (the "short-run") and take the average of outcomes in years 2-5 (the "long-run"). In this section, we consider effects on mental health outcomes in each individual interview year.

In particular, we estimate the following specification.

$$Y_{it} = \text{Treatment}_i * \mathbf{Year} * \boldsymbol{\delta} + \mathbf{Year} + \nu_{it} \tag{4}$$

Y_{it} is a mental health outcome for participant i in interview year t, $1 \leq t \leq 5$. **Year** is a vector of five indicators corresponding to each interview year. $\boldsymbol{\delta}$ is a vector of five corresponding coefficients. Note that we omit a constant term so that there is no excluded interview year category. Thus, our estimates of $\boldsymbol{\delta}$ can be interpreted as the causal effect of the treatment on Y_{it} in each interview year. We cluster the standard error, ν_{it}, at the level of the participant, i.

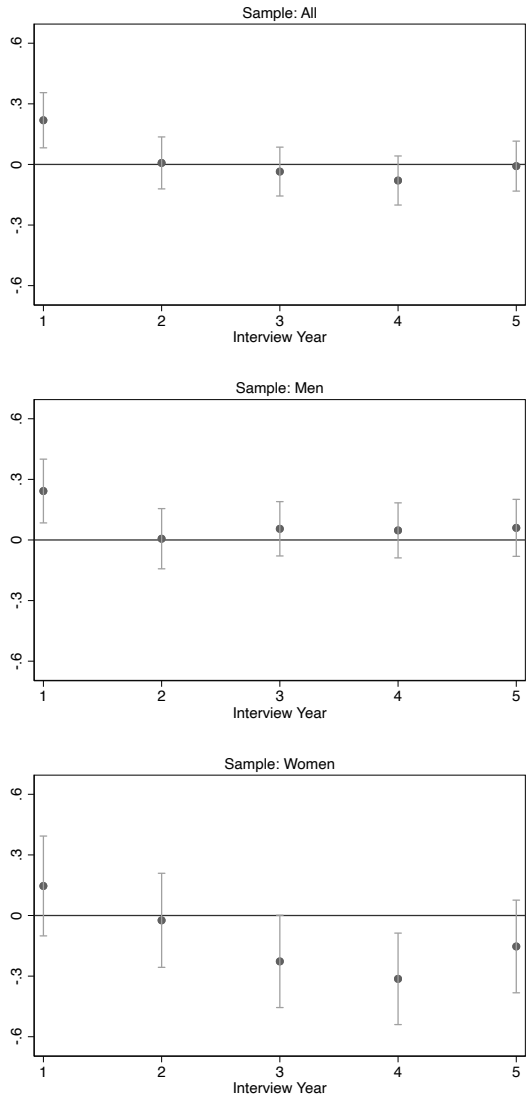
For each of the mental health outcomes, we plot our estimates of $\boldsymbol{\delta}$, along with 95% confidence intervals. The results are shown in Figure A1 and Figures A2-A4. We also report the corresponding point estimates and standard errors in Tables A5-A7.

As can be seen in Figure A1, there is a clear increase in the distress scale (i.e., a worsening of mental health) in the first year after the cessation treatment. By comparison, the point estimates in years 2-5 suggest that distress improves in year 2 and continues to improve for women over time, but not for men.[24] In Figure A2, there is an initial increase in the incidence of severe distress for men that appears to stay elevated in the long-run.

The overall trends in use of anti-anxiety and anti-depressant drugs are somewhat less clear. Still, there appears to be a slight upward trend in the likelihood that men take anxiolytics over time (Figure A3) and a downward trend in the likelihood that women take anti-depressants (Figure A4).

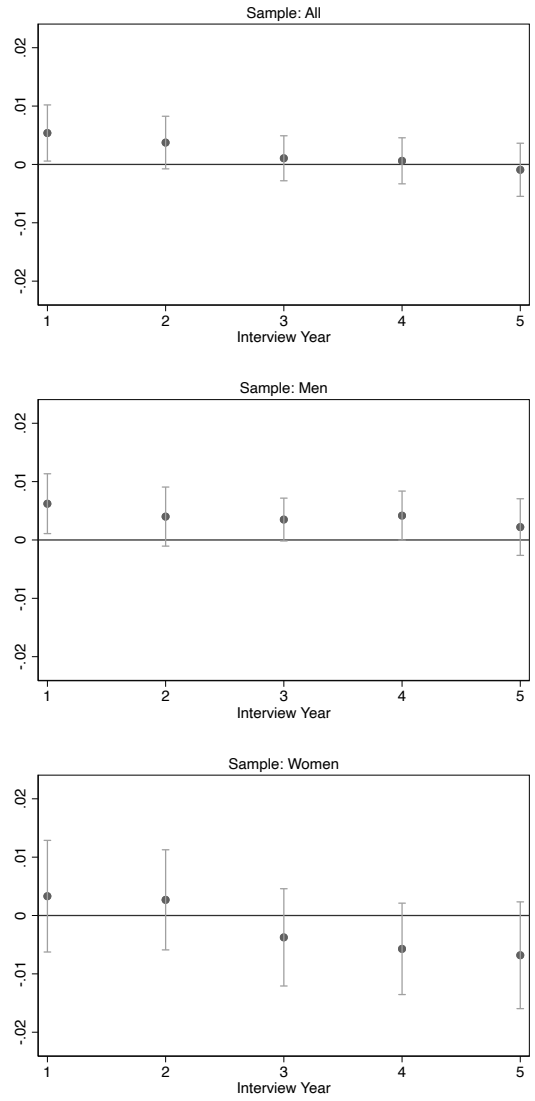
[24] As we are mostly underpowered to detect differences in these effects between interview years, these comparisons should be treated with caution.

Figure A1: Dynamic Effects of Cessation Program on Distress Scale



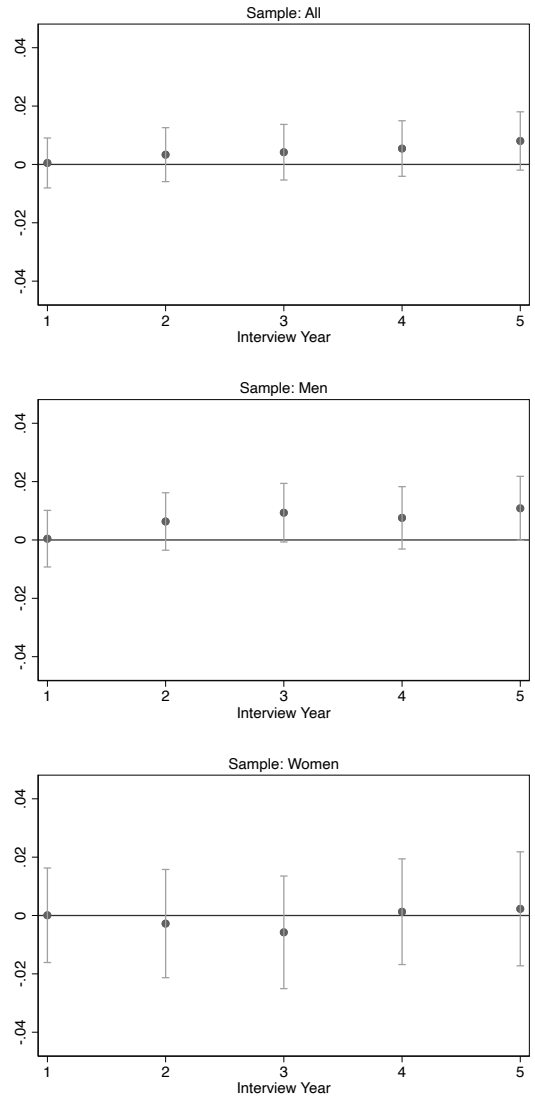
Notes: Displayed above are point estimates and 95% confidence intervals corresponding to $\boldsymbol{\delta}$ from Eq. (4). The dependent variable is equal to the sum of the distress scores across the five mental health conditions, as reported in the given interview year. An increase in the score indicates an increase in distress. The point estimates, standard errors, and p-values from these regressions are reported in Column (1) of Tables A5-A7. The regressions additionally include fixed effects for interview year. Standard errors are clustered at the level of participant ID. See the notes to Table A5 for more information on the sample.

Figure A2: Dynamic Effects of Cessation Program on Severe Distress



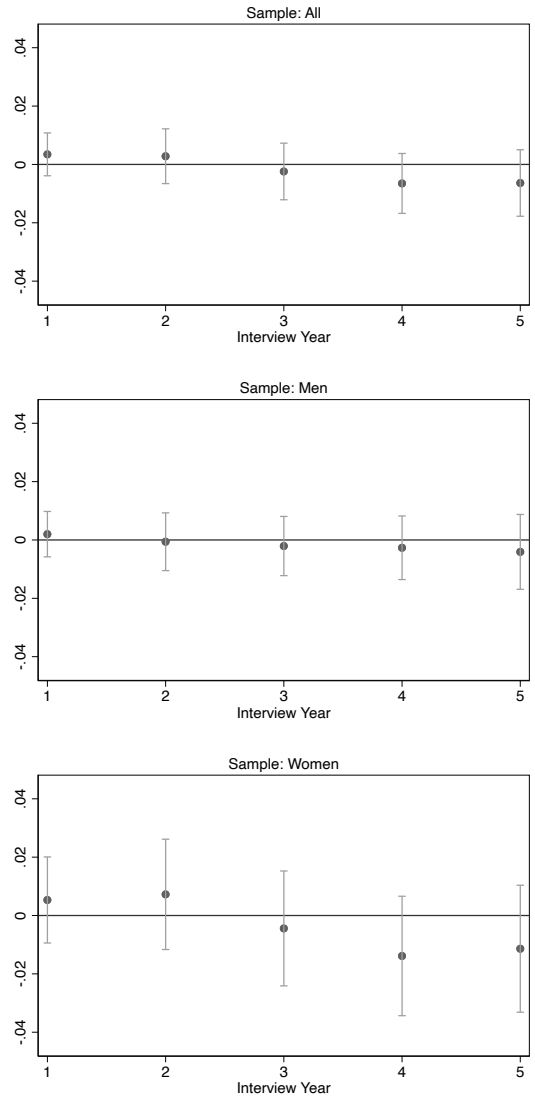
Notes: Displayed above are point estimates and 95% confidence intervals corresponding to $\boldsymbol{\delta}$ from Eq. (4). The dependent variable is equal to an indicator for severe distress, averaged across the five mental health conditions, as reported in the given interview year. The point estimates, standard errors, and p-values from these regressions are reported in Column (2) of Tables A5-A7. The regressions additionally include fixed effects for interview year. Standard errors are clustered at the level of participant ID. See the notes to Table A5 for more information on the sample.

Figure A3: Dynamic Effects of Cessation Program on Anxiolytic Usage



Notes: Displayed above are point estimates and 95% confidence intervals corresponding to $\boldsymbol{\delta}$ from Eq. (4). The dependent variable is equal to an indicator for whether the participant took anti-anxiety drugs at the time of the given interview. The point estimates, standard errors, and p-values from these regressions are reported in Column (3) of Tables A5-A7. The regressions additionally include fixed effects for interview year. Standard errors are clustered at the level of participant ID. See the notes to Table A5 for more information on the sample.

Figure A4: Dynamic Effects of Cessation Program on Anti-Depressant Usage



Notes: Displayed above are point estimates and 95% confidence intervals corresponding to $\boldsymbol{\delta}$ from Eq. (4). The dependent variable is equal to an indicator for whether the participant took anti-depressant drugs at the time of the given interview. The point estimates, standard errors, and p-values from these regressions are reported in Column (4) of Tables A5-A7. The regressions additionally include fixed effects for interview year. Standard errors are clustered at the level of participant ID. See the notes to Table A5 for more information on the sample.

Table A5: Dynamic Effects of Cessation Program on Mental Health, Pooled Sample

	(1) Distress Scale	(2) Distress: Severe	(3) Anxiolytic	(4) Anti-Depressant
Treatment × Year 1	0.2188	0.0054	0.0005	0.0035
	(0.0697)	(0.0025)	(0.0044)	(0.0037)
	[0.0017]	[0.0283]	[0.9083]	[0.3561]
Treatment × Year 2	0.0075	0.0037	0.0034	0.0028
	(0.0657)	(0.0023)	(0.0047)	(0.0048)
	[0.9089]	[0.1030]	[0.4772]	[0.5569]
Treatment × Year 3	-0.0354	0.0011	0.0042	-0.0024
	(0.0617)	(0.0020)	(0.0049)	(0.0050)
	[0.5665]	[0.5911]	[0.3890]	[0.6271]
Treatment × Year 4	-0.0796	0.0006	0.0054	-0.0065
	(0.0620)	(0.0020)	(0.0049)	(0.0052)
	[0.1995]	[0.7580]	[0.2617]	[0.2138]
Treatment × Year 5	-0.0083	-0.0009	0.0080	-0.0064
	(0.0631)	(0.0023)	(0.0051)	(0.0058)
	[0.8955]	[0.6928]	[0.1146]	[0.2742]
Obs.	27,447	27,555	27,555	27,555
Control Mean	1.3819	0.0155	0.0274	0.0315

Notes: The dataset is the Lung Health Study, limited to individuals with non-missing values of the dependent variable in each of the five annual interviews. Each observation is a unique combination of participant ID and interview year. Each point estimate, standard error (in parentheses) and p-value (in brackets) is from a separate regression estimating Eq. 4. The dependent variable in Column (1) is equal to the sum of the distress scores across the five mental health conditions, as reported in a given interview year. The dependent variable in Column (2) is equal to an indicator for severe distress, averaged across the five mental health conditions. The dependent variables for Columns (3) and (4) are equal to indicators for whether the participant took anti-anxiety drugs or anti-depressants over the 12 months before the given interview date. All specifications include fixed effects for each interview year, and the constant term is excluded. Standard errors are clustered at the level of participant ID.

Table A6: Dynamic Effects of Cessation Program on Mental Health, Men

	(1) Distress Scale	(2) Distress: Severe	(3) Anxiolytic	(4) Anti-Depressant
Treatment × Year 1	0.2423	0.0062	0.0004	0.0020
	(0.0805)	(0.0026)	(0.0049)	(0.0040)
	[0.0026]	[0.0174]	[0.9285]	[0.6148]
Treatment × Year 2	0.0063	0.0040	0.0063	-0.0006
	(0.0760)	(0.0026)	(0.0050)	(0.0050)
	[0.9344]	[0.1206]	[0.2072]	[0.9051]
Treatment × Year 3	0.0553	0.0035	0.0093	-0.0021
	(0.0686)	(0.0019)	(0.0051)	(0.0052)
	[0.4199]	[0.0617]	[0.0680]	[0.6881]
Treatment × Year 4	0.0475	0.0042	0.0076	-0.0027
	(0.0695)	(0.0021)	(0.0055)	(0.0056)
	[0.4944]	[0.0517]	[0.1643]	[0.6314]
Treatment × Year 5	0.0599	0.0022	0.0108	-0.0041
	(0.0720)	(0.0025)	(0.0056)	(0.0065)
	[0.4049]	[0.3713]	[0.0527]	[0.5329]
Obs.	17,132	17,199	17,199	17,199
Control Mean	1.1073	0.0097	0.0192	0.0228

Notes: The dataset is the Lung Health Study, limited to men with non-missing values of the dependent variable in each of the five annual interviews. Each observation is a unique combination of participant ID and interview year. Each point estimate, standard error (in parentheses) and p-value (in brackets) is from a separate regression estimating Eq. 4. The dependent variable in Column (1) is equal to the sum of the distress scores across the five mental health conditions, as reported in a given interview year. The dependent variable in Column (2) is equal to an indicator for severe distress, averaged across the five mental health conditions. The dependent variables for Columns (3) and (4) are equal to indicators for whether the participant took anti-anxiety drugs or anti-depressants over the 12 months before the given interview date. All specifications include fixed effects for each interview year, and the constant term is excluded. Standard errors are clustered at the level of participant ID.

Table A7: Dynamic Effects of Cessation Program on Mental Health, Women

	(1) Distress Scale	(2) Distress: Severe	(3) Anxiolytic	(4) Anti-Depressant
Treatment × Year 1	0.1462	0.0033	0.0001	0.0053
	(0.1261)	(0.0049)	(0.0083)	(0.0075)
	[0.2463]	[0.4975]	[0.9916]	[0.4794]
Treatment × Year 2	-0.0237	0.0027	-0.0028	0.0072
	(0.1188)	(0.0044)	(0.0095)	(0.0096)
	[0.8416]	[0.5393]	[0.7696]	[0.4524]
Treatment × Year 3	-0.2271	-0.0037	-0.0058	-0.0044
	(0.1166)	(0.0043)	(0.0098)	(0.0100)
	[0.0516]	[0.3787]	[0.5589]	[0.6599]
Treatment × Year 4	-0.3135	-0.0057	0.0013	-0.0139
	(0.1155)	(0.0040)	(0.0092)	(0.0104)
	[0.0067]	[0.1528]	[0.8877]	[0.1845]
Treatment × Year 5	-0.1532	-0.0068	0.0023	-0.0114
	(0.1170)	(0.0047)	(0.0100)	(0.0111)
	[0.1907]	[0.1447]	[0.8186]	[0.3054]
Obs.	10,315	10,356	10,356	10,356
Control Mean	1.8622	0.0256	0.0417	0.0468

Notes: The dataset is the Lung Health Study, limited to women with non-missing values of the dependent variable in each of the five annual interviews. Each observation is a unique combination of participant ID and interview year. Each point estimate, standard error (in parentheses) and p-value (in brackets) is from a separate regression estimating Eq. 4. The dependent variable in Column (1) is equal to the sum of the distress scores across the five mental health conditions, as reported in a given interview year. The dependent variable in Column (2) is equal to an indicator for severe distress, averaged across the five mental health conditions. The dependent variables for Columns (3) and (4) are equal to indicators for whether the participant took anti-anxiety drugs or anti-depressants over the 12 months before the given interview date. All specifications include fixed effects for each interview year, and the constant term is excluded. Standard errors are clustered at the level of participant ID.