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Reducing Disparities in Smoking for Adults with Mental Illness: Are U.S. Tobacco Prevention Policies Effective?

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Reducing Disparities in Smoking for Adults with Mental Illness: Are U.S. Tobacco Prevention Policies Effective?

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

By

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Abstract

One in five people in the U.S. are estimated to experience "any mental illness" (AMI); however this group represents an estimated 40% of the annual, adult cigarette consumption in the U.S. Tobacco prevention policies have been successful at reducing smoking prevalence among the U.S. population as a whole, however it is unclear whether these efforts have had significant impact on tobacco use rates among individuals with AMI. The long-term purpose of this project is to reduce the disparity in tobacco use rates for adults with AMI by illustrating differences in demand for cigarettes in response to current and potential tobacco prevention policies among individuals with and without AMI, and exploring variation in the role of abuse liability as an explanatory factor influencing these behavioral responses.

Chapter 1: To investigate whether this disparity in smoking rates might be explained, in part, by variation in response to state-level smoking prevention policies over time, we conducted a longitudinal study of 7,842 young adults who participated in the National Longitudinal Survey of Youth 1997 cohort, modelling associations between AMI, tobacco policy, and smoking outcomes and the role of treatment for AMI in potentially ameliorating these effects. Our results suggest that, while adults with AMI may be more likely to smoke and to have increased cigarette consumption, they do not appear to respond differently to price policies than adults without AMI. Our findings offer evidence that current popular tobacco prevention policies may be just as effective at reducing smoking among this population, but therefore underscore the need to further investigate the role of mental health and tobacco cessation treatment alternatives tailored to the unique needs of adults suffering from the dual burdens of both AMI and chronic tobacco use.

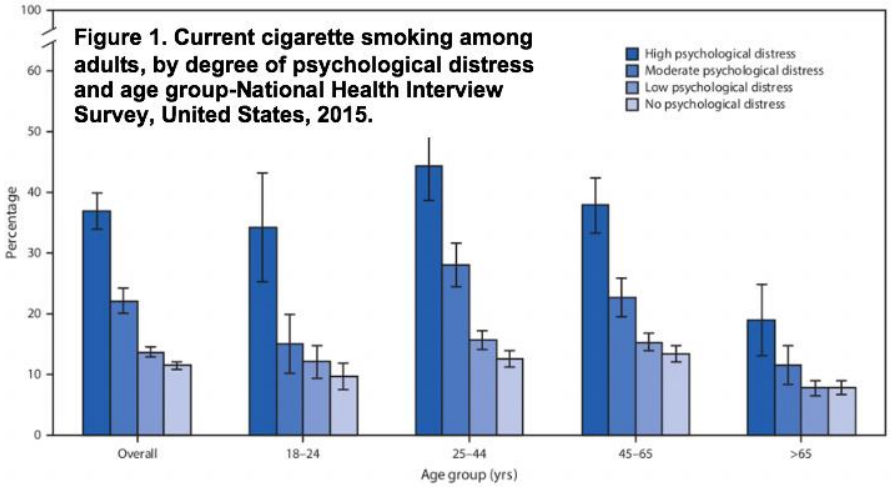
Chapter 2: This study addresses a significant gap in our knowledge regarding tobacco use among a population of smokers who smoke at higher rates than the general population of U.S. adults, tend to smoke more cigarettes and be more dependent on nicotine, and may have additional difficulty reducing or quitting smoking. We recruited a sample of 407 adult smokers to investigate whether AMI may moderate associations between price policies and demand for cigarettes, and if it may moderate responsiveness of adult smokers to availability of alternative products representing different potential regulatory scenarios. In contrast to our study described in Chapter 1, where we relied upon secondary data and a more constrained range of price variation, we found that smokers with AMI may have less elastic demand for cigarettes in the face of rising prices, and that though they are willing to substitute alternative products when cigarettes prices are raised, the extent to which they are willing to do so, and whether they do so at rates different from those without AMI, depends on a variety of factors.

Chapter 3: Adult smokers with symptoms of any mental illness (AMI) are highly dependent on nicotine and may face additional difficulty quitting smoking. Using data from 7,290 U.S. adults who participated in four waves of the Population Assessment of Tobacco and Health (PATH) Study, we investigated whether AMI may moderate the association between nicotine dependence and use behaviors. Adults with AMI are particularly affected by the burden of tobacco use, in part because of the likely interaction between nicotine dependence and AMI. Tobacco control efforts that focus on this interplay may provide an opportunity to better target interventions for this vulnerable population.

Introduction

Smoking-related disease remains the leading cause of preventable morbidity and mortality worldwide, and account for over 480,000 deaths and approximately $300 billion in annual costs in the U.S alone.[1,2] In 2018, more than 35 million adults, or approximately 13.7% of the U.S. adult population, were current cigarette smokers.[3] Between 2005 and 2018 the prevalence of smoking among adults in the U.S. declined by almost 7 percentage points, from 20.9% to 13.7%.[2] However, the prevalence of smoking among adults with any mental illness (AMI) remained as high as 36% in 2015, ranging from 18%-49% depending on state of residence.[4,5]

One in five people in the U.S. are estimated to experience "any mental illness" (AMI); however this group represents an estimated 40% of the annual, adult cigarette consumption in the U.S.[6–9] While tobacco prevention and control policies such as taxes and indoor clean air laws have been successful at reducing smoking prevalence among the U.S. population as a whole,[2,10,11] it is unclear whether these efforts have had significant impact on tobacco use rates among individuals with AMI. Experience of AMI has been linked in many previous studies to higher susceptibility to smoke, lower overall rates of cessation,[12,13] and reduced success when attempting to quit smoking.[9,14,15] The U.S. Food and Drug Administration (FDA) has prioritized reducing the public health burden of combustible tobacco use, exploring strategies such as reducing nicotine in combustible cigarettes to lower their addictive potential,[16] and evaluating the safety of e-cigarettes in comparison to combustible cigarettes to inform policy.[17] We have limited knowledge about whether these policies will be equally effective for those with AMI, or whether they might exacerbate an existing disparity.



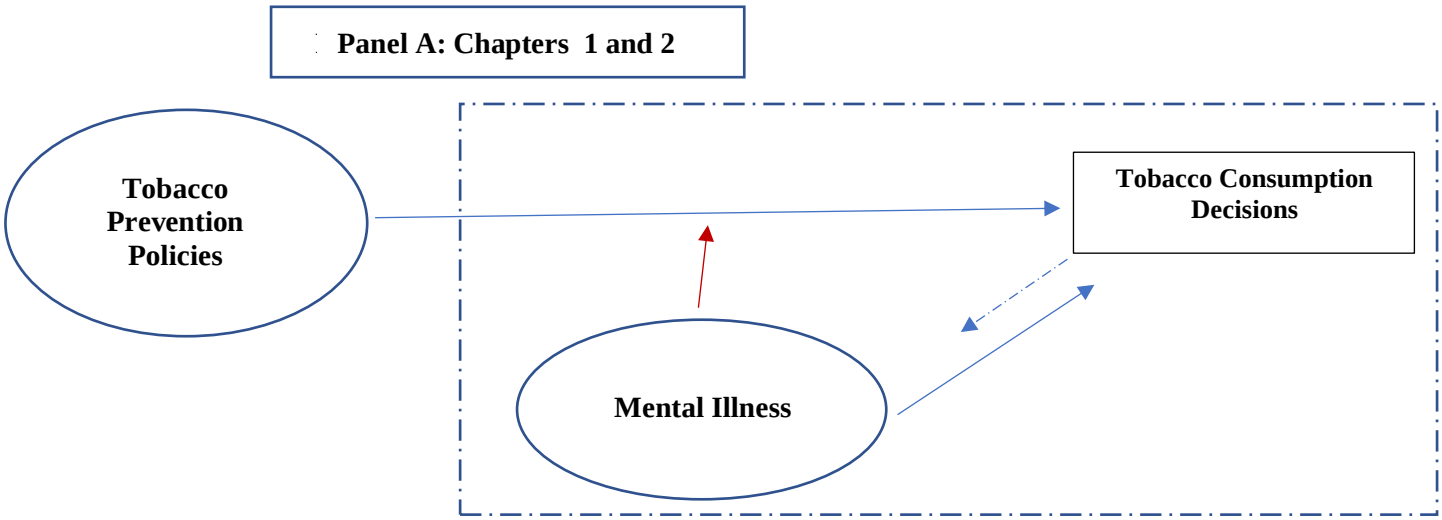
Adults with mental illness or substance use disorders die about 5 years earlier than those without these disorders; many of these deaths are caused by smoking cigarettes.[18] The most common causes of death among people with AMI are heart disease, cancer, and lung disease, for which all smoking is a major contributing

factor.[19,20] Previous research has identified possible pathways to explain this disparity, including the suggestion that adults with AMI are less responsive to tobacco policies (e.g. cigarette taxes), are less likely to quit smoking,[21] and have higher abuse liability (likelihood of persistent tobacco use or dependence),[22,23] than adult smokers without AMI. Despite the benefit of this evidence, described in detail in subsequent chapters, much of it relies on smaller, non-representative samples, cross-sectional data, or provides limited information that requires integration to provide a more robust understanding of whether these policies can reduce the burden of smoking among U.S. adults equitably.

The long-term purpose of this project is to reduce the disparity in tobacco use rates for adults with AMI by illustrating differences in demand for cigarettes in response to current and potential tobacco prevention policies among individuals with and without AMI, and exploring variation in the role of abuse liability as an explanatory factor influencing these behavioral responses. Abuse liability, or the likelihood of persistent tobacco use or dependence,[22] may be higher among those with AMI due to use of tobacco, in part, to help cope with symptoms of mental illness.[9,24,25] Stakeholders such as the Centers for Disease Control (CDC), the National Cancer Institute (NCI), and the National Institute on Drug Abuse (NIDA) have identified the relationship between AMI and tobacco use behaviors as a top priority,[4,25–28] particularly since policy models 1) have not sufficiently tested for varying policy efficacy across AMI and non-AMI populations and 2) have not sufficiently explored whether nicotine dependence influences cessation outcomes differently for adults with AMI than those without.

Conceptual Model

Figure 2. Overview of Conceptual Model



Guiding this project are the relationships illustrated in Figure 2, Panels A and B, and described in further detail in the Background section (below). Panel A illustrates a conceptual relationship between tobacco prevention policies, such as excise taxes, clean indoor air laws, education campaigns, and marketing and advertising, which seek to reduce tobacco use at the population level, and tobacco consumption decisions by individuals over time. If effective, tobacco prevention policies reduce tobacco consumption. However, adults with mental illness suffer from adverse symptoms of that illness and consume tobacco to manage symptoms and as a coping tool. In this way, mental illness may moderate the effectiveness of policy at reducing tobacco consumption for this population. Papers 1 and 2 rely upon the framework described in Figure 2, Panel A, to investigate this hypothesis and offer legislators timely information about the effectiveness of tobacco prevention policies among a population of adults at high risk for tobacco use.

Panel B: Chapter 3

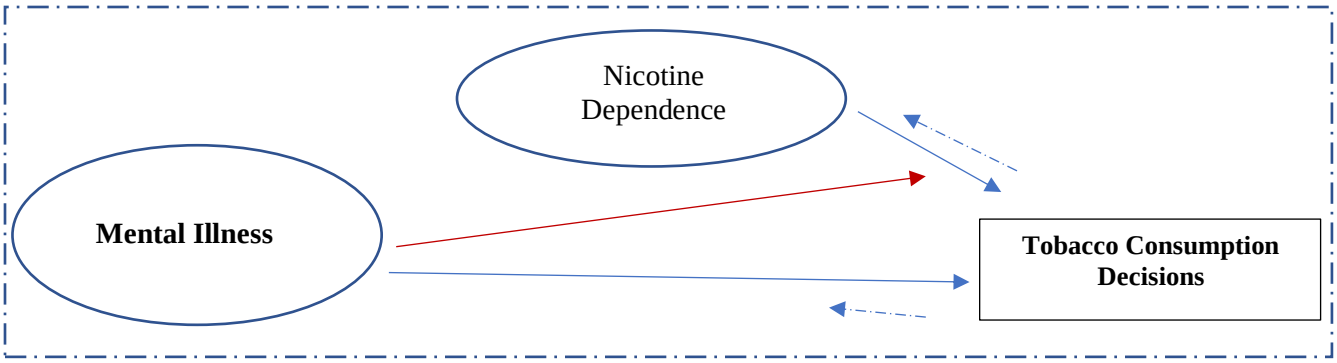


Figure 2, Panel B illustrates the conceptual framework for the role of nicotine dependence in tobacco consumption decisions over time, specifically the choice and ability to successfully quit smoking. Tobacco contains nicotine, an addictive chemical that fosters dependence and addiction over time among users, which then encourages continued use. An individual's level of dependence is therefore associated with past, present, and future tobacco consumption decisions, including his or her ability to quit smoking if desired. Among adults with AMI, use of tobacco fosters dependence in the traditional sense, however use of tobacco as a tool to cope with or self-medicate symptoms of mental illness may also mean that AMI moderates the role of dependence in its association with tobacco consumption, when compared to the role that dependence plays in tobacco consumption choices for adults without AMI. Chapter 3 specifically investigates this question in order to shed light on a mechanism that could help explain hypothesized results from Papers 1 and 2.

The three papers described in this proposal combined longitudinal, nationally-representative data and online behavioral experiments from U.S. adults to compare adult smokers with and without AMI in: 1) historic responses to tobacco price policies, 2) responsiveness to different potential tobacco prevention policy scenarios federal regulators are currently considering, and 3) the relationship between nicotine dependence and smoking cessation.

Without understanding whether tobacco prevention and control policies are less effective at reducing tobacco use among those with AMI and whether this is, in part, due to differences in the effect of nicotine

dependence on behavior, policy makers will continue to struggle to provide equitable and effective tobacco prevention policies.

Background

Figure 3. Detailed Conceptual Model of Mental Illness, Tobacco Prevention Policy, and Tobacco Use Outcomes

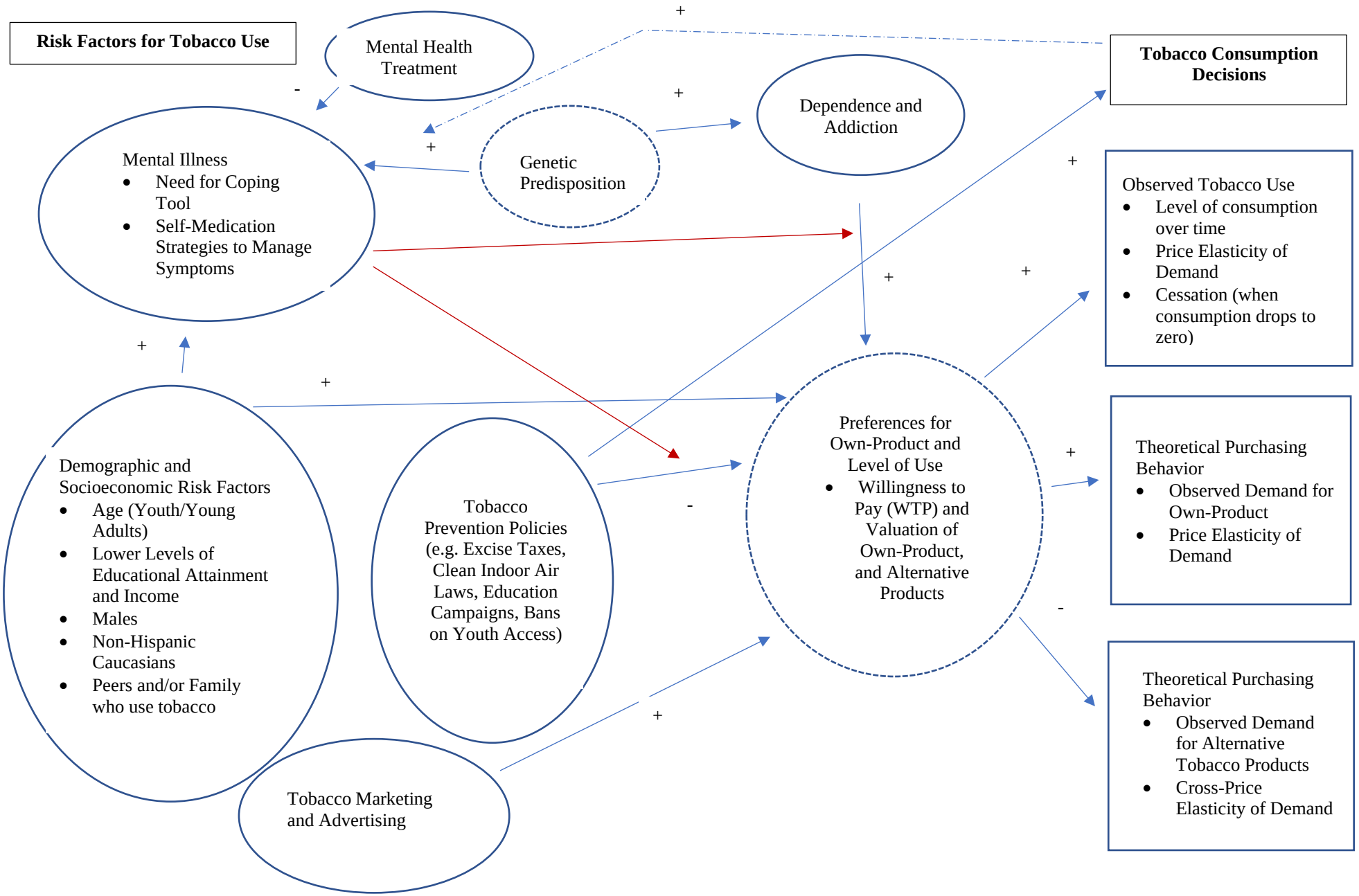


Figure 3 (above) offers more detailed insight into the theoretical and practical associations between mental illness and smoking behavior that have guided this project. There are a number of general demographic and socioeconomic risk factors for initiating and continuing tobacco use for which we now have strong base of evidence. Evidence suggests that youth and young adults, males, those with lower education and income, and those with family and friends who use tobacco all face enhanced risk for initiating and continuing smoking behavior.[29] Exposure to tobacco advertising and marketing, as well as receptivity to tobacco advertising, is also significantly associated with higher rates of tobacco product initiation.[29–34]

In addition to these broadly-applicable risk factors for smoking, youth and adults suffering from mental illness also face enhanced risk for initiating and continuing smoking.[5,19,20,24,35] Risk factors for mental illness include having a parent or relative with a mental illness, experiencing stressful or traumatic life events, experiencing an ongoing medical condition, being abused or neglected, and social isolation.[36] In addition, genetic predisposition plays a role in influencing both the risk of developing mental illness, and the risk of becoming dependent on substances of abuse.[36,37] Youth and adults suffering from mental illness symptoms, as well as all individuals, make choices about their health behavior based on their beliefs about the likely consequences of those actions. This proposal relies upon a health belief model to illustrate why adults choose to smoke, and why adults suffering from mental illness symptoms smoke at higher rates,[5] and smoke with increased intensity compared to those who do not suffer from these symptoms.[38]

A health belief model describes how individuals rely on positive expectancies and negative expectancies about the consequences of engaging in a health behavior to guide their decision-making. Positive expectancies about the effects of smoking include pleasure, reduction of stress, reduction of withdrawal symptoms, energy, improved social image and weight control or reduction. Negative expectancies include negative social image, reduced social acceptance, harm to immediate or long-term health, smelling bad, causing harm to others, and becoming addicted.[39] Previous research on smoking expectancies among youth,[40] adults,[41,42] and adults with mental illness[37] has identified that adults experiencing mental illness are unique in that they report the positive expectancy "reduction of negative affect" as most important factor in guiding their decisions about smoking.[42–

[45] Negative affect refers to adverse symptoms they experience due to mental illness. Smoking, therefore, is one tool of many that adults with mental illness may rely upon to cope with their symptoms.[a]

In addition to the influence of genetic and personal factors in their association with mental illness symptoms and smoking outcomes, evidence, albeit conflicting, has emerged regarding the role of receiving mental health treatment and these outcomes. Some recent evidence has suggested that adults with mental illness who are receiving treatment may be more likely to be able to reduce and cease smoking.[5] This makes intuitive sense, as the goal of treatment is to reduce the types of negative emotions and symptoms experienced by adults with AMI. As previous research has suggested, many smokers with AMI have rated "reduction of negative affect" i.e. negative mood symptoms as their most important positive expectancy in regard to their smoking behavior. If treatment could reduce such symptoms, it follows logically that this could also reduce the need for a tool such as smoking to help cope with those symptoms. However, other recent evidence has suggested that adults with AMI who received treatment smoked at rates no different than their peers who had not been treated.[35] While a number of studies have sought to characterize differences in smoking behavior among those with and without AMI, as well as across a spectrum of mental illness diagnoses, very few studies have specifically examined this factor in explaining differences in smoking and cessation rates among adults with AMI, and the evidence we have available conflicts. If treatment has a positive impact on symptoms of AMI, our expectation would mirror results from the first study mentioned above, and smokers with AMI who receive treatment should experience a reduction in symptoms of AMI, therefore the impact of AMI on tobacco consumption should be reduced.

Economic models of addiction can also be particularly helpful in shaping our expectations about the relationships between mental illness, dependence and addiction, tobacco prevention and control policies, and smoking behavior outcomes.[46] Cigarettes contain nicotine, an addictive chemical that encourages continued use after initiation of smoking;[47] continued use of cigarettes fosters both behavioral and physical dependence,

[a] Previous research has also described the role of the tobacco industry in positioning cigarettes as a tool to cope with mental illness or stress symptoms, and to self-medicate.[24,69] Internally-funded and externally-funded research by tobacco companies suggested that adults with mental illness need to smoke to cope with their symptoms, and that cigarettes could be used to self-medicate and reduce symptoms. Marketing messages appealing to those with mental illness, as well as close ties between tobacco manufacturers and behavioral health practitioners also contributed to this pervasive public perception of cigarettes as a positive tool for coping.

leading to addiction. Economic models of addiction include 1) rational models of addiction, in which individuals make consumption decisions with perfect foresight about the future consequences of past and current consumption, 2) myopic models of addiction, in which individuals make decisions about current consumption that ignore the effects of past and current consumption on future consumption, and 3) imperfectly rational models of addiction, in which individuals are conflicted about choosing current consumption since choices that maximize their future well-being may be different than those which maximize their current well-being.[48] Critiques of economic addiction models abound, as individuals may underestimate their individual likelihood of addiction when making consumption choices, and the effects of addiction may vary across individuals.[49] Despite these critiques, economic models of addiction can adapted to explain how individuals make choices about cigarette consumption, and our expectations about how policy may influence preferences regarding consumption.

Estimating demand for cigarettes in response to tobacco prevention policy strategies requires that the addictive nature of cigarettes, and their utility as a strategy for coping with mental illness, be accounted for in order to model these relationships as accurately as possible. For example, the rational addiction model assumes that all individuals wish to maximize their well-being (utility) over time, and that their consumption choices fluctuate in response to what they consider marginal benefits and harms (or costs) of those choices. By consuming an addictive good such as cigarettes, smokers build up an *addictive stock* over time, which influences their utility and preferences. Rational addiction models include three critical elements of addiction and addictive stock to help explain consumption choices: tolerance, withdrawal, and reinforcement. *Tolerance* refers to the tendency for smokers to habituate to a specific level of nicotine consumption, suggesting that smokers therefore require increasing levels of nicotine over time to maintain the same level of utility, otherwise they risk withdrawal. *Withdrawal* refers to negative physical and psychic symptoms experienced when an individual consumes less nicotine than the level to which they are currently accustomed. If an individual gains utility from smoking in the current period, reducing consumption would risk reduced utility through the experience of withdrawal. Finally, *reinforcement* occurs when consumption choices help the smoker maximize

utility in the past and current period by avoiding negative states such as withdrawal, through continued smoking and contribution to his or her addictive stock.[46,50]

This description of an economic model of addiction, and the debate about proper assumptions underlying these models, has been simplified, however several important insights surface regarding the role of dependence, addiction, and tobacco prevention policies in influencing smoking behavior and how these influences may differ across adults with and without mental AMI. Figure 3 offers a visual description of our expectation that, based on the addictive nature of tobacco products, initiation and continued use should increase an individual's dependence and addictive stock, and motivate them to maximize utility by continuing to smoke. If an individual with mental illness has higher risk for being more dependent on cigarettes than an individual who does not suffer from these symptoms,[5] then those suffering from mental illness may get more utility from smoking and be less likely to reduce smoking behavior. Additionally, tobacco prevention policies should influence smokers' preferences and valuation of their smoking behavior by increasing the costs borne by smokers when they choose to smoke (both monetary and time costs), as well as making the health consequences of smoking more salient through public health and counter-advertising campaigns. Evidence suggests that price policies such as taxes, and non-price policies such as clean indoor air laws and information campaigns, have been successful over the past several decades at increasing the "cost" of smoking in relation to its benefits for addicted smokers.[29,51–54] One insight from economic models of addiction is that the degree of policy response is expected to be proportional to the level of increased "cost" policies impose on smokers relative to the level of positive marginal utility each smoker receives by maintaining their current consumption.

Chapter 1 describes our investigation of the role of price policy in changing consumption of cigarettes over time, with a specific focus on whether smokers suffering from any mental illness may be less responsive to increases in the costs of consumption. Chapter 2 describes the role of several prospective alternative tobacco prevention policies in influencing smokers' preferences for consumption of their own tobacco product. Finally, Chapter 3 describes the role of dependence in moderating smoking behavior among smokers with symptoms of mental illness. Taken together, these three studies offer needed insight into key pathways in the conceptual model described above, with the goal of offering insight to policymakers struggling to craft equitable and

effective tobacco prevention policies.

Chapter 1 Associations Between Mental Illness and Variation in Response to Cigarette Price Policy Among U.S. Adults.

Abstract

Background: Policy alternatives such as excise taxes on the purchase of cigarettes, indoor clean air laws, youth access laws, cessation support, and public information campaigns are all widely agreed to be significant contributors to the decline in smoking rates over time.[29] However, the extent to which smoking prevention policies, particularly cigarette taxes, are equally effective across sub-populations of smokers is still a focus of debate.

Methods: 7,842 participants who participated in 5 rounds of data collection (2002, 2004, 2006, 2008, 2010) for the National Longitudinal Survey of Youth 1997 cohort answered questions about both mental health and smoking behavior. Fixed-effects linear probability and Poisson models were fit to the data, modeling associations between AMI, cigarette price, and 1) the likelihood of smoking participation, 2) cigarette consumption, conditional upon participation.

Results: Adults who experienced AMI were 4 percentage points more likely to report smoking since the date of last interview (ß=0.04, 95% CI: 0.02, 0.05), and having AMI was associated with a 10.5% increase in CPD and an 11.6% increase in total consumption compared to participants with no AMI (ß=0.10, 95% CI:0.01, 0.16; ß=0.11, 95% CI:0.06, 0.16, respectively). Among participants with AMI, whether they reported receiving any treatment for AMI from a health professional was a positive predictor of increased smoking participation and all consumption outcomes.

Conclusions: While adults with AMI may be more likely to smoke and to have increased cigarette consumption, they do not appear to respond differently to price than adults without AMI. As excise taxes on cigarettes are a common policy tool widely considered to reduce smoking among youth and adults, this offers positive indications that such policies may prove equally effective at doing so among this population, rather than contributing to a growing gap in prevalence of use compared to the general population of U.S. adults.

Introduction

Policy alternatives such as excise taxes on the purchase of cigarettes, indoor clean air laws, youth access laws, cessation support, and public information campaigns are all widely agreed to be significant contributors to the decline in smoking rates over time.[29] However, the extent to which smoking prevention policies are equally effective across sub-populations of smokers is still a focus of debate. Much of the literature on this topic has focused on youth,[55–58] as the majority of cigarette smoking originates in youth and young adulthood,[29,59] or on the association between prevention policies and income,[60–62] as many argue that the burden of cigarette excise taxes in particular may disproportionately burden low-income adults. Despite this evidence, a still-limited body of work exists to inform policymakers about the response to these policies by another group of individuals highly vulnerable to initiating and continuing smoking: adults with symptoms of mental illness.

In 2018, 19.1% of U.S. adults had experienced any mental illness (AMI) in the previous 12 months, and 4.6% experienced serious mental illness (SMI);[b] both rates were higher in 2018 than they had been in most years during the previous decade.[63] Adults with AMI are significantly more likely to report current cigarette use than adults without these disorders (28.1% vs. 16.3% in 2018),[21,63] to smoke more cigarettes,[64,65] have higher nicotine dependence,[66,67] and to suffer from early mortality due to tobacco-related disease.[18,67,68] The prevailing theory regarding the link between AMI and smoking behavior is based on use of cigarettes and nicotine by adults with AMI who believe cigarettes to be a helpful behavioral or chemical tool to self-medicate when coping with symptoms of AMI, a theory both supported by tobacco industry-funded research and exploited in advertising efforts.[45,68,69] Evidence supports the reverse: use of cigarettes may exacerbate symptoms of AMI and reducing or quitting smoking is associated with an amelioration of symptoms.[68] Within this group of adults, the prevalence of smoking also varies widely across a variety of factors: prevalence of smoking has been estimated to be as high as 40%-60% among adults with depression, and 45%-88% among adults with schizophrenia,[70] and

[b]AMI was defined as experiencing an emotional, behavioral, or mental disorder that met DSM-IV criteria; SMI classification includes that stipulation that the disorder 'substantially interfered' with at least 'one major life activity.' The AMI category does not include individuals with substance abuse or developmental disorders.[63]

overall smoking rates among adults with AMI across states ranged from 18% (Utah) to 49% (West Virginia) across states.[4]

While regulated at the federal level, authority to implement smoking prevention policies is also devolved to individual states, leading to significant variation in the extent of smoking prevention efforts across states.[71] Levying excise taxes on the purchase of cigarettes is a common policy tool employed at both the federal and state level to prevent or reduce tobacco use, among other goals, and the shared authority to regulate excise taxes leads to wide variation in tax rates (the lowest rate in 2020 was $0.17 in Missouri, the highest $4.35 in New York).[29,46,52,72] Price responsiveness, or own-price elasticity of demand, is an important outcome to measure when assessing the effectiveness of taxes in reducing tobacco use, as these elasticity estimates represent how much smoking was reduced, or anticipated to be reduced, for a given increase in price.[46] Evidence reviews on price elasticity of cigarette demand in the U.S. typically offer estimates between -0.3 and -0.5,[55] representing an estimated decrease in purchase of cigarettes of 3%-5% for every 10% increase in the cost of cigarettes. However, tax rates effective at the population level may not be equally impactful across specific populations, as not all individuals may respond to increases in price in exactly the same way.[53,61,73,74] For example, one study found that smokers experiencing financial stress had a lower price elasticity of demand for cigarettes, which means that despite having more limited resources to purchase cigarettes, adults experiencing financial stress were less likely than their non-stressed counterparts to reduce smoking behavior at a similar rate when faced with rising prices.[73] Additional studies have focused on factors such as age,[53–55,75–78] and race and ethnicity[53,57,79] to investigate variation in response among individuals, and at the population level, to price increases over time. Findings from these studies suggest that youth may have a higher price elasticity of demand for cigarettes than adults, which could be attributable to factors such as lower spending power than adults and lower levels of addiction in the early stages of cigarette use.[29,55]

While there is a robust body of literature on price elasticity of demand for cigarettes among youth and adults, there is little evidence documenting whether cigarette taxes are equally effective at reducing smoking among individuals with AMI,[48,74,80] and the evidence thus far provides conflicting answers on this point. One study explored the association between conventional cigarette price elasticity of demand and AMI among a

national sample of youth only, using depression and suicidality as measures of AMI.[48] The study's authors found youth with suicidality symptoms to have less elastic demand for cigarettes than non-suicidal youth (although the magnitude of this difference was small), a finding which conflicts with results from nationally-representative data suggesting that youth with behavioral or emotional problems were at least as responsive to price as those without such disorders.[80]

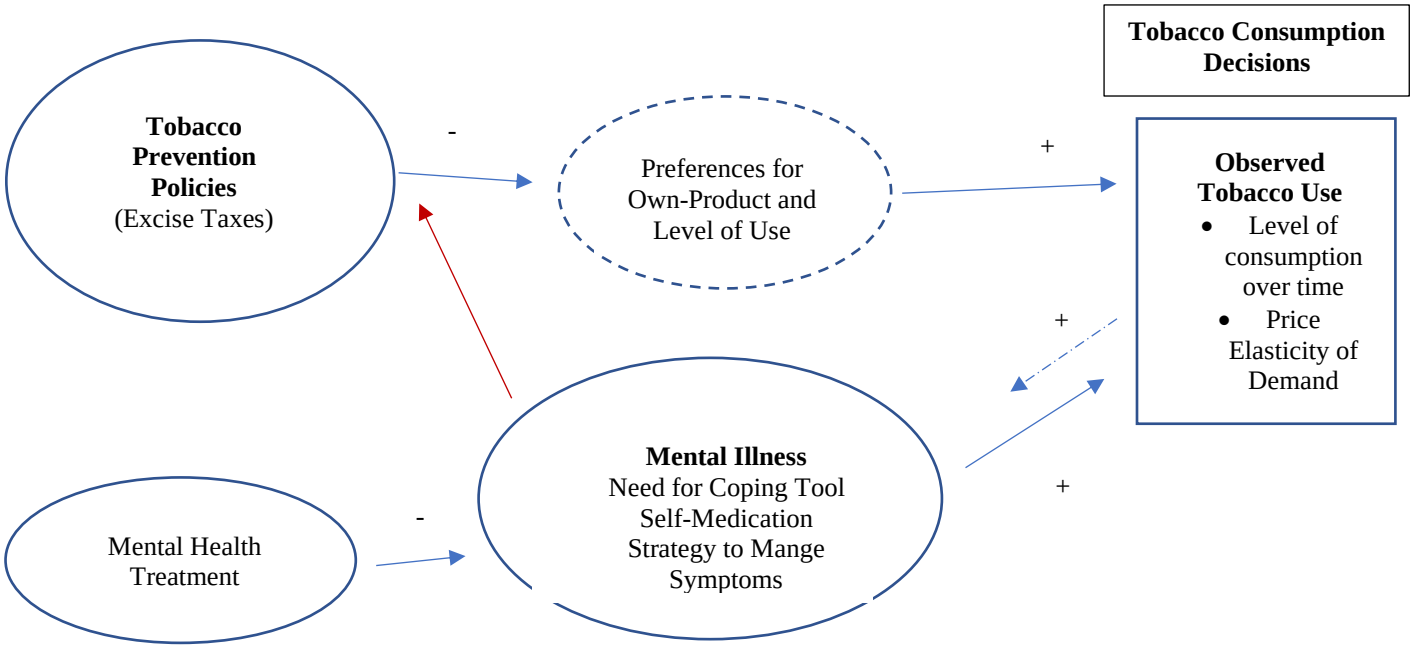
Among the limited studies focusing on adults with AMI, there are also conflicting conclusions. A foundational study by Saffer and Dave (2006) used a nationally-representative cross-sectional sample of adults from 1991, and found that adults with a past-year or lifetime diagnosis of mental illness had a less elastic demand for cigarettes than those without such diagnoses, but, again, this difference was small.[74] In contrast, another study surveying U.S. adults with alcohol, drug, and/or mental disorders (any behavioral health disorder), found that a 10% increase in price was associated with an 18% reduction in smoking participation,[81] which is significantly higher than the 3%-5% range offered based on many previous studies based upon general population data. This finding has been replicated outside of the U.S. as well: among Taiwanese adults, symptoms of depression were associated with more elastic cigarette demand than that of adults without such symptoms.[82]

Finally, adults with AMI may find relief from some of their symptoms as a result of participation in treatment for AMI, which could reduce dependence on cigarettes as a coping tool and increase success in reducing or quitting cigarette use.[5] This is particularly important in light of the heavy health burden of smoking within this particular population, as well as the financial implication of higher costs of smoking among a group of adults who may be prone to both lower levels of income and potentially less elastic demand in the face of rising prices.[67,83,84] In order to more effectively carry out policy efforts to reduce smoking among U.S. adults with AMI, without unintentionally exacerbating this disparity through the use tobacco control policy tools such as increases in excise tax rates, we still require generalizable, longitudinal information about whether adults with AMI have a lower price elasticity of cigarette demand than adults without such symptoms. We also require further investigation of the role of treatment for AMI in moderating the relationship between symptoms of AMI

and initiating and continuing cigarette consumption. Both of these outcomes are particularly important to understand in young adulthood, as 98% of smokers try their first cigarette by the age of 26.[85]

This study employed longitudinal, nationally-representative data from a cohort of approximately 7,000 adult participants from 5 waves of the National Longitudinal Survey of Youth 1997 (NLSY97) geo-coded data to investigate whether young adults with AMI have been equally as responsive to increases in the cost burden of smoking, or whether a lower price elasticity of demand for cigarettes may help illuminate one possible reason for the persistence of a disparity in smoking rates for this group. Additionally, we offer insight into whether receiving treatment from a mental health provider is associated with variation in smoking behavior.

Conceptual Model



This study focused on the associations between mental illness, tobacco prevention and control policies, smoker's preferences, and observed tobacco consumption over time, as illustrated in the detailed conceptual framework in Figure 3. Based on the conceptual model, a price policy such as an increase in the excise tax on cigarettes should increase the cost of smoking faced by the smoker, reducing some of the benefit (utility) a smoker receives from consumption. If smokers with mental illness rely on smoking to help cope with symptoms of mental illness, their preferences for maintaining consumption of cigarettes may be stronger, leading to a

lower price elasticity of demand than smokers without such symptoms (more reluctance to reduce smoking in the face of higher prices over time). However, use of mental health treatment should reduce these symptoms of mental illness, therefore potentially mitigating the expected positive association between mental illness and tobacco use.

Hypotheses

H1a: Demand for cigarettes among adults with AMI will be less responsive to changes in cigarette prices due to excise taxes than those without AMI, reflected by a lower price elasticity of demand.

H1b: Receiving treatment by a mental health professional will be associated with lower probability of smoking participation, and with reduced cigarette consumption.

Methods

Sample

The National Longitudinal Survey of Youth (NLSY) is a nationally representative, longitudinal cohort study administered by the U.S. Bureau of Labor Statistics (BLS). Confidential, geo-coded data was obtained from BLS to allow the addition of policy variables for each participant, such as the excise tax rate in every state each year, and presence of other state-based tobacco prevention policies to which they would have been subject and would have influenced the tobacco use policy environment in which they resided (e.g., youth access laws, clean indoor air laws and state-level tobacco prevention funding over time; see below).

8,984 individuals born between 1980 and 1984 were interviewed in Round 1 (1997) of the NLSY97 sample and are interviewed annually, data collection is ongoing. The NLSY97 cohort is was selected based on a multi-stage area probability design and is made up of two sub-samples: a cross-sectional sample (n=6748) designed to be nationally-representative of the U.S. population at Round 1, and a supplemental sample (n=2,236) which oversampled Hispanic or Latino and African American residents.[c] At round 18 (2017-2018), nearly 75% of Round 1 participants responded. Our analytical sample included the 7,842 participants who participated in the 5 rounds of data collection (2002, 2004, 2006, 2008, 2010) during which all participants were

[c] For more information, see the *NLSY97 Technical Sampling Report.*[182]

ages 18+, and which included questions about both mental health and smoking behavior, and for which comparable smoking prevention policy data were available to add to our analytical data set.[86,87]

Smoking Behavior Measures

Based on the distribution of our outcomes over time and best practices from previous research in this field,[53,88,89] we estimated our models in two stages: 1) the probability of smoking participation (Yes/No), and 2) given smoking participation, the price elasticity of demand for cigarettes, calculated as the percent change in quantity demanded of cigarettes per 10% increase in the price of cigarettes (see Statistical Analysis, below, for further detail). Demand for cigarettes can be defined in multiple ways, such as the number of days smoking cigarettes within the previous month, and the number of cigarettes smoked per day on the days smoking occurred.[48,53] This study used a monthly, continuous measure of total cigarettes smoked in the past 30-days to estimate demand, consistent with previous models.[48] We also examined whether our main parameters of interest were robust to variation in the measurement of demand, by estimating models where cigarettes smoked per day (CPD) and number of days smoking cigarettes were alternative outcomes. While mental health questions were only asked in selected years (see below), a monthly, continuous measure of cigarette consumption was available for all participants for rounds 1-17 of data collection. As mentioned above, we included smoking data from the 5 waves in which both mental health and smoking indicators were available.

Any Mental Illness (AMI) Measures

The Mental Health Inventory (MHI-5) was administered to all participants starting in Wave 4 (2000), and asked them to rate how much of the time during the past month they experienced five different mental health states (both positive and negative), with a 4-item response scale from "All of the time" to "None of the time." Higher scores indicate better mental health, thus the two positive mental health state questions were reverse coded to be congruent with scoring guidelines.[90,91] The Cronbach's alpha score for scale reliability was 0.79, indicating acceptable reliability for our analyses.[92] To score the MHI-5, individual question scores are added together, then normalized to create a score ranging from 0-100, with *lower scores* indicating *greater mental health distress* over the previous month. The appropriate clinically relevant threshold for indicating high likelihood of having AMI and needing services is still a subject of debate. Our study relied upon the traditional

threshold score of 60 (those with scores under 60 in each wave were recorded as having AMI),[90,91] however alternative thresholds have been proposed based on different method of classification (Youden Index, 0/1 method, minimax method).[91] We also tested the sensitivity of our model outcomes to these alternative thresholds (see Discussion and Appendix 1-A).

Additionally, all participants were asked in Round 14 (2010) how many times in the past 12 months they 'had an emotional, mental or psychiatric problem' and were treated by a mental health professional. A three-level categorical variable for treatment was created (No AMI, AMI and no treatment received, and AMI with one or more visits for treatment).

Price and Tobacco Policy Measures

Price policies: While previous studies have used a variety of specifications to represent price such as real, average price for a pack of cigarettes, or excise tax rate in each locality,[88] our models were estimated by defining price as the excise tax rate facing each participant by state and year, as previous authors have suggested this might be the most appropriate measure of variation in price, as state excise tax rates are not subject to market forces.[76] This data is available from *The Tax Burden on Tobacco,* a publicly available report published each year by Orzechowski and Walker.[86] We indexed excise tax rates to 2002 US dollars using the Average Annual Consumer Price Index-All Urban Consumers to provide comparable estimates of change across time,[93]and used a natural log transformation to estimate an elasticity as the change in log consumption based on change in log of the real tax rate.[89]

Non-price policy variables: Additionally, an index describing the comprehensiveness of each state's tobacco prevention policies was included in our models to help isolate the effects of tax policy by controlling for other factors influencing the policy environment for smoking in each state over time.[87] The American Lung Association provides a publicly-available, annual State of Tobacco Control (SOTC) report that scores each state based on the comprehensiveness of its tobacco control policy compared to widely-accepted best practices.[94] Each factor score is a summary measure based on a state's performance across a number of sub-categories (see Appendix 1-B). Individual SOTC category scores have been validated in a previous investigation to be significantly, negatively correlated with state mortality amenable to tobacco.[87]

We created an index for tobacco control by standardizing each state's score per category in each survey period (z-score transformation), and adding each policy category z-score to create an individual total tobacco control index score per state in every survey period.[87] While the previous study cited,[87] and the SOTC reports, also include a category for state excise tax rate, we omitted this from our tobacco control index as we include tax rate as a separate variable in our models. We tested the sensitivity of our main models to including SOTC excise tax rate scores in the tobacco control index and found our parameters of interest similar when excluding this factor.

Covariates

Covariates included time-variant demographic factors associated with variation in smoking behavior,[2,29] such as age category (18-20, 21-25, 26-30), highest level of educational attainment (measured as No Degree, HS Diploma or GED Equivalent, Some College/Associate Degree, Bachelor's degree or higher), and average annual household income (Less than $12,400, $12,401-$37,499, $37,500-$73,499, $73,500+).

Statistical Analysis

We estimated our models in two stages:[53,88,89]

1. $\text{Smoking Participation}_{it} = ß(AMI_{it}) + \eta \ln(tax_{gt}) + \lambda(AMI_{it} \times \ln tax_{gt}) + X_i\Omega + Z_{gt}\gamma + \varepsilon_{igt}$
2. $\text{Consumption}|\text{Smoking}_{it} = ß(AMI_{it}) + \eta \ln(tax_{gt}) + \lambda(AMI_{it} \times \ln tax_{gt}) + X_i\Omega + Z_{gt}\gamma + \varepsilon_{igt}$

Where X is a matrix of time-variant individual factors and Z is a matrix of state-level factors such as the strength of additional tobacco prevention policies, ß, η, λ are parameters to be estimated. Our hypotheses predict that λ will be both positive and statistically significant.

Modelling these outcomes separately is a strategy that has been used frequently in previous studies to help account for the distribution of outcomes among participant sample,[89] as the more limited frequency of smoking would introduce a number of 0 or missing results into the second model where we estimate parameters for cigarette consumption based on price. For our main models pictured above, we used biannual data from 2002-2010. Both models employed person-level fixed effects to control for unobservable time-invariant heterogeneity at the individual participant level, and heteroskedasticity-robust standard errors clustered at the

individual level.[95] Model 1 was estimated with data from the full analytic sample, using a linear probability model to estimate the association between likelihood of smoking participation across time, AMI, cigarette price, an interaction between AMI and price, and time-variant sociodemographic covariates. In Model 2, we further accounted for distribution of our limited dependent variables by employing a Poisson model with heteroskedasticity-robust standard errors, a generalized linear model with strengths in regard to modeling count data (number of cigarettes smoked, number of days smoked, total number of cigarettes consumed), as well as non-negative continuous data with skewed distribution of outcomes.[96,97] Cross-sectional survey weights were used to account for design effects and provide a nationally-representative description of the sample in period one of the study (2002).

To model the association between our smoking behavior outcomes, AMI, treatment for AMI, and covariates, we also estimated Models 1 and 2 with no person-level fixed effect, as only one time period was available for this analysis (2010), however this allowed us to include time-invariant characteristics such as sex and race/ethnicity (defined in the survey as Caucasian, Black or African American, Hispanic, or Mixed Race) in our models. Cross-sectional survey weights were used to account for design effects and to offer nationally representative estimates from our single-period treatment models (2010). All analyses were performed using Stata 16 (College Station, TX).

Results

Weighted Characteristics of Sample Participants at the Beginning of the Study Period (2002)

In 2002, a majority (53.6%) of study participants reported no smoking participation (95% CI: 52.0, 55.2; Chapter 1- Table 1). Among smokers, the mean number of cigarettes smoked per day within the past 30-days was 9.3 (SE: 0.23), the number of days smoking cigarettes in the past 30-days was 19.1 (SE: 0.25); mean total monthly consumption was 256.1 cigarettes (SE: 6.85) within the previous month. Most participants (76.3%, 95% CI: 75.3, 77.3) did not exhibit an MHI-5 score that indicated symptoms of AMI, and the mean U.S. cigarette excise tax rate facing all participants was $0.69 (SE: 0.02). From a sociodemographic perspective, there were more male participants (51.2%, 95% CI: 49.8, 52.6) than female, most participants were ages 18-20

years of age (59.7%, 95% CI: 58.6, 60.7), Caucasian (70.5%, 95% CI: 68.4, 72.5), and had received High School diploma or GED equivalent (75.4%, 95% CI: 74.2, 76.7).

Associations Between AMI, Excise Taxes, Tobacco Control Policies, and Smoking Behavior

Modelling the association between cigarette price and smoking participation revealed that, without adjusting for AMI status, other tobacco prevention policies, or covariates, a 10% increase in excise tax was associated with a 0.2 percentage point decrease in the probability of smoking participation (ß=-0.02, 95% CI: -0.04, -0.02) (Table 1-2, Column 1). Adding our measure for AMI revealed that having AMI was associated with a 3 percentage point increase in the probability of smoking (ß=0.03, 95% CI: 0.02, 0.04), and tax remained statistically significant with an association of the same magnitude as in the first model (Table 1-2, Column 2). Adding interactions between AMI and price and the strength of other tobacco prevention policies did not impact the magnitude or significance of price parameters, however the magnitude of the positive association between AMI and smoking rose from 3 percentage points to 4 (ß=0.04, 95% CI: 0.02, 0.05). Once the model was fully saturated, having AMI was associated with a 4-percentage point increase in the probability of smoking since the date of last interview (ß=0.04, 95% CI: 0.02, 0.05). The association between excise tax rate and smoking participation was still negative as expected, as was our tobacco control index parameter, but the magnitude of the association was reduced (ß=-0.01, 95% CI: -0.02, -0.00), and it was no longer statistically significant. We hypothesized that the interaction between AMI and price would be both positive and statistically significant; while positive, it was not significantly associated with variation in likelihood of smoking participation. Finally, in the saturated model, participants were also 6 percentage points less likely to report smoking participation in 2010 compared to 2002 (ß=-0.06, 95% CI: -0.08, -0.03), and while not statistically significant, increased age and higher educational attainment were associated with lower probability of smoking.

For two of our consumption measures, total consumption and cigarettes smoked per day (CPD), we observed a similar pattern, whereby AMI was significantly association with outcomes, but price and our interaction term were not (Table 1-3). Having AMI was associated with a 10.5% increase in CPD and an 11.6% increase in total consumption compared to participants with no AMI (ß=0.10, 95% CI:0.01, 0.16; ß=0.11, 95% CI:0.06, 0.16, respectively). While our hypothesis that an interaction between AMI and price would be positive

held true, it was not statistically significant, nor were the negative associations between price and tobacco control policies and these behaviors. Regarding number of days smoking, having AMI was not associated with significant variation, however a 10% increase in state excise tax rate was significantly associated with a 0.2% decrease in number of days smoked (ß=-0.02, 95% CI: -0.03, -0.01) across all participant groups. Contrary to our hypothesis, the association between number of days smoking and an interaction between AMI and price was both negative and not statistically significant. Though not statistically significant, we observed that increased age was associated with greater consumption of cigarettes and more frequent use, whereas higher income was associated with reduced consumption, and higher education associated with fewer CPD and lower total consumption.

Weighted Associations Between Treatment for AMI and Smoking Behavior

Among participants with AMI, whether they reported receiving any treatment for AMI from a health professional was a positive predictor of increased smoking participation and all consumption outcomes compared to those with no AMI and no treatment, however differences between those with AMI who did and did not receive treatment were not uniformly significant across outcomes (Table 1-4). For example, compared to those without AMI, those with AMI who received no treatment were 11 percentage points more likely to report smoking participation (ß=0.11, 95% CI: 0.08, 0.14), and those with both AMI and any treatment over the previous months were 15 percentage points more likely to report smoking than those with no AMI (ß=0.15, 95% CI: 0.07, 0.23). However, an adjusted Wald test revealed that we could not reject the null hypothesis that these two coefficients were equal.

Similarly, all cigarette consumption outcome revealed no significant differences between those with or without AMI and no treatment, the only significant coefficients were those estimating differences between no AMI versus those with AMI who had received treatment. Having AMI and receiving treatment was associated with a 10.5% increase in the number of days smoking (ß=0.10, 95% CI: 0.04, 0.25). Regarding CPD, having AMI was associated with an 40.5% increase in CPD compared to those without AMI (ß=0.34**,** 95% CI: 0.12, 0.57), and for total consumption, having AMI and receiving any treatment was associated with a 43.3% increase in total consumption (ß=0.37**,** 95% CI: 0.12, 0.60). These estimates contradict our hypothesis that treatment

would ameliorate symptoms and therefore reduce the magnitude of the coefficients for the 'treated' AMI participants relative to the 'untreated' participants with AMI. Regarding sociodemographic variation, in this set of cross-sectional models where we were able to include time-invariant characteristics, women were less likely to smoke, to smoke fewer CPD, and have lower total consumption than men. Nearly universally, Black or African American and Hispanic participants smoked at lower rates and consumed fewer cigarettes than Caucasian participants, and higher education was associated with reduced smoking, a relationship for which the magnitude of the association grew stronger with increased educational attainment.

Discussion

Despite significant progress on reducing smoking rates among U.S. youth and adults,[3,29] these benefits vary widely across sociodemographic subgroups of smokers.[2,29] One group of adults that smokes at particularly high rates is adults suffering from symptoms of any mental illness, a condition that affects 1 in 5 adults annually.[63] In order to investigate whether this disparity might be explained, in part, by variation in response to state-level smoking prevention policies over time, we conducted a longitudinal study of young adults who participated in the National Longitudinal Survey of Youth 1997 cohort, modelling associations between AMI, tobacco policy, and smoking outcomes and the role of treatment for AMI in potentially ameliorating these effects. Strengths of the study include the large pool of participants with available data across five time periods to rely upon for our models, the availability of the MHI-5 to capture young adults with symptoms of AMI without relying on self-reported previous diagnosis of AMI, and a modelling approach that controlled for time-invariant heterogeneity across individuals.

Our findings regarding the significant and positive association between having AMI and all measured smoking outcomes are consistent with previous research, as those with AMI have been found to smoke at higher rates, to consume more cigarettes, and to have higher nicotine dependence.[21,66,68] However, our sensitivity analysis of AMI classification revealed that how AMI is defined can significantly impact our perspective on this relationship. Minimizing the misclassification rate suggests that a score of 60 is the appropriate threshold for determining AMI (scores<60 indicate likely AMI), also most frequently cited as the clinically-relevant cutoff based on scoring guidelines,[90] whereas the Minimax and prevalence matching methods suggest 68 is the

appropriate threshold.[91] Finally, using the Youden Index and 0,1 method both yield a suggested threshold of 76.[91] Results of our sensitivity analysis revealed that smoking participation was robust to variation in the threshold for determining AMI status (Appendix 1-A), however we observed variation in statistical significance of AMI in its association with smoking behavior. Number of days smoking cigarettes was robust to raising the threshold to 68 (including more participants in the AMI group), however using a cutoff score of 76 rendered main findings statistically insignificant based on a 95% confidence interval. For both CPD and total consumption, raising the threshold from 60 to either 68 or 76 rendered the association between AMI and smoking behavior statistically insignificant. A conservative threshold requiring greater frequency of experiencing symptoms for classification as having AMI revealed that AMI was significantly associated with all smoking outcomes. The least conservative threshold allowed the greatest number of participants to be assigned as having AMI, reducing the magnitude and significance of these associations. While the strength of the MHI-5 tool is its ability to capture likely AMI even among those who may not have received a diagnosis or treatment, further work in this area should explore opportunities to leverage the power of nationally-representative longitudinal data offering mental health information that may offer greater clinical relevance and data regarding symptom acuity.

The lack of statistical significance for our estimates for associations between price, tobacco control policies, and smoking outcomes in our saturated models (with the exception of number of days smoking) seems counterintuitive in light of a wealth of previous evidence on this topic, in a variety of settings.[29,58,87–89,98] There are a number of possible explanations for this result, the first related to the specification of price in our particular modelling approach. We employed person-level fixed effects in our models to control for unobservable and time-invariant heterogeneity among our study participants, however this requires models to only use information from participants for whom excise tax rate varied within their state of residence over time, or who relocated to a state with a higher or lower rate. As evidenced by the findings of a previous longitudinal study looking at similar outcomes among smokers in California,[99] it could be that the frequency and magnitude of changes to excise tax rates within individual states across time, particularly after being adjusted to reflect real rather than nominal changes, were not large enough to reveal significant effects of excise tax rate on smoking

behavior. This factor may also be true of our findings regarding lack of statistically significant associations between other tobacco control policies and smoking behaviors, as such policies may not change dramatically within states over the time horizon for our study, though we observe shifts in the strength of tobacco control initiatives across states. One way that other studies have circumvented this particular issue is by employing average price per pack of cigarettes as the primary price metric, as this value varies more widely across locality and over time.[53,56] We tested the sensitivity of our models to use of real average cost per pack of cigarettes during the study time horizon, and found that doing so rendered the association between AMI and smoking participation no longer statistically significant, and increased the magnitude and significance of the interaction between AMI and price, in congruence with our original hypothesis (see Appendix 1-C). In addition, using cost per pack as our price measure also increased the magnitude of the significant, negative association between price and number of days smoking, and the magnitude of the significant, positive association between AMI and number of days smoking. We also observed that the coefficients for AMI in our CPD and total consumption models became both negative, quite small in magnitude, and statistically insignificant. While average cost per pack has an advantage over excise tax in our models in terms of the magnitude of variation over time, tobacco companies have been able to respond to increases in tax rates by passing price increases on to consumers and concurrently raising per-pack prices in high consumption areas to offset a decline in overall demand,[76] while also offering purchase price incentives such as coupons,[100] making average cost per pack an imprecise measure subject to market forces,[76] reducing the usefulness of our estimates to inform policy as easily as findings regarding excise tax rates.

A final thought regarding the role of price and other policies in determining our outcomes relates to the addictive nature of nicotine contained in cigarettes. Our current models do not account for the influence of addiction on future smoking behavior, however other investigators have pointed out that this can significantly impact smoking despite rising prices and increased strength of other tobacco prevention policies.[89] Incorporating measures representing cigarette use or level of consumption in the previous period represents a state of myopic addiction by allowing use behaviors in the current period to reflect the addictive nature of nicotine, predicting that use in a previous period will be both a positive and significant predictor of current

use.[89] We tested this hypothesis using cross-sectional data from 2010, including a variable representing smoking behaviors in the 2008 period in our models. Results from this sensitivity analysis support those expectations, revealing that previous smoking behavior was positively associated with current use patterns (see Appendix 1-D). Subsequent analyses of our participants sample revealed that the rate of smoking participation did indeed go down between 2002 and 2010 as participants grew older, and many gained both higher educational attainment and higher levels of income, all factors associated with reductions in overall cigarette smoking compared to youth and young adult experimentation and use.[29]

In addition, previous work has indicated that other factors such as parental and peer smoking or tobacco use may be some of the most significant predictors of initiating and continuing smoking during youth and young adulthood,[101,102] factors for which we were unable to account in our current study. Future efforts in this area could explore the sensitivity of our estimates to use of the real, average price of cigarettes facing each participant rather than excise tax rate alone, to extending the survey period to potentially capture wider variation in excise tax rates, inclusion of variation in federal cigarette excise tax rates which would affect all participants, inclusion of municipal-level taxation data in real price calculations, and utilizing data offering insight into other highly significant predictors of tobacco use such as parental and peer influence..

Finally, our findings related to the role of treatment in predicting smoking outcomes present a different picture from what we hypothesized. Rather than pointing to an association between AMI and cigarette consumption of smaller magnitude for those who had experienced any treatment within the previous 12 months, our estimates suggest that those with AMI who participated in any treatment smoked more cigarettes per day and had higher total consumption than those without AMI. In addition, there were no statistically significant differences across treatment participation among smokers with AMI related to probability of smoking or measures of consumption. This finding could be due to selection into treatment, the fact that those who sought treatment had significantly more acute symptoms, and potentially smoked at higher rates already, which would be consistent with previous evidence describing the association between diagnosis category and variation in smoking rates.[21,38,66,68] We also relied upon a small sample size of adults with AMI who had participated in any treatment (n~200), and did not have access to data regarding diagnosis, making it difficult to assess

representativeness of the sample or to generalize findings to the full population of adults with AMI. Finally, we investigated whether treatment for AMI was associated with variation in smoking behavior and found in a very limited sample that it was not. Despite this finding, a wealth of previous evidence has suggested that treatment for smoking cessation can be effective among this population if offered diagnosis-specific cessation support,[67,68,103] offering positive news regarding cessation potential among adults with AMI. Further work in this area could harness the power of large, nationally representative data sources offering AMI classification tools that do not require self-report of a diagnosis, but which offer increased ability to offer advanced classification in regard to severity of symptoms, treatment, and smoking behavior.

Limitations

Several limitations should be noted regarding the study. The first is that all data related to smoking behavior are self-reported. In addition, previous studies have noted that smoking may in fact impact experience and severity of symptoms of mental illness, therefore the direction of these associations bears further investigation. In terms of measurement of price and policy variables, municipalities share authority to levy additional taxes on cigarette sales, therefore state-level excise tax rates may not sufficiently capture the tax rate to which each participant would have been subject across location and time. Further, rising per-pack prices may fuel interest in obtaining cigarettes from a locality in close proximity that offers lower excise tax rates ('smuggling'), or via online purchasing, a factor which has been shown to be associated with smoking behavior, but was not captured in our models.[104] We also face a lack of advanced classification in the available mental health measure; an ideal measure would offer insight into how symptom severity for those with AMI may influence our outcomes.

Conclusion

U.S. adults with AMI suffer disproportionately from the burden of tobacco-related morbidity and mortality, and effective public policy strategies tailored to help this group of smokers reduce or quit cigarette use remain elusive. Our results suggest that, while adults with AMI may be more likely to smoke and to have increased cigarette consumption, they do not appear to respond differently to price policies than adults without AMI. Our findings offer evidence that current popular tobacco prevention policies may be just as effective at

reducing smoking among this population, but therefore underscore the need to further investigate the role of mental health and tobacco cessation treatment alternatives tailored to the unique needs of adults suffering from the dual burdens of both AMI and chronic tobacco use.

Table 1-1. Weighted Descriptive Characteristics of NLSY 97 Participants in Study Period 1 (2002) (n=7,165)

	Total Sample n= **7,165** % (CI)
Smoked Since Date of Last Interview	
Yes	46.4 (44.8, 48.0)
No	53.6 (52.0, 55.2)
Total Cigarette Consumption[2]	256.1 (6.85)
Cigarettes Per Day[2]	9.3 (0.23)
Number of Days Smoked[2]	19.1 (0.25)
AMI Symptoms	17.41 (16.53, 18.30)
Yes	23.7 (22.7, 24.7)
No	76.3 (75.3, 77.3)
State Cigarette Excise Tax Rate ($)	0.69 (0.02)
Sex	
Female	48.8 (47.4, 50.2)
Male	51.2 (49.8, 52.6)
Age	
18-20	59.7 (58.6, 60.7)
21-25	40.3 (39.3, 41.4)
Race/ethnicity[3]	
Caucasian	70.5 (68.4, 72.5)
Black or African American	15.5 (13.8, 17.2)
Hispanic	12.8 (11.5, 14.2)
Mixed Race	1.3 (0.9, 1.7)
Education	
No Degree	22.4 (21.3, 23.6)
HS Diploma or GED Equivalent	75.4 (74.2, 76.7)
Some College/Associate Degree	1.0 (0.8, 1.3)
Bachelor's Degree	1.2 (0.9, 1.5)
Annual HH Income	
Less than $12,400	21.4 (19.3, 23.6)
$12,401-$37,499	23.4 (21.7, 25.3)
$37,500-$73,499	25.7 (24.1, 27.3)
$73,500+	29.5 (27.5, 31.6)

[2]All smoking behavior measures refer to past 30-day use among participants currently smoking; total cigarettes is a summary measure of consumption constructed by multiplying cigarettes per day and number of days smoked; weighted sample means and standard errors reported.
[3]Categories assigned by NLSY97 investigators.

Table 1-2. Associations between Variation in AMI Symptoms, Excise Tax, and Smoking Participation among NLSY97 Participants (2002-2010)

			Smoked Since Date of Last Interview[1] ß (95% CI) n=7,087		
AMI					
No					Ref
Yes		**0.03** (0.02, 0.04)	**0.04** (0.02, 0.05)	**0.04** (0.02, 0.05)	**0.04** (0.02, 0.05)
AMI * ln(State Excise Tax)			0.01 (-0.01, 0.01)	0.01 (-0.01, 0.02)	0.01 (-0.01, 0.02)
ln(State Excise Tax)[2]	**-0.02** (-0.03, -0.01)	**-0.02** (-0.03, -0.01)	**-0.02** (-0.03, -0.01)	**-0.02** (-0.03, -0.01)	-0.01 (-0.01, 0.01)
Tobacco Control Index				-0.01 (-0.01, 0.01)	-0.01 (-0.01, 0.01)
Age					
18-20					Ref
21-25					0.01 (-0.01, 0.03)
26-30					-0.01 (-0.03, 0.02)
Education					
No Degree					Ref
HS Diploma/GED					-0.02 (-0.06, 0.02)
Some College/Assoc.					-0.02 (-0.07, 0.03)
Degree					
Bachelor's Degree+					-0.03 (-0.08, 0.01)
Annual HH Income					
Less than $12,400					Ref
$12,401-$37,499					0.01 (-0.01, 0.02)
$37,500-$73,499					-0.01 (-0.02, 0.01)
$73,500+					0.01 (-0.01, 0.02)
Year					
2002					Ref
2004					-0.01 (-0.03, 0.01)
2006					-0.01 (-0.03, 0.01)
2008					-0.03 (-0.05, -0.01)
2010					**-0.06** (-0.09, -0.03)

Bolded p-values indicate statistical significance <0.05.

[1]A fixed effects regression with heteroskedasticity-robust standard errors tested associations between smoking participation, AMI, and state tax rates over time.

[2]State Excise Tax is the tax rate facing each participant during each survey period.

Table 1-3. Associations between Variation in AMI Symptoms, Excise Tax, and Total Cigarette Consumption among NLSY97 Participants (2002-2010)

	Number of Days Smoked Cigarettes[1,2] ß (95% CI) n=2,599	**Cigarettes Per Day**[1,3] ß (95% CI) n=2,555	**Total Cigarette Consumption**[1,4] ß (95% CI) n=2,529
AMI			
No	Ref	Ref	Ref
Yes	0.01 (-0.01, 0.03)	**0.10** (0.06, 0.15)	**0.11** (0.06, 0.16)
AMI * State Excise Tax	-0.01 (-0.03, 0.01)	0.01 (-0.04, 0.05)	0.01 (-0.04, 0.07)
State Excise Tax[5]	**-0.02** (-0.03, -0.01)	-0.01 (-0.06, 0.03)	-0.03 (-0.07, 0.02)
Tobacco Control Index	-0.01 (-0.02, 0.01)	-0.01 (-0.03, 0.02)	-0.01 (-0.03, 0.02)
Age			
18-20	Ref	Ref	Ref
21-25	0.03 (-0.01, 0.07)	0.05 (-0.03, 0.12)	0.07 (-0.02, 0.15)
26-30	0.01 (-0.04, 0.05)	0.03 (-0.07, 0.13)	0.05 (-0.06, 0.16)
Education			
No Degree	Ref	Ref	Ref
HS Diploma or GED Equivalent	0.04 (-0.02, 0.09)	0.01 (-0.10, 0.10)	0.03 (-0.08, 0.13)
Some College/Associate Degree	0.01 (-0.09, 0.11)	-0.01 (-0.16, 0.15)	-0.01 (-0.19, 0.17)
Bachelor's Degree+	0.01 (-0.09, 0.09)	-0.09 (-0.22, 0.05)	-0.10 (-0.26, 0.05)
Annual HH Income			
Less than $12,400	Ref	Ref	Ref
$12,401-$37,499	-0.01 (-0.04, 0.01)	0.01 (-0.05, 0.06)	0.01 (-0.05, 0.07)
$37,500-$73,499	-0.02 (-0.04, 0.01)	-0.02 (-0.08, 0.03)	-0.02 (-0.08, 0.05)
$73,500+	-0.03 (-0.06, 0.01)	-0.01 (-0.07, 0.05)	-0.01 (-0.08, 0.06)
Year			
2002	Ref	Ref	Ref
2004	0.03 (-0.01, 0.05)	-0.01 (-0.07, 0.05)	0.01 (-0.06, 0.07)
2006	0.02 (-0.02, 0.05)	0.02 (-0.05, 0.08)	0.02 (-0.05, 0.09)
2008	0.02 (-0.02 0.06)	0.03 (-0.05, 0.10)	0.03 (-0.05 0.12)
2010	0.04 (-0.01, 0.09)	0.01 (-0.08, 0.10)	0.02 (-0.08, 0.12)

Bolded p-values indicate statistical significance <0.05.

[1]Fixed effects Poisson regressions tested associations between cigarette consumption, AMI, and state tax rates over time. Coefficient represents the change in log value associated with each measure.

[2]Number of days smoked refers to the number of days within the past 30-days a participant smoked cigarettes.

[3]Cigarettes per day represents the average number of cigarettes smoked on days smoking in the past 30-days.

[4]Total consumption in the past 30-days was constructed by multiplying the number of cigarettes smoked per day by the number of days a participant smoked cigarettes in the past 30 days.

[5]State Excise Tax is the tax rate facing each participant during each survey period.

Table 1-4. Weighted Associations between Treatment for AMI Symptoms, Smoking Participation, and Cigarette Consumption among NLSY97 Participants, 2010 (n=6,918)

	Smoking Participation ß (95% CI) n= 5,523	**Number of Days Smoked Cigarettes[1,2]** ß (95% CI) n=1,803	**Cigarettes Per Day[1,3]** ß (95% CI) n=1,803	**Total Cigarette Consumption[1,4]** ß (95% CI) n=1,782
AMI/Treatment				
No AMI, No Treatment	Ref	Ref	Ref	Ref
Yes AMI, No Treatment	**0.11*** (0.08, 0.14)	0.03* (0.00, 0.11)	0.10 (-0.01, 0.20)	0.09 (-0.02, 0.20)
Yes AMI, Yes Treatment	**0.15*** (0.07, 0.23)	**0.10*** (0.04, 0.25)	**0.34** (0.12, 0.57)	**0.36** (0.12, 0.60)
State Excise Tax[5]	-0.01 (-0.01, 0.02)	0.01 (-0.02, 0.04)	-0.01 (-0.06, 0.03)	-0.01 (-0.06, 0.04)
Tobacco Control Index	0.01 (-0.01, 0.01)	-0.01 (-0.03, 0.02)	0.01 (-0.04, 0.04)	0.01 (-0.04, 0.05)
Sex				
Male	Ref	Ref	Ref	Ref
Female	**-0.03** (-0.06, -0.01)	0.01 (-0.04, 0.06)	**-0.20** (-0.29, -0.10)	**-0.18** (-0.29, -0.07)
Age				
21-25	Ref	Ref	Ref	Ref
26-30	-0.01 (-0.11, 0.09)	-0.10 (-0.21, 0.02)	0.06 (-0.17, 0.30)	0.01 (-0.24, 0.27)
Race/ethnicity[3]				
Caucasian	Ref	Ref	Ref	Ref
Black or African American	**-0.14** (-0.18, -0.11)	**-0.12** (-0.18, -0.05)	**-0.47** (-0.58, -0.36)	**-0.54** (-0.66, -0.41)
Hispanic	**-0.17** (-0.20, -0.13)	**-0.25** (-0.34, -0.16)	**-0.62** (-0.79, -0.45)	**-0.73** (-0.91, -0.54)
Mixed Race	0.05 (-0.09, 0.19)	0.04 (-0.14, 0.22)	-0.30 (-0.65, 0.04)	-0.28 (-0.66, 0.10)
Education				
No Degree	Ref	Ref	Ref	Ref
HS Diploma or GED Equivalent	**-0.16** (-0.21, -0.12)	**-0.06** (-0.10, -0.02)	**-0.19** (-0.30, -0.08)	**-0.23** (-0.35, -0.10)
Some College/Associate Degree	**-0.32** (-0.38, -0.27)	-0.09 (-0.19, 0.01)	**-0.34** (-0.59, -0.09)	**-0.42** (-0.70, -0.14)
Bachelor's Degree+	**-0.38** (-0.43, -0.34)	**-0.43** (-0.54, -0.31)	**-0.72** (-0.91, -0.54)	**-0.90** (-1.13, -0.67)
Annual HH Income				
Less than $12,400	Ref	Ref	Ref	Ref
$12,401-$37,499	-0.02 (-0.07, 0.04)	0.04 (-0.03, 0.10)	0.01 (-0.23, 0.11)	0.03 (-0.11, 0.16)
$37,500-$73,499	-0.04 (-0.10, 0.01)	0.05 (-0.01, 0.11)	-0.08 (-0.18, 0.03)	-0.03 (-0.15, 0.10)
$73,500+	**-0.07**(-0.12, -0.01)	-0.01 (-0.09, 0.06)	-0.08 (-0.22, 0.05)	-0.06 (-0.22, 0.10)

Bolded p-values indicate statistical significance <0.05; *indicates that while both estimates are individually significant, an Adjusted Wald test revealed they were not significantly different from each other.

[1]A linear model with person-level fixed effects tested associations between treatment and smoking participation; Poisson regressions with heteroskedasticity-robust standard errors tested associations between cigarette consumption, AMI, and state tax rates over time.
[2]Number of days smoked refers to the number of days within the past 30-days a participant smoked cigarettes.
[3]Cigarettes per day represents the average number of cigarettes smoked on days smoking in the past 30-days.
[4]Total consumption in the past 30-days was constructed by multiplying the number of cigarettes smoked per day by the number of days a participant smoked cigarettes in the past 30 days.
[5]State Excise Tax is the tax rate facing each participant during each survey period.

Chapter 2 Investigating the Responsiveness of Adult Smokers with Mental Illness to Prospective Regulatory Strategies to Reduce Combustible Cigarette Use.

Abstract

Background: Overall use of potentially less harmful products such as e-cigarettes among adults remains significantly lower than combustible cigarette use (3.2% vs 13.7% in 2018), and combustible cigarette use and its associated health risks are remain stubbornly higher over time among some populations, such as adults with symptoms of any mental illness (AMI)[d] (28.1% in 2018). We still lack evidence regarding price elasticity of demand for cigarettes, and likelihood of substitution to potentially less harmful products among adults with AMI.

Methods: 407 U.S. adult smokers were recruited to perform theoretical online cigarette purchase tasks to estimate difference in own-brand (OB) price elasticity of demand, and demand for alternative tobacco products among adults with AMI and those without. Linear regression models were fit to the data, modeling associations between AMI, price, and 1) variation in demand for own-brand cigarettes at different prices, 2) demand for four alternative products when the price of the own-brand product varied.

Results: A 10% increase in OB price was significantly associated with an 8% reduction in OB demand across all participants (ß=-0.788, SE: 0.041, $p<0.05$), and the association an interaction between AMI and price was positive and significant (ß=0.133, SE: 0.600, $p<0.05$). OB price was a significant and positive predictor of increased demand for all products but the reduced harm e-cigarette, and AMI was only significant in predicting increased demand for an e-cigarette with equivalent nicotine to the OB cigarette.

Conclusions: Adults with AMI may be more reluctant to reduce smoking in the face of higher prices; however, they may be just as likely to choose substitutes under certain price and product policy conditions. Further

[d] AMI was defined as experiencing an emotional, behavioral, or mental disorder that met DSM-IV criteria; severe mental illness (SMI) classification includes that stipulation that the disorder 'substantially interfered' with at least 'one major life activity.' The AMI category does not include individuals with substance abuse or developmental disorders.[63]

research focusing on perceptions of and demand for various potentially less harmful products among this population could further illuminate a path to more effective policies related to alternative tobacco products.

Introduction

While combustible cigarette smoking recently reached its lowest recorded rate (13.7%) among U.S. adults,[3] the market for tobacco products continues to expand, with smokers facing a wide array of nicotine-containing product choices. The United States Food and Drug Administration (FDA) cites nine different classes of tobacco products available to consumers, with a tenth available as of April 2019.[105,106] Included in this list are a category of alternative, non-combustible electronic nicotine delivery systems (ENDS) such as electronic (e-) cigarettes,[105] use of which has been growing in popularity among youth and young adults.[107,108] E-cigarettes heat a nicotine-containing liquid to produce an aerosol inhaled by the user, which some evidence suggests may prove less harmful to the user than inhaling chemicals produced through combustion when smoking conventional cigarettes.[109,110] Despite substantial progress in reducing adults smoking rates and the availability of potentially less harmful alternative tobacco products, overall use of e-cigarettes among adults remains significantly lower than combustible cigarette use (3.2% vs 13.7% in 2018),[3,111] and combustible cigarette use and its associated health risks are remain stubbornly higher over time among some populations, such as adults with symptoms of any mental illness (AMI)[e] (28.1% in 2018).[18,21,63] The FDA is currently exploring several options to reduce combustible tobacco use, however the extent to which these strategies will be effective across subgroups of established smokers depends on the relative abuse liability of smokers' preferred product and these alternative choices.[23]

Abuse liability refers to the likelihood of persistent use of a drug or product, including the likelihood of developing dependence or addiction, and experiencing adverse consequences from continued use.[23] Nicotine is the primary addictive component of tobacco products, promoting continued use of once an individual begins using nicotine-containing products, though its abuse liability may vary depending on the attributes of the method it is delivered (inhaled by smoke produced through combustion in a conventional cigarette, or inhaled in e-cigarette aerosol, for example).[23] Previous studies have found variation in abuse liability across nicotine

[e] AMI was defined as experiencing an emotional, behavioral, or mental disorder that met DSM-IV criteria; severe mental illness (SMI) classification includes that stipulation that the disorder 'substantially interfered' with at least 'one major life activity.' The AMI category does not include individuals with substance abuse or developmental disorders.[63]

delivery alternatives,[23] such as conventional and e-cigarettes,[112–114] and across product characteristics (flavors) and potential regulatory scenarios (messaging about risks associated with use).[115] One frequently used measure of abuse liability is the own-price elasticity of demand for a product, an index that reflects the relative value of cigarettes to the individual and how demand for cigarettes changes when they become more difficult to obtain (e.g., increase in price).[113,116] A lower own-price elasticity of demand would therefore reflect higher abuse liability of cigarettes because it would signify that the participant is less willing to forego their own product even in the face of increasing prices.[116] Abuse liability can also be compared across cigarettes and alternative tobacco product choices that are garnering interest from federal regulators for their potential to reduce the harm of combustible tobacco products (e.g., electronic cigarettes, low-nicotine cigarettes)[117,118] by estimating a cross-price elasticity of demand. While it remains difficult to observe smokers as they make choices between products offered at different prices in a real-world setting, simulated purchase tasks offer researchers alternative tools to assess abuse liability,[23] and to compare abuse liability across products and among sub-groups of participants.

Adults with AMI smoke at significantly higher rates than those without these symptoms, smoke more cigarettes, report higher dependence on nicotine, and may have greater difficulty achieving cessation when they attempt to quit smoking.[5,21,25,35,66,67] They also suffer at greater rates than the general population from tobacco-related premature morbidity and mortality, making them a priority population for reducing disparities in adult smoking.[68] Adults with AMI may use cigarette smoking as a tool to cope with symptoms of mental illness,[45,68,69] thus experiencing greater difficulty reducing or ceasing use, despite evidence that this behavior may in fact exacerbate symptoms.[68] If smokers with AMI have a stronger preference for their own-brand product and maintaining consumption than those without these symptoms, they will be less responsive to increases in price, thus less likely to reduce smoking as prices increase, and less willing to switch to a potentially less harmful and/or less expensive alternative product, limiting the efficacy of tobacco prevention and control policies aimed at reducing the public health burden of tobacco.

Previous investigation focused on price elasticity of demand among smokers with AMI is limited. One landmark study in this area found that adults with AMI may be as responsive to price increases as those without AMI,[74] other studies have focused on youth, and provide conflicting evidence that youth with symptoms of

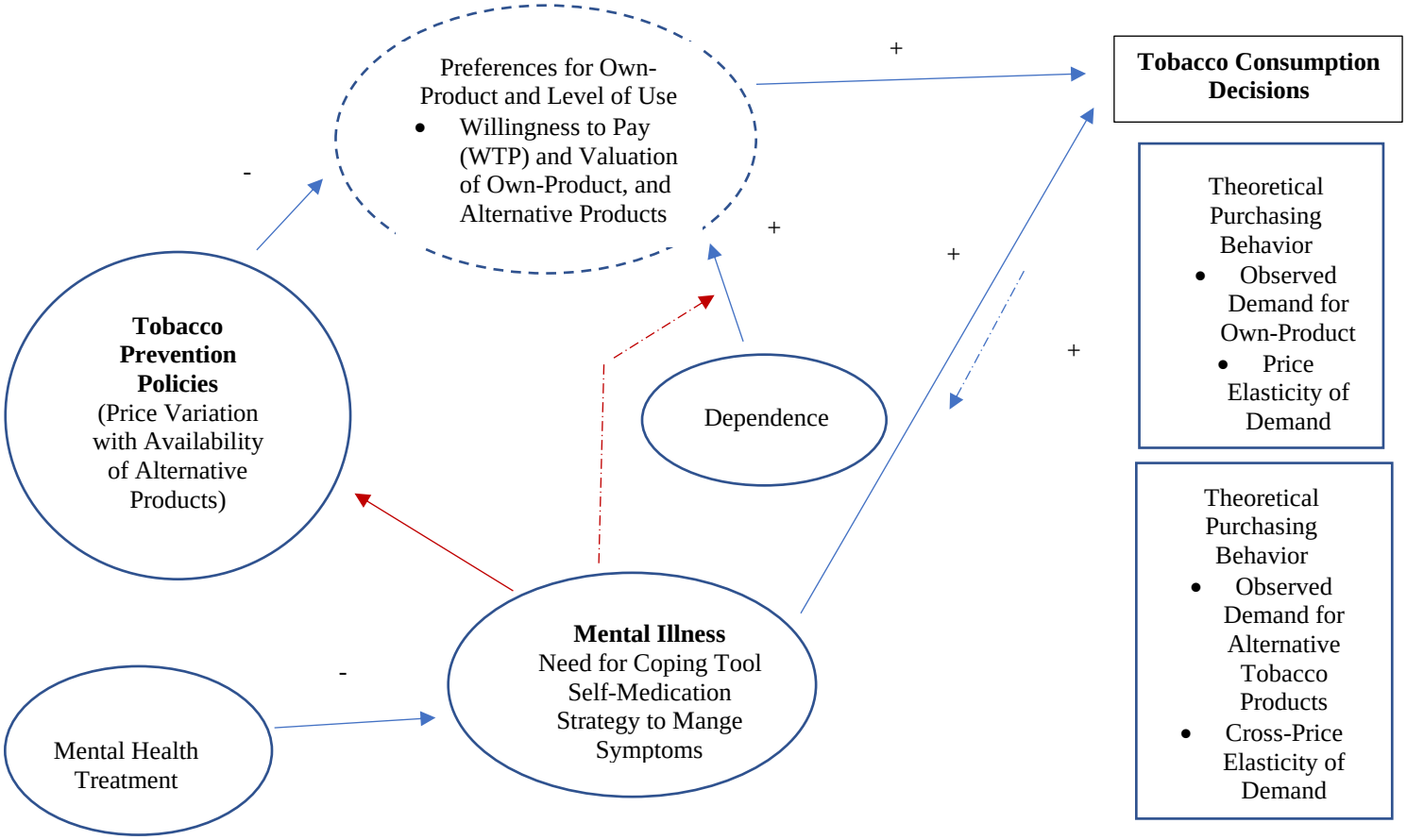
AMI may be just as price elastic in their demand as youth without,[80] but that youth experiencing symptoms such as suicidality may have less elastic demand.[48] Recent work in this area has focused primarily on emerging tobacco products such as e-cigarettes, and suggests that adult smokers may be willing to substitute cigarettes for electronic cigarette liquid (e-liquid), that e-cigarettes may serve as a substitute for cigarettes at certain prices, and that e-cigarettes may have lower abuse liability than combustible cigarettes.[113–115,119] Our review of the literature has only identified one published, lab-based study that has specifically included adults with AMI in the study sample.[120] Results suggested that adults with AMI may be as likely as those without AMI to choose low-nicotine cigarettes under certain price conditions, however the sample size for the study was small (n=56), and comparison groups were opioid dependent participants and socioeconomically disadvantaged women, rather than comparing results to adults without AMI symptoms. No studies to date have examined the relationship between demand for cigarettes and e-cigarettes among smokers with and without AMI, which is particularly important as policymakers try to regulate non-combustible tobacco products, like e-cigarettes, to reduce combustible product use among population group that use combustible products at high rates.

The FDA is currently exploring two options to reduce combustible tobacco use: reducing nicotine levels in cigarettes to non-addictive levels, and evaluating the use of e-cigarettes as a lower harm alternative (see Appendix 2-A).[16,17] An additional policy tool is the regulatory power to grant permission for use of advertising language suggesting a product (such as an e-cigarette) reduces exposure to a substance or that it poses less harm, if a Modified Risk Tobacco Product (MRTP) Application is approved (none have yet been approved).[121] FDA will not benefit from longitudinal data about the likely effects of these policy alternatives for smokers with AMI for years to come, however strategies such as the CPT allow researchers to model hypothetical purchasing behavior that is highly correlated with real world purchasing.[122,123] Doing so creates an opportunity to offer insight into whether FDA regulatory strategies under consideration are likely to induce the desired behavior among adult smokers, and if smokers with and without AMI are equally likely to benefit.

To address a gap in knowledge regarding the abuse liability of different products among smokers with AMI, this study will test for differences in hypothetical demand for cigarettes and substitution to potentially lower harm alternative tobacco products between adult smokers with and without AMI, under several potential

policy conditions - using survey data collected online from 407 survey participants via Amazon's Mechanical Turk. Policy scenarios include 1) the option to have a combustible cigarette with half the amount of nicotine as their own brand choice, 2) an e-cigarette with the same amount of nicotine as their own-brand cigarette, 3) an e-cigarette with a reduced harm message, and 4) an e-cigarette with a reduced exposure message.

Conceptual Model



The conceptual model from Figure 3 describes expectations regarding the role of mental illness, and nicotine dependence in shaping preferences about consumption of a smoker's own-brand product, and the relative value of alternative products. In order to maximize their well-being (utility) smokers weigh the costs and benefits of purchasing these products, and shape preferences regarding their willingness to pay (WTP) to consume their own product or an alternative product. WTP can be observed through theoretical purchasing behavior, and the conceptual model illustrates a hypothesis that smokers with AMI may have higher dependence on their own product, as consumption maximizes their utility and maintains their addictive stock, and also may believe that smoking helps them reduce symptoms of AMI such as negative affect. If smokers

with AMI have a stronger preference for their own-brand product and maintaining consumption, they will be less responsive to increases in price (have lower price elasticity of demand), thus less willing to switch to a potentially less harmful and/or less expensive alternative product.

Hypotheses

H2: AMI will moderate the association between price and demand.

H2a) Adult smokers with AMI will be less sensitive to price increases of their own brand cigarette and,

H2b) more reluctant to switch to a potentially less harmful alternative when the price of their own-brand product increases.

Methods

Sample

A convenience-sourced sample of 407 adult smokers was recruited via Amazon's Mechanical Turk (MTurk) to participate in the study (201 smokers with AMI symptoms and 206 without) between April 21,2020 and June 6, 2020. 3,854 MTurk users were screened to obtain the sample of 407 study participants. Each participant was asked to complete assessments of AMI and cigarette purchase tasks (CPT) that were used to estimate the abuse liability of cigarettes for their own brand product alone and in comparison to four alternative tobacco products (see above).

Screening Participants for Eligibility

Adult users of the MTurk platform with a U.S. IP address were invited to complete a short, five question screener survey via Qualtrics to see if they qualified for the study, with the goal of enrolling 200 smokers with AMI and 200 smokers with no AMI symptoms (see Appendix 2-B for screener questions). A goal of 200 participants per group was obtained by performing a power analysis using information about mean price elasticity of demand across multiple studies,[89] compared to that statistic from the limited number of studies that have focused on demand among participants with AMI.[48,80] Non-institutionalized, U.S. adults (ages 18+) who currently smoked every day or some days (within the previous week) and who had smoked at least 100 cigarettes in his/her lifetime were eligible to participate in the full survey. In order to populate the study sample

with smokers with and without AMI, we included two screening questions from the Patient Health Questionnaire (PHQ)-2, a two-item scale asking participants how frequently over the past two weeks they have been bothered by "feeling down, depressed, or hopeless" and experienced "little interest or pleasure in doing things." Response options include a range from "not at all" (score of zero) to "every day" (score of three), with a total score of three or higher representing a reliable and validated threshold for assessing likely depression.[124,125] Interested participants completed the eligibility screener and received $0.50 for successful completion. We employed a quota system to deem eligible the first 200 smokers without PHQ-2 scores above three (smokers without AMI), and to deem eligible the first 200 smokers with scores of three or above on the two-question mental illness assessment (likely AMI).

Eligible participants were then randomized at the end of the screener to receive a link in Qualtrics to one of eight versions of the full survey to complete in REDCap , each of the eight versions varied the order with which participants completed the cross-product tasks; they always completed the own-brand CPT first. Completion of the survey offered them a code redeemable for $2.00 via MTurk. This level of compensation is greater than or commensurate with compensation levels for other MTurk surveys; the effect of varying levels of compensation on survey participation has been evaluated to impact speed of recruiting participants rather than compromising quality of data in any way.[126,127] Previous research has indicated that MTurk yields participant pools that may be equally as diverse as traditionally-recruited samples, despite the tendency for participants to be slightly younger and more educated than traditional samples.[127–129] 3,854 interested MTurk workers completed the screener, yielding 623 eligible participants, 420 of whom completed the survey, of which 407 correctly answered a mandatory attention check question to be retained into the final sample.

Cigarette Purchase Task Measures

Each participant was asked to complete five total cigarette purchase tasks, hypothetical tasks highly-correlated with real-world behavior.[122] The first task asked participants how many times they would buy 10 puffs of their own-brand cigarette at sixteen different prices ($0.00-$10.24). The remaining four CPTs were cross-product tasks that asked participants how many times they would buy 10 puffs of their own-brand cigarette and 10 puffs of an alternative product if both were available, while the price of their own-brand

product varied (16 alternatives, $0.00-$10.24) and the cost of the alternative product stayed fixed at $1.00 (see Appendices 2-C and 2-D). Cross-product condition choices included availability of 1) a cigarette with half the amount of nicotine as their own-brand product, 2) an e-cigarette with the same amount of nicotine as their own-brand cigarette, 3) an e-cigarette "*that reduces your risk of developing cancer or heart disease compared to your own brand cigarette*" (reduced harm condition), 4) an e-cigarette "*that exposes you to fewer toxicants that cause cancer compared to your own brand cigarette"* (reduced exposure condition).

The primary outcomes of interest are differences in own-brand price elasticity of demand, and in cross-price elasticities of demand, for individuals with and without AMI, and interactions between AMI and price. Own-brand price elasticity of demand is reported as the percent change in reported consumption associated with a 10% increase in price.[46,89] Cross-product elasticity estimates represent the percent change in consumption of the alternative product associated with a 10% increase in own-brand product price. Consumption and price were log-transformed to provide elasticity estimates.[89] Secondary own-brand product demand measures of interest include: 1) Intensity (the level of consumption when price equals $0.00), 2) Breakpoint (the first price at which cigarette consumption equals zero), 3) O_{max} (the maximum amount spent on cigarettes), and 4) P_{max} (the price at which participants maximized their expenditure).[122,130] Intensity, O_{max}, and P_{max} were also transformed using a natural log transformation, based on the distribution of participant responses.

Two data quality checks were conducted to exclude participant data if responses to hypothetical purchasing indicated significant or systematic deviation from typical trends: participant data was excluded if responses reported a trend of increasing consumption as price increased (potentially indicating a participant did not understand the task), or if a participant exhibited 'reversal from zero'.[131] Reversal from zero would occur if a participant chose to consume zero puffs at two consecutive prices, and then reversed course at a higher price to choose to consume again.[131] 12 participants were excluded from analyses based on these quality check measures.

Any Mental Illness Measures

Depression was used in this study as the primary symptom measure of AMI, as it is one of the most prevalent mental illnesses experienced by U.S. adults,[132] and in 2016 alone, approximately 6.7% of all U.S.

adults were estimated to have experienced a major depressive episode within the previous year.[133] The Patient Health Questionnaire 9-Item Scale (PHQ-9) assessed likely AMI among enrolled study participants. Participants were asked to rate how frequently they have experienced nine different symptoms of depression within the previous week, with response options ranging from "Not at all" (0) to "Nearly every day" (3). A total score was obtained by adding the response values across questions (range: 0, 27). The PHQ-9 is a validated measure of depression, with a clinically-relevant threshold of scores greater than or equal to 10 indicating moderate to severe depression, with a sensitivity and specificity of 88% at this threshold.[132,134,135] A meta-analysis of PHQ-9 alternative thresholds found no significant differences for use of scores between 8 and 11 for depression classification.[135] In order to account for unusual circumstances during data collection, we also asked participants to repeat the PHQ-9 but instead we asked about how frequently they experienced the symptoms above within the previous 12 months.[f] We used this measure in sensitivity analyses to account for potential bias due to unusual circumstances.

Nicotine Dependence and Tobacco Use Measures

Nicotine Dependence: Nicotine dependence is significantly associated with real-world smoking behavior, therefore we asked participants to rate their dependence on cigarettes, using 12 items from the primary and secondary dependence motives scales from the Wisconsin Inventory of Smoking Dependence Motives (WISDM).[136] Participants received an average score (range: 1-5), with higher average scores indicating higher dependence.

Weekly Spending on Cigarettes: Weekly spending on cigarettes offers insight into how much financial investment each participant makes in tobacco use per week, an important distinction from frequently included financial covariates such as household income, as it offers insight into the relative value of cigarettes to each participant, and potentially the likelihood of reporting continuing spending at price higher levels in the purchase

[f] Data collection was launched in late April 2020, approximately one month after the novel coronavirus 2019 (Covid-19) pandemic forced nationwide implementation of state by state stay at home or shelter in place orders. During this period, the proportion of U.S. adults reporting symptoms of anxiety and depression was significantly higher than normal,[146] and stress and anxiety related to the pandemic could be exacerbated among some populations, such as those with AMI.[183]

tasks. Spending categories were created based on distribution of responses (Less than $10, $10-$24, $25-$49, $50-$150).

Smoking Motivation, Peer and Family Effects Measures

We included additional variables in our model to validate our assumptions and to control for factors influencing both smoking behavior and experience of AMI. To validate the assumption underlying our hypothesis, that participants with AMI will find it more difficult to forego consumption as the price of their preferred product increases, due to use of smoking as a coping tool,[45,68] we asked participants whether they agreed with the following statement from the "Why Do You Smoke?" self-assessment questionnaire: "When I feel blue or want to take my mind off cares and worries, I smoke cigarettes" (Yes/No).[137] We also asked participants to rate the perception of tobacco use by people who were important to them (ordinal scale with Negative/Very Negative grouped together in contrast with Positive/Very Positive),[138] as peer and family tobacco use significantly influences use behaviors starting at a young age and continuing into adulthood.[37,85,102] To control for factors associated with both experiencing AMI and substance use,[139,140] we also asked participants whether a biological parent or sibling had ever been diagnosed with anxiety, depression, or any other psychiatric illness (Yes/No).

Demographic Covariates

Covariates also associated with tobacco use behaviors included sex (Male/Female), age (18-24, 25-34, 35-44, 45-54, 55+), race/ethnicity (White non-Hispanic, Black or African American non-Hispanic, Asian, Hispanic or Latino, or Other) educational attainment (HS/GED or less, Some College, Bachelors' degree or higher), and annual income (Less than $10,000, $10,000-$24,999, $25,000-$49,999, $50,000-$99,999, $100,00+).[27,141]

Statistical Analysis

Characteristics of the study sample were described using univariate statistics, and Pearson's chi-square tests and t-tests were used to provide bivariate statistics describing significant between-group differences across AMI status. Linear regressions with standard errors clustered at the individual level were used to estimate

relationships between consumption and own-brand (OB) price elasticity of demand based on variation in self-reported consumption at the sixteen different price points offered for own-brand cigarettes (see Appendix 2-C), AMI, an interaction between AMI and price elasticity, and covariates described above. A similar model was used for the cross-purchase tasks, however the consumption variable represented consumption of the alternative product as the price of the OB product varied (see Appendix 2-D). Linear regressions with standard errors clustered at the individual level estimated the associations between four secondary outcomes (Intensity, Breakpoint, O_{max}, P_{max}), AMI, and covariates. Primary models were estimated as follows:

OB Price Elasticity of Demand

1) $\ln Consumption_{OB} = \alpha + ß \ln Price_{OB} + \eta AMI + \lambda AMI \times \ln Price_{OB} + X_i\Omega + \varepsilon_i$

Cross Product Price Elasticity of Demand

2) $\ln Consumption_{Alternative} = \alpha + ß \ln Price_{OB} + \eta AMI + \lambda AMI \times \ln Price_{OB} + X_i\Omega + \varepsilon_i$

Where η and λ are the parameters of interest to be estimated, and additional covariates include individual level demographic controls, nicotine dependence and tobacco spending, smoking motivation, and peer and family effects.

If AMI moderates the relationship between price and consumption as hypothesized, λ will be both positive and significant in the OB task, and negative and statistically significant in the cross-product tasks.

Secondary Outcomes

3) $Intensity/Breakpoint/O_{max}/P_{max} = \eta AMI + X_i\Omega + \varepsilon_i$

Models were estimated and are reported progressively, from a simple regression of consumption on price, AMI, and an interaction between AMI and price, to a fully saturated model with all covariates, in order to describe relevant changes to coefficients of interest as additional factors were accounted for in our models. All analyses were performed using Stata 16 (College Station, TX).

Results

Sample Description and Unadjusted Associations between AMI Status and Participant Characteristics

Our study sample of smokers was predominantly male (68.1%), ages 25-44 (77.3%), identified as Non-Hispanic Caucasian (49.6%), with a Bachelors' degree or higher (66%), and reported earning between $25,000 and $100,00 per year (57.8%) (Table 2-1). The average nicotine dependence score was 2.8 (range: 1-5), with most participants reporting that people close to them had a negative or very negative opinion about tobacco use (79.6%). Weekly spending on cigarettes was approximately evenly split across categories, with just slightly more participants than not reporting smoking to cope with negative feelings (53.1%) and having a family history of AMI (53.3%). We observed significant between group differences across a number of characteristics, with those classified as having AMI more likely to be younger (73.1% under the age of 35, versus 52% of those without AMI, $p<0.01$), less likely to identify as Non-Hispanic Caucasian (42.8% vs. 56.3% for those without AMI, $p<0.01$), and more likely to identify as Hispanic (22.9% of those with AMI vs. 9.2% of those without, $p<0.01$) or "Other" (4.0% vs. 1.9% for those without AMI, $p<0.01$). Adults with AMI were also more likely to report earning less than $50,000 per year (71.7% vss. 50% of those without AMI, $p<0.01$). Adults with AMI reported higher average nicotine dependence scores than those without AMI (3.04 vs. 2.56 respectively, $p<0.01$), were more likely to report smoking to cope with feelings of worry or sadness (53.2%) than those without AMI (40.8%, $p<0.05$), to report that people important to them perceived tobacco use to be positive or very positive (29.1% of those with AMI vs. 10.5% of those without, $p<0.01$), and that a biological family member had been diagnosed with AMI (64.4% vs. 29.1% of those without AMI, $p<0.01$).

Price Elasticity of Demand for Own Brand Cigarettes

Estimating the price elasticity of demand for OB cigarettes using solely AMI, price, and an interaction between price and AMI as regressors revealed that across participants, a 10% increase in price of OB cigarettes was significantly associated with an 8% reduction in demand for OB cigarettes (ß=-0.796, SE: 0.035, $p<0.05$), and having AMI was associated with a 146% increase in demand (ß=0.901, SE: 0.249, $p<0.05$) (100(exp(0.901)-1)=146) (Table 2-2, Rows 1a-1c). The interaction between AMI and price was positive and significant, revealing that AMI may moderate the association between price and demand and that adults with AMI may have less elastic demand despite rising prices (ß=0.198, SE: 0.051, $p<0.05$). Adding demographic covariates to the model produced similar results (Table 2-2, Rows 2a-2c), though the magnitude of the

coefficients for AMI, price, and the interaction term slightly decreased in magnitude (interaction: (ß=0.193, SE: 0.051, p<0.05). Including measures of nicotine dependence and current demand (weekly spending) reduces the magnitude of the coefficient for price (ß=-0.717, SE: 0.026, p<0.05), and renders the association between AMI and demand no longer statistically significant, though the interaction between AMI and price remains both significant and positive (ß=0.163, SE: 0.052, p<0.05). Finally, including all covariates in previous models and adding indicators for smoking to cope and peer and family effects revealed in a fully saturated model that a 10% increase in price remained significantly associated with an 8% reduction in demand across all participants (ß=-0.788, SE: 0.041, p<0.05), the association between AMI and demand became negative but not statistically significant, and the interaction between AMI and price remained positive and significant (ß=0.133, SE: 0.600, p<0.05).

Cross Product Price Elasticities of Demand

Patterns were not uniform across alternative products. In initial models including only AMI, price, and the interaction term, positive and significant associations between OB price and demand for three out of four products was observed (Table 2-3, Rows 5a-5c). A positive and significant coefficient indicates that the alternative product functions as a substitute for OB cigarettes,[113] thus a 10% increase in OB cigarette price was associated with a 1.06% increase in demand for a low nicotine combustible cigarette (ß=0.106, SE: 0.042, p<0.05), a 1.19% increase for an e-cigarette with the same level of nicotine (ß=0.119, SE: 0.039, p<0.05), and a 0.63% increase in demand for an e-cigarette with a reduced harm message (ß=0.063, SE: 0.031, p<0.05). Across all four conditions, demand was also positive and significant for those experiencing AMI. For those with AMI, demand for a low nicotine combustible cigarette was nearly five times higher than it was for those without AMI (ß=1.598, SE: 0.335, p<0.05) (exp(1.598)=4.9), and demand for an e-cigarette with the same amount of nicotine as their OB cigarette approximately 7.4 times higher (ß=2.004, SE: 0.345, p<0.05). The interaction between AMI and price was positive but not significant for all products with the exception of the e-cigarette with equivalent nicotine, where it was both negative and significant, representing more reluctance to substitute to this alternative product as OB prices rose, consistent with our hypothesis Hb (ß=-0.025, SE: 0.050, p<0.05). When we controlled for demographic variables (Rows 6a-6c), price remained significant and positive for all but the

reduced exposure condition e-cigarette, and AMI remained both positive and significant. Including demographic variables rendered the interaction term no longer significant in the reduced harm condition. Adding indicators of dependence and weekly spending on cigarettes rendered AMI no longer a significant predictor of variation in demand for the low nicotine cigarette (Rows 7a-7c), and in the fully saturated models we observed that price was a significant and positive predictor of increased demand for all but the reduced harm e-cigarette (Rows 8a-8c), and AMI was only significant in predicting increased demand for the e-cigarette with equivalent nicotine to the OB cigarette.

Our final set of models predicted associations between secondary measures of OB cigarette abuse liability and AMI status, where the outcomes are natural log of intensity, Omax, and Pmax, and Breakpoint measured in dollars. Having AMI was associated with having a higher Breakpoint (price at which consumption reached zero), with a coefficient representing a Breakpoint on average $1.31 higher for those with AMI than those without (ß=1.31, SE: 0.40, $p<0.05$). Having AMI was associated with an O_{max} (maximum level of expenditure) nearly twice as high than that of participants without AMI (ß=0.63, SE: 0.19, $p<0.05$) ($\exp(0.63)= 1.9$), aligning with our hypotheses. This trend was consistent when demographic controls were introduced, though the magnitude of those relationships was reduced. The parameter for the dependent variable P_{max} was also positive though not significant, until we introduced measures of dependence and weekly spending, which rendered that association negative, and then statistically significant in the fully-saturated model, representing an average price at which spending was maximized more than one-third lower for those with AMI compared to participants without AMI (ß=-0.46, SE: 0.20, $p<0.05$). Intensity was uniformly lower for those with AMI, though not significant at $p<0.05$, and Breakpoint and O_{max} also changed signs in our fully saturated model to represent lower spending when we included family history of AMI and peer perceptions of tobacco use in our models.

Discussion

This study addresses a significant gap in our knowledge regarding tobacco use among a population of smokers who smoke at higher rates than the general population of U.S. adults,[5,21,67,68] tend to smoke more cigarettes[63,142] and be more dependent on nicotine,[5] and may have additional difficulty reducing or quitting

smoking.[21] We investigated whether AMI may moderate associations between price policies and demand for cigarettes, and if it may moderate responsiveness of adult smokers to availability of alternative products representing different potential regulatory scenarios[16,121,143] FDA may pursue to reduce the public health harms associated with combustible tobacco cigarettes. We found that smokers with AMI may have less elastic demand for cigarettes in the face of rising prices, and that though they are willing to substitute alternative products when cigarettes prices are raised, the extent to which they are willing to do so, and whether they do so at rates different from those without AMI depends on a variety of factors. A particular strength of our study is our use of a classification strategy for AMI that does not rely on previous diagnosis, expanding our ability to provide evidence that may offer more generalizable conclusions.

Characteristics of our study sample and associations between AMI and use behaviors are congruent with previous investigations in this area that have found smokers with AMI to have higher nicotine dependence than those without,[5] and the importance of the role peer and family perceptions of tobacco use play in influencing use.[37,102] We were also able to confirm our prediction based on previous work in this area,[45,68] that smokers with AMI may smoke in part to 'reduce negative affect,' or undesirable mood symptoms, and that family history of AMI is significantly associated with current classification of having AMI as well.[139] Including these factors in our models helps illustrate how significantly these factors may influence demand for cigarettes. When we controlled for AMI and demographic covariates alone (Table 2-2, rows 2a-2c), we observed higher OB demand among those with AMI symptoms, however including additional measures correlated with AMI and demand, such as nicotine dependence and weekly spending on cigarettes, led to our observation that AMI alone was no longer a significant predictor of higher demand and the magnitude of the coefficient was significantly reduced. Including information about peer perception of tobacco use, or of family history of AMI resulted in a negative association between AMI and OB demand, suggesting that these were strong and positive factors correlated with demand for tobacco. Findings from our investigation of secondary demand measures such as Breakpoint and O_{max} also supported this conclusion, as those with AMI exhibited higher willingness to spend and maximum spending until we introduced controls for these factors. However, the coefficient on the interaction between AMI and price remained statistically significant and positive in our main OB demand

model, indicating that AMI may indeed moderate the relationship between price and demand such that those with AMI are more reluctant to reduce smoking as price increases. To our knowledge, this is the first study to investigate this relationship as a moderating one and to confirm that hypothesis. Doing so indicates that policymakers should consider whether price policies are equitable in their ability to reduce smoking among high-risk populations.

Conclusions regarding demand for alternative products present a less cohesive story, as we found that different product conditions exhibited fairly different outcomes, which is intuitive on some level given the level of variation between alternatives presented. In congruence with a limited number of previous studies assessing substitutability of OB cigarettes with low-nicotine cigarettes,[120,144] increased price was associated with positive demand for the low-nicotine cigarette. AMI was no longer a significant predictor of this relationship once we included covariates such as dependence and weekly spending on cigarettes, which builds upon knowledge gained from previous studies in a general population of adults to suggest that willingness to substitute may also be highly dependent on factors such as beliefs about whether low-nicotine cigarettes pose less harm,[145] and whether a higher nicotine substitute is available.[144] If FDA were to mandate lower levels of nicotine in combustible products, or increase taxes on cigarettes at nicotine levels present today, these results present tentative evidence that smokers, even those with AMI, may be willing to switch to a product with lower abuse liability. An e-cigarette with the same level of nicotine as the OB cigarette was more uniformly appealing, and those with AMI exhibited a strong positive response, though an interaction between AMI and price revealed that, under certain circumstances, those with AMI may prove more reluctant to switch to this alternative. A reduced harm e-cigarette garnered positive substitution rates, suggesting that, as found in previous studies, pairing of product type and risk message may significantly influence cross-price elasticity of demand.[130] However, in the fully saturated model, the effects were no longer statistically significant. Finally, those with AMI generally responded positively to the availability of a reduced exposure product, suggesting that there may be specific impact related to harm communication wording that those with AMI find meaningful. This bears further investigation as FDA must decide what modified risk messaging they may allow tobacco product manufacturers to employ in advertising if MRTP applications are approved.

Finally, we performed this study among a sample of users experiencing an extraordinary pandemic event, with the potential to increase both reports of AMI among those who do not typically experience these symptoms,[146] and to exacerbate symptoms among those who do suffer from AMI. Thus, one concern is that the extant public health crisis occurring during data collection may influence the generalizability of our estimates. To address this concern, we performed a sensitivity analysis of our main models to including a version of the PHQ-9 that asked participants to select answers based on their experiences in the 12 months prior, rather than the two-week period standard in the PHQ-9 instrument. Our analysis revealed that 10 participants currently classified as having AMI would have been classified in the no AMI group if we used our 12-month rather than two-week scale, and that doing so did not significantly influence our estimates nor our conclusions, thus giving us some added confidence that this study's findings provide support for the potential moderating effect of AMI on elasticity that are not limited to the period of the pandemic during which the data were collected.

Limitations

We relied upon self-report data on theoretical purchasing, from a convenience-sourced sample of participants, thus our ability to provide generalizable estimates is limited. Further study in this area could seek to recruit a larger pool of participants with and without AMI to participate in these abuse liability tasks in a lab setting, where they are able to interact with alternative products and mimic real-world use more easily. The use of Amazon's Mechanical Turk as a platform for a convenience-sourced participant pool for this study offers both benefits and limitations. The limitations to this method are that the sample cannot be generalized to the U.S. population of adult smokers, and the participants have self-selected to participate in online work such as survey response. While this poses a limitation, as researchers have begun to use MTurk to conduct studies, evaluations of its strengths and limitations, as well as best practices, have also emerged. While MTurk does not yield a representative sample, it can yield a highly diverse sample, and offer the opportunity to reach subpopulations difficult to attract to studies using conventional menthods.[126–128,147] We did not control for factors that may influence willingness to substitute alternative products, such as prior use and perceptions of low nicotine cigarettes or e-cigarettes, nor did we investigate whether menthol or flavored tobacco preference

might affect our conclusions, all factors likely correlated with willingness to engage with the alternative products and the valuation of such products.[148–150] Future studies could include such measures to account for this likely source of variation. Finally, while depression is one of the most common mood disorders affecting U.S. adults, understanding the extent to which our conclusions generalize across mood and/or behavior disorders and their measurement tools would be important in understanding the reach of future policy alternatives.

Conclusion

Among adult participants with AMI, we observed both higher demand for cigarettes, and that AMI moderated the association between price and consumption, revealing that adults with AMI were more reluctant to reduce consumption in the face of rising costs associated with smoking. However, these adults generally found alternative products to be acceptable substitutes at rates similar to adults without AMI, though willingness to substitute varied significantly by product for all participants. Our results provide cautionary evidence that policymakers should carefully weigh likely responses to increased tobacco prices across subgroups of smokers when assessing how successful price policies may be in reducing smoking. In addition, the extent to which smokers will substitute alternative, potentially less harmful products varies, demanding further inquiry in order to ameliorate rather than exacerbate disparities in use of combustible products under future likely regulatory conditions.

Table 2-1. Selected Sociodemographic and Tobacco Use Characteristics of the Study Sample (n=407)

	Total Sample N=407 %	AMI Symptoms N=201 %	No AMI Symptoms N=206 %	P-value[1]
Sociodemographic Covariates				
Sex				0.73
Male	68.1	67.2	68.8	
Female	31.9	32.8	31.2	
Age				**p<0.01**
18-24	9.3	11.9	6.8	
25-34	53.1	61.2	45.2	
35-44	24.2	18.9	29.1	
45-54	9.1	6.5	11.7	
55+	4.4	1.5	7.3	
Race/Ethnicity				**p<0.01**
Non-Hispanic Caucasian	49.6	42.8	56.3	
Non-Hispanic African American	4.4	3.0	5.3	
Asian	27.4	27.9	27.2	
Hispanic	15.7	22.4	9.2	
Other	2.9	4.0	1.9	
Educational Attainment				0.16
High School/GED or Less	11.3	12.4	10.2	
Some college	22.7	18.9	26.7	
Bachelors or higher	66.0	68.7	63.1	
Annual HH Income				**p<0.01**
Less than $10,000	13.0	17.4	8.7	
$10,000-$24,999	19.1	25.4	13.1	
$25,000-$49,999	28.9	28.9	28.2	
$50,000-$99,999	28.9	22.9	35.0	
$100,000+	10.1	5.5	15.1	
Dependence and Tobacco Use				
Nicotine Dependence Score[2]	2.80 (0.95)	3.04 (0.06)	2.56 (0.67)	**p<0.01**
Average Weekly Spending on Cigarettes				**p<0.01**
Less than $10	20.9	18.6	23.2	
$10-$24	29.9	29.3	30.1	
$25-$49	20.9	16.0	25.6	
$50-$150	28.3	36.2	21.2	
Smoking Motivation, Peer and Family Effects				
When I feel blue or want to take my mind off cares and worries, I smoke cigarettes.				**0.01**
Yes	46.9	53.2	40.8	
No	53.1	46.8	59.2	
Peer/Family Perception of Tobacco Use				**p<0.01**
Positive/Very Positive	20.4	29.1	10.5	
Negative/Very Negative	79.6	70.9	89.5	
Family History AMI				**p<0.01**
Yes	46.7	64.4	29.1	
No	53.3	35.6	70.9	

[1]P-value represents the test statistic from Pearson's chi-square tests for significant between-groups differences.[2]Mean and standard error reported.

Table 2-2. Demand for Own Brand Cigarettes (n=407)

	Price Elasticity of Demand n=407 β (SE)
1) AMI, ln(Price), AMI*ln(Price) Only	
a. Price	**-0.796** (0.035)
b. AMI	**0.901** (0.249)
c. AMI*Price	**0.198** (0.051)
2) + Demographics	
a. Price	**-0.792** (0.035)
b. AMI	**0.801** (0.262)
c. AMI*Price	**0.193** (0.051)
3) + Demographics, dependence, and tobacco use	
a. Price	**-0.717** (0.026)
b. AMI	0.233 (0.246)
c. AMI*Price	**0.163** (0.052)
4) + Demographics, dependence, tobacco use, smoking motivation, peer and family effects	
a. Price	**-0.788** (0.041)
b. AMI	-0.278 (0.286)
c. AMI*Price	**0.133** (0.600)

Bolded values indicate $p<0.05$

Table 2-3. Cross Product Price Elasticities of Demand

	Low Nicotine Cigarette Condition n=407 β (SE)	**Same Nicotine E-cigarette Condition** n=406 β (SE)	**Reduced Harm E-cigarette Condition** n=406 β (SE)	**Reduced Exposure E-cigarette Condition** n=407 β (SE)
5) AMI, ln(Price), AMI*ln(Price) Only				
a. Price	**0.106** (0.042)	**0.119** (0.039)	**0.063** (0.031)	0.057 (0.035)
b. AMI	**1.598** (0.335)	**2.004** (0.345)	**1.600** (0.345)	**1.658** (0.355)
c. AMI*Price	0.001 (0.055)	-0.025 (0.050)	0.015 (0.042)	0.001 (0.044)
6) + Demographics				
a. Price	**0.106** (0.042)	**0.122** (0.040)	**0.063** (0.031)	0.057 (0.035)
b. AMI	**1.098** (0.340)	**1.566** (0.359)	**1.101** (0.368)	**1.295** (0.384)
c. AMI*Price	-0.001 (0.055)	-0.029 (0.050)	0.015 (0.042)	0.005 (0.045)
7) + Demographics, dependence, and tobacco use				
a. Price	**0.107** (0.043)	**0.122** (0.040)	**0.062** (0.031)	0.057 (0.035)
b. AMI	0.660 (0.344)	**1.276** (0.376)	**0.951** (0.385)	**1.115** (0.400)
c. AMI*Price	0.010 (0.057)	-0.029 (0.051)	0.015 (0.042)	0.005 (0.045)
8) + Demographics, dependence, tobacco use, smoking motivation, peer and family effects				
a. Price	**0.110** (0.051)	**0.147** (0.046)	0.059 (0.035)	**0.093** (0.039)
b. AMI	0.204 (0.409)	**1.233** (0.435)	0.830 (0.478)	0.868 (0.477)
c. AMI*Price	0.020 (0.067)	-0.024 (0.061)	0.050 (0.051)	-0.012 (0.054)

Bolded values indicate $p<0.05$

Table 2-4. Additional Abuse Liability Outcomes for Own-Brand Cigarette Purchasing Behavior

	ln(Intensity)[1] n=392 β (SE)	**Breakpoint[2] ($)** n=395 β (SE)	**ln(Omax)1** n=395 β (SE)	**ln(P_{max1})** n=395 β (SE)
AMI	-0.01 (0.121)	**1.31** (0.40)	**0.63** (0.19)	0.28 (0.15)
+ Demographics	0.07 (0.136)	**0.97** (0.44)	**0.51** (0.22)	0.19 (0.17)
+ Demographics, dependence, tobacco use	-0.15 (0.135)	0.03 (0.43)	0.07 (0.19)	-0.07 (0.19)
+ Demographics, dependence, tobacco use, smoking motivation, peer and family effects	-0.16 (0.164)	-0.93 (0.52)	-0.30 (0.23)	**-0.46** (0.20)

Bolded values indicate p<0.05

[1]Intensity, Omax and P_{max} coefficients represent change in log value of each outcome associated with AMI and other covariates. Mean O_{max} (original units: $) among sample participants was 39.1 (117.6); Mean P_{max} (original units: $) among sample participants was $5.12 (3.75); mean Intensity was 19.01 (26.49).

[2]Sample mean breakpoint was $6.21(4.02).

Chapter 3 A Longitudinal Assessment of Nicotine Dependence, Mental Health, and Attempts to Quit Smoking: Evidence from Waves 1-4 of the Population Assessment of Tobacco and Health (PATH) Study.

Abstract

Background: Adult smokers with symptoms of any mental illness (AMI) are highly dependent on nicotine and may face additional difficulty quitting smoking. While there is evidence that adult smokers with AMI have high dependence, there is insufficient evidence regarding the unique role that AMI may play in moderating the relationship between dependence and cessation outcomes over time.

Methods: 7,290 current established adult smokers at Wave 1 (2013-2014) of the PATH Study also participated in data collection in Waves 2-4 (2014-2018). Fixed-effects linear probability models were fit to the data, modeling associations between AMI, nicotine dependence, and the 1) likelihood of achieving cessation during the study period, 2) making a cessation attempt within the previous 12 months, and 3) past 30-day total consumption of cigarettes.

Results: Adults who experienced both any AMI symptoms and high dependence were 3.8 percentage points (PP) less likely to achieve cessation at any point during the study period ($p<0.01$), and smoked 76.5 more cigarettes per month (95% CI: 48.6, 103.4), than those with high dependence alone, despite being as likely to attempt to quit. Adults with high internalizing symptoms and high dependence were 3.6 PP less likely to report cessation ($p<0.05$).

Conclusions: Adults with AMI are particularly affected by the burden of tobacco use, in part because of the likely interaction between nicotine dependence and AMI. Tobacco control efforts that focus on this interplay may provide an opportunity to better target interventions for this vulnerable population.

Introduction

One in four people in the U.S. are estimated to experience "any mental illness" (AMI); however this group represents an estimated 40% of annual cigarette consumption,[64,65,142] and experience of AMI has been linked to increased smoking initiation [13,38] and more difficulty quitting.[5,12] The most common causes of death among people with AMI are heart disease, cancer, and lung disease, which can all be caused by smoking.[19,151]

Previous research has identified possible pathways to explain this disparity, including the suggestion that adults with AMI have higher abuse liability, or the likelihood of persistent tobacco use or dependence,[5,24] than adult smokers without AMI. Abuse liability may be higher among those with AMI due to use of tobacco, in part, to help cope with symptoms of mental illness.[9,24,25] Previous research on smoking expectancies among youth,[40] adults,[41] and adults with AMI has identified that adults experiencing mental illness are unique in that they report the positive expectancy "reduction of negative affect" as most important factor in guiding their decisions about smoking.[42–44] Negative affect in the case of adults with AMI refers to adverse symptoms they may experience due to mental illness. Smoking, therefore, is one tool that adults with mental illness may rely upon to cope with symptoms,[152] and previous studies on mental health and smoking have linked AMI with higher nicotine dependence,[5] and with reduced success when attempting to quit smoking.[153]

Quitting smoking has been linked to significant improvements in symptoms of mental illness and overall well-being.[154] Adult smokers with AMI may be interested in quitting but less likely to attempt to quit.[155] However, at least one systematic review found that smokers with AMI may be just as motivated to make a quit attempt as those without.[156] Additionally, smokers suffering from specific illnesses such as depression may be able to reduce or quit smoking without exacerbating symptoms of their illness,[103] and can be successful in cessation attempts if offered sufficient support.[24,25] However, it is rare for behavioral health specialists to incorporate medication or behavioral strategies to promote smoking cessation among patients with AMI, leading some to call smoking among those with AMI a "neglected epidemic." [67]

Cessation research among adults with AMI has relied primarily on cross-sectional data,[5,13,38] or has been conducted among smaller samples of smokers with specific diagnoses,[42,43,157] making it difficult to generalize findings and inform policymaking. As cessation is the primary means of reducing the risk of smoking-related

disease among current smokers,[158] a more complete understanding of how dependence and cessation are linked among adults with AMI is a critical area of investigation. Previous studies have also not explicitly investigated whether the role of nicotine dependence in cessation outcomes varies across smokers with and without symptoms of mental illness. While adults with AMI tend to have higher nicotine dependence, it is unclear how AMI may moderate the relationship between nicotine dependence and smoking behavior, thus providing an additional barrier for highly nicotine dependent adults at risk for tobacco-related disease to quit. This study uses longitudinal, nationally-representative data from a cohort of U.S. adult smokers who participated in four waves of the Population Assessment for Tobacco and Health (PATH) Study to explore associations between experiencing AMI symptoms during the study period, high nicotine dependence, and variation in cessation outcomes over time to inform more targeted tobacco prevention and control strategies. We hypothesize that adults reporting symptoms of AMI will be less likely to report having quit smoking compared to adults without these symptoms, and that dependence will moderate the association between AMI and cessation outcomes.

Conceptual Model

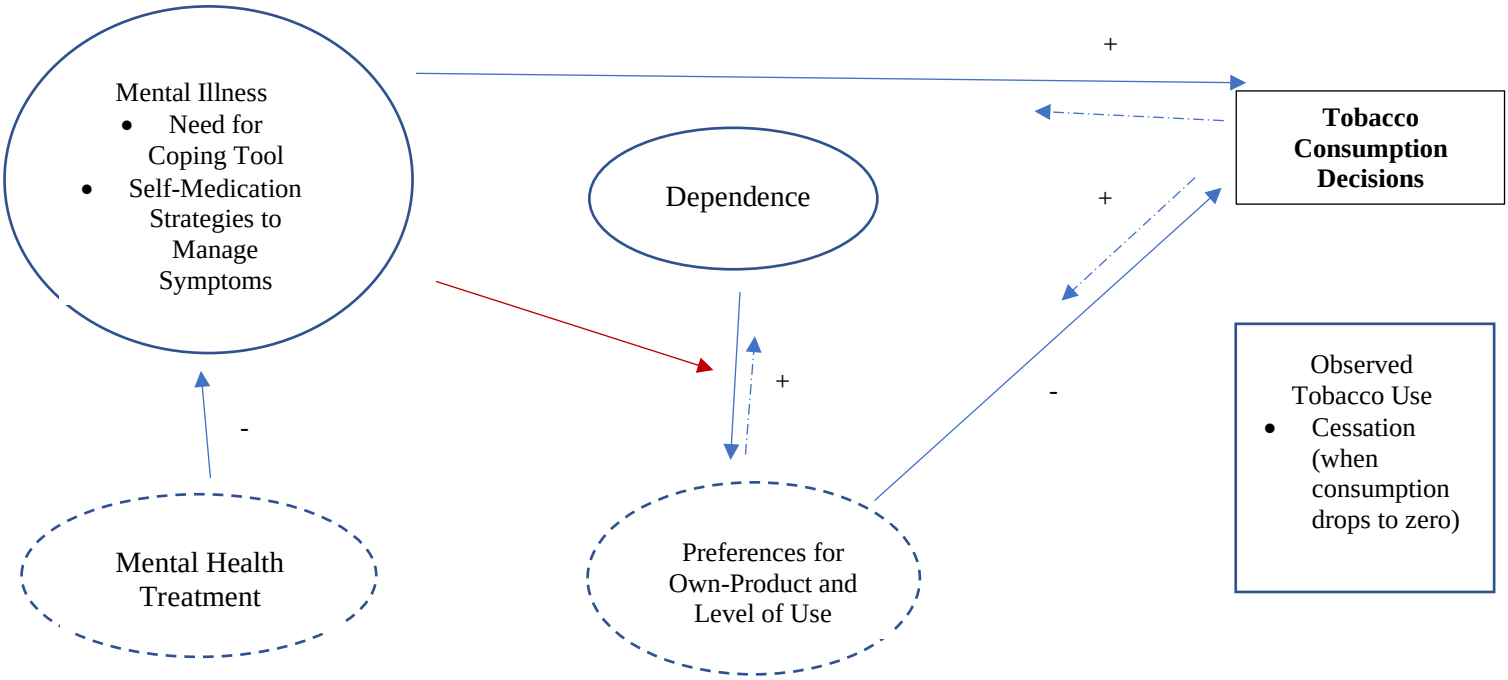


Figure 3 illustrates a hypothetical relationship between symptoms of mental illness and increased dependence on cigarettes and therefore stronger preference to continue smoking, and more dependent or

addicted smokers are then likely to have more difficulty reducing or ceasing tobacco use. Reducing tobacco use can induce symptoms of physical and behavioral withdrawal, which may make it more difficult for smokers who are highly dependent and using smoking to cope with negative affect to make a quit attempt, and to maintain cessation. Smokers with AMI may use cigarettes because use breeds dependence, and because they believe smoking helps them cope with symptoms. As previous research has shown that adults with AMI may have high nicotine dependence (physically and behaviorally), adults with AMI may be more reliant and less able to reduce consumption of cigarettes to zero (cessation).

Hypotheses

H3 (a) Adults with AMI will report higher nicotine dependence, (b) have a lower probability of making a cessation attempt or achieving self-reported cessation during the study period. Further, (c) dependence will moderate the association between AMI and cessation outcomes.

Methods

Sample

Data was obtained for 7,290 adults who were current, established cigarette smokers during data collection for Wave 1 (October 2013 - December 2014) of the PATH Study, and who participated in the subsequent three waves of data collection (Wave 2: October 2014 - October 2015; Wave 3: October 2015-October 2016; Wave 4: October 2017- October 2018). Current, established cigarette smoking is defined in the PATH Study as having smoked at least 100 cigarettes in a participant's lifetime and currently smoking every day or some days.[159] The PATH study is a nationally representative, longitudinal cohort study of U.S. youth and adult smokers and non-smokers. Participants were selected based on a multi-stage area, probability design, and asked about current and former tobacco use, attitudes toward and perceptions of tobacco products, exposure to marketing and advertising, and demographic and health information. Adult tobacco users, African Americans, and young adults were oversampled, and survey weights allow estimates to be generalized to the non-institutionalized U.S. population.[160] The PATH Study offers all-waves weights for participants surveyed in Waves 1-3 who remained eligible to participate in Wave 4.[161] All waves-weights were used to provide

generalizable estimates and allow for appropriate non-response adjustments. The weighted Wave 1 to Wave 4 response rate among adult survey participants was 74%.[161]

Smoking Behavior Measures

Cessation: Participants were asked in each wave to describe their current smoking behavior, and participants who were current, established smokers at Wave 1 and reported currently smoking "Not at all" and had not smoked within the past 30 days were classified as having quit smoking (Cessation: Yes/No).

Quit Attempts: All participants currently smoking in each wave were asked whether they had tried to quit smoking completely within the past 12 months (Attempt: Yes/No).

Cigarette Consumption: All participants who reported smoking "Some days" were asked how many days they smoked in the previous 30 days. "Every day" smokers were assigned a score of 30. Some-day smokers were also asked how many cigarettes on average they smoked on days smoked, every-day users were asked on average how many cigarettes they now smoked every day. Per wave, participants still smoking were assigned a total, monthly cigarette consumption as a measure of intensity of consumption by multiplying the number of days smoked by the number of cigarettes per day (CPD). This value was transformed for analysis using the natural log.[162]

Health Care and Cessation Measures

All participants were asked in each wave whether they had seen a medical doctor in the previous 12 months (Yes/No), if any health care professional had advised quitting smoking (Yes/No), and, among those who attempted quitting, if they had used any cessation support during their last attempt, to quit completely, and to avoid negative effects of quitting smoking. Cessation support options included: 1) nicotine replacement therapy (NRT); 2) prescription cessation aids; and 3) Other cessation support (Assigned indicator if used support from family or friends, counseling or self-help materials, or tried using other tobacco products to help quit smoking).

Mental Illness Measures

Symptoms of AMI were assessed in PATH using instruments from the Global Appraisal of Independent Needs Assessment-Short Screener (GAIN-SS), a validated, clinically-relevant tool for assessing likelihood of mental illness, as well as how recently those symptoms were experienced.[163] The GAIN-SS Instrument is part of

the NIH-sponsored PhenX Toolkit of recommended research protocols, for use among youth and adults in a wide variety of settings.[164] This instrument was further adapted for the PATH Study,[13] and participants were assessed using three subscales: Substance Abuse Symptoms, Internalizing Problem Symptoms, and Externalizing Problem Symptoms. As our study population is comprised of established smokers, we did not to include the substance abuse scale (which includes items related to smoking behavior) in our analyses, and primary results were not sensitive to excluding the substance abuse subscale. High *internalizing* problem scores are most closely associated with disorders such as depression, anxiety, trauma, and (at extremely high levels) schizophrenia and bipolar disorder, while high *externalizing* problem scores are most closely associated with diagnoses of attention deficit disorders and impulsivity.[163]

Participants were asked how frequently (never, over a year ago, 2-12 months ago, or within the past month) they experienced 4 symptoms from the internalizing scale and 7 symptoms from the externalizing scale. Possible scores were 0-4 for internalizing problems and 0-7 for externalizing problems. Consistent with previously validated and clinically-relevant cut points, participants were assigned a score per subscale of 0-1 (unlikely to have a diagnosis or need services), 2-3 (moderate, indicating possible diagnosis), or 4 for internalizing problems and greater than or equal to 4 for externalizing problems (indicating high severity and likely need for services).[13,163,165] While some previous, cross-sectional studies have focused on lifetime AMI,[13,38] we focused on high AMI symptoms in the time period most closely linked to our measured smoking behavior. Participants who received a high severity score for symptoms in the past year during any wave were classified as having AMI during the study period. Participants were also assigned a "high internalizing" or "high externalizing" indicator representing whether they had received a high severity score on each subscale at any point during the survey period.

Nicotine Dependence Measures

Nicotine dependence was assessed using a 16-item composite scale of questions from the Wisconsin Inventory of Smoking Dependence Motives (WISDM), the Nicotine Dependence Syndrome Scale (NDSS), and the American Psychological Association's Diagnostic and Statistical Manual of Mental Disorders (DSM) measure for Impaired Control. This combined scale was developed using the PATH Study data, to provide a

validated common instrument for assessing nicotine dependence across users of different tobacco products.[166] While the PATH Study includes several dependence measures, WISDM includes dependence motives such as negative reinforcement, cognitive enhancement, and social reinforcement that may be particularly relevant to tobacco use among adults experiencing AMI. All 16 questions asked participants to rate statements about dependence on tobacco products on a 5-item Likert scale (from "Not true of me at all" to "Extremely true of me"). Participants received an average score during each wave, with higher scores indicating higher dependence.[166,167] In order to assess the unique association between smoking behaviors and the experience of both high AMI symptom severity and high nicotine dependence, an indicator in each wave for high dependence was created to denote smokers with a dependence score above the sample median.

Covariates

Additional factors associated with variation in smoking behavior and nicotine dependence were measured in each wave. We included factors such as past 30-day use of other tobacco products (electronic cigarettes, cigars, cigarillos, pipe tobacco, hookah, smokeless products, snus, and dissolvable tobacco), past 30-day use of alcohol, [168] and having seen a medical professional in the previous 12 months.

We also included demographic and social factors that varied over time through indicator variables for levels of age, educational attainment, and annual household income.

Statistical Analysis

We described our participant sample using weighted proportions and used weighted Pearson's chi- squared tests and t-tests to detect any systematic differences among participants based on whether they experienced high AMI symptoms at any point during the study period. We employed a fixed-effects linear probability model to provide adjusted estimates for associations between our smoking outcomes and the interaction of a high AMI symptom score with high dependence, controlling for high dependence, other tobacco and alcohol use, and sociodemographic covariates. Fixed-effects models in panel data control for within-individual unobserved, time invariant confounders.[95]We employed the same method to test for associations between smoking behavior and specific interactions between a high internalizing symptom score and high dependence, and high externalizing score and high dependence. Finally, we used a similar approach to provide adjusted estimates for the association

between health behaviors and cessation support and interactions between high internalizing or externalizing symptom scores and high dependence. Estimates for cigarette consumption were retransformed for interpretability, using a smearing factor to account for nonparametric, heteroskedastic distribution of regression residuals,[169] and standard errors bootstrapped to provide a confidence interval for the retransformed estimates.[170] Because participants who experienced AMI symptoms at any point during the study period were classified as having AMI, AMI alone was time-invariant in our models, and therefore only the interaction between AMI and high dependence may be estimated in our models. The probability of making a type I error of 0.05 was used as the threshold for all tests, and all analyses were performed using Stata 15.1 (College Station, TX).

Results

Participant Characteristics and Unadjusted Associations between AMI Status and Participant Characteristics in Wave 1

Population weighted estimates (Table 3-1) indicated that participants who were cigarette smokers in Wave 1 were primarily composed of Non-Hispanic Caucasians (69.9%), between the ages of 25 and 54 (64.1%), who earned a high school education or less (54.2%), with an annual household income between $10,000 and $49,999 (53.0%). 28.8% of the sample at Wave 1 was classified as having AMI (receiving a high score for either internalizing or externalizing problems), and 52.8% of participants were classified as having high Wave 1 nicotine dependence. The mean number of days smoked in the past 30 days was 26.5, with a mean number of cigarettes per day of 10.5. Nearly half (41.4 %) of participants had used other tobacco products in addition to cigarettes in the past 30 days, and 59.4% had used alcohol within that time frame. There were statistically significant unadjusted differences in nearly all measures by AMI status among Wave 1 smokers, with those who had AMI symptoms expressing higher dependence (59.9% vs. 42.0% for those without AMI, $p<0.01$), higher rates of past 30 days use of other tobacco products (48.9% vs. 37.4%, $p<0.01$), and higher rates of past 30 day alcohol use (63.9% vs. 57.6%, $p<0.01$). There were also statistically significant differences by AMI status by sex, race/ethnicity, age, educational attainment, and annual household income: participants with

AMI were more likely to be female, younger, non-Hispanic Caucasian, to have achieved a high school degree/GED or less, and to have a lower annual income ($p<0.05$).

Adjusted Associations between AMI Symptoms, Nicotine Dependence, and Smoking Behavior

Participants who reported both high levels of AMI symptoms from either scale during the survey period and high nicotine dependence were 3.8 percentage points (PP) less likely to have achieved self-reported cessation ($p<0.01$) and reported smoking more cigarettes per month ($\beta=0.171$, $p<0.05$) than those with AMI symptoms alone (Table 3-2). This estimate from the natural log model translates to 76.5 more cigarettes per month (95% CI: 48.6, 103.4). High dependence without high AMI symptoms was associated with increased monthly cigarette consumption ($\beta=0.202$, $p<0.01$) or 126.2 cigarettes (95% CI: 98.9, 150.2), but also with a 2.7 PP increase in the likelihood of achieving cessation. Past 30-day use of other tobacco products was associated with reduced likelihood of achieving cessation (-1.3 PP, $p<0.01$), but increased probability of reporting a quit attempt (2.1 PP, $p<0.05$).

Participants who reported both high levels of internalizing symptoms during the survey period and high nicotine dependence were 3.6 percentage points (PP) less likely to achieve cessation during the survey period ($p<0.05$) (Table 3-3).

Past 30-day use of alcohol was associated with a 3.6 PP reduction in the likelihood of cessation ($p<0.01$), whereas increased educational attainment predicted a higher probability of making a quit attempt: adults with a Bachelor's degree or higher were 8.6 PP more likely to report cessation than those with a high school degree or less ($p<0.01$). Reporting a past 12-month doctor visit was associated with an increased likelihood of cessation (1.7 PP, $p<0.01$) and making a quit attempt (2.0 PP, $p<0.05$). Time was also significantly associated with increased likelihood of achieving cessation (Wave 2: 11.0 PP; Wave 3: 15.1 PP, $p<0.01$; Wave 4: 16.8 PP, $p<0.01$), making a quit attempt (Wave 3: 13.7 PP, $p<0.01$); Wave 4: 12.5 PP, $p<0.01$), and for decreases in overall cigarette consumption (-27.6 cigarettes (CI: -42.2, -15.2) in Wave 2 ($\beta=-0.214$, $p<0.01$), -54.7 cigarettes (CI: -66.4, -39.9) in Wave 3 ($\beta=-0.400$, $p<0.01$), and -55.1 cigarettes (CI: -68.5, -39.2) in Wave 4 ($\beta=-0.406$, $p<0.01$).

Adjusted Associations between AMI Symptoms and Health Behaviors

Having either high internalizing or externalizing symptoms and high dependence was associated with an increase in the probability of reporting seeing a medical doctor within the previous 12 months (2.3 PP and 2.7 PP respectively, $p<0.05$); Table 3-4), and with increased likelihood of using NRT during a recent quit attempt (5.1 PP, $p<0.05$). High dependence was associated with a 3.6 PP increase in the probability of reporting that a healthcare professional had advised quitting ($p<0.05$). AMI plus high dependence as well as high dependence alone were not significantly associated with reporting the use of any cessation aid or use of a prescription cessation aid. Past 30-day users of other tobacco products were 3.6 PP ($p<0.01$) less likely to report that a healthcare professional advised quitting, and more likely to report use of a cessation aid (8.5 PP, $p<0.01$). Finally, the likelihood of reporting seeing a medical doctor, using a non-NRT or non-Rx cessation aid, and using NRT significantly differed over time, with respondents less likely to report all three behaviors in Waves 2 through 4 than Wave 1 ($p<0.01$).

Discussion

While significant progress has been achieved in reducing overall smoking rates among U.S. adults,[171] adult smokers with symptoms of AMI suffer from significantly higher smoking rates than the general population[65] and increased rates of tobacco-related morbidity and early mortality.[18] Previous studies have found higher rates of nicotine dependence among smokers with AMI symptoms and diagnoses,[5] and that cessation success may be lower across all diagnoses.[25,38] Longitudinal, diagnosis-specific cohort studies with smaller samples of adult participants have also indicated that adults with AMI may be equally motivated to quit,[156,172] and that they may be able to do so with appropriate support, although behavioral health specialists may still be reluctant to incorporate smoking cessation into therapeutic strategies.[66] This study offers specific insight into an additional aspect of the association between AMI and nicotine dependence, namely whether smokers experiencing both high levels of AMI symptoms and high nicotine dependence might be at a particular disadvantage when attempting to reduce or quit smoking.

To understand if AMI moderates the association between dependence and smoking cessation over time, this study tested whether having both high levels of AMI symptoms during the study period and high nicotine dependence was associated with variation in the likelihood of making a quit attempt, of achieving self-reported

cessation at any point during the study period, and of variation in cigarette consumption. We found that adults with any AMI symptoms and high dependence, and specifically both high internalizing symptoms and high dependence, reported less success achieving short-term, self-reported cessation than those with high dependence alone. Despite this finding, participants suffering from high AMI symptoms and high dependence did not exhibit significant variation in the likelihood of making a quit attempt, consistent with some previous studies assessing motivation to quit,[156] and suggesting that these smokers may simply be less successful at achieving cessation than those coping with high dependence alone. We also tested the sensitivity of our main findings regarding smoking behavior to use of alternative strategies for modeling whether symptoms of AMI may be considered time-invariant in this relationship, the approach taken in this study and those that employ a lifetime measure of AMI.[13] To do so, we tested whether our main conclusions would differ under assumptions that allow AMI status to vary based on score per wave of the GAIN-SS instrument (see Appendix 3-A). We found that varying our approach for classifying AMI as either a fixed or varying symptom condition did have an impact on the conclusions we would draw from these models. This suggests there may be further study to do in this area, as we don't yet know how closely variation in GAIN-SS score actually reflects change in symptoms or need for coping mechanisms at different survey points. Or, if the underlying condition will affect symptoms and behavior despite minor variation in classification based on scale responses.

Despite lower rates of success, those with either high internalizing or externalizing symptoms and high dependence were more likely to report contact with the health system within the previous 12 months. And, while counterintuitive, the increased probability of achieving cessation at some point during the survey period among those with high dependence may be due, in part, to increased likelihood of reporting being advised to quit by a healthcare professional. This may help explain why we observed a comparable likelihood of making a quit attempt among two distinct groups of adult smokers generally perceived to be highly vulnerable to reduced cessation success. Reduced success in cessation among those with AMI, despite likelihood of attempting to quit, lends support for previous work [66] which suggests that cessation support may need to be tailored to account for diagnosis-specific AMI symptoms to help highly dependent smokers combat lower probability of cessation success.

Limitations

Several limitations should be considered when evaluating the internal and external validity of this study. All data were self-reported, thus there may be measurement error in tobacco use behaviors and dependence scores. The PATH study does not include the full range of questions from the WISDM, and questions referred to all tobacco products that are not e-cigarettes (e-cigarette dependence was queried separately) if a participant uses more than one of these products. We were unable to validate the assumption that smokers with AMI may smoke to cope with symptoms they experience, nor do we have information available about whether participants with AMI had been treated by a mental health professional, which could influence both symptoms and smoking behavior. Despite these limitations, a particular strength of this study is that it relied upon self-reported symptoms of mental illness without diagnostic information. Only 43.3% of adults with symptoms of AMI received treatment in 2018, and the average time between symptom onset and treatment is 11 years.[173] By capturing likely AMI in a national sample of smokers rather than relying on diagnosis or treatment information, our results may offer generalizable insight for many U.S. adults. Regarding the statistical approach, fixed effects models are designed to control for unobserved confounders within individuals that do not change over time but may produce biased estimates if important time-varying confounders are not accounted for. Finally, the study followed smokers over approximately 3 time periods (Wave 1 to Wave 4). Given the number of attempts most smokers make before achieving cessation, and the high rate of relapse, future work should endeavor to follow smokers beyond several years.

Conclusion

One in five U.S. adults is estimated to experience symptoms of AMI, and this group remains vulnerable to initiating and continuing smoking, and tobacco-related early mortality, despite decades of progress among the general population. This study provides further evidence that certain groups of AMI symptoms and disorders may put nicotine-dependent adults at particular disadvantage when attempting to quit or reduce smoking, despite their attempts. Policymakers could be best served to focus not merely on motivating quit attempts among adults with AMI, as they already appear likely to attempt cessation. Research related to how best to tailor sustained cessation support to adults with certain classes of AMI symptoms may prove more effective in

turning attempt into success, particularly in light of the fact that these smokers are more likely to report contact with the healthcare system. Further work could leverage the power of additional waves of PATH data to better understand the trajectory of smoking behavior among adults with AMI who are attempting to reduce or cease smoking, to inform policy targeted to alleviating this disparity.

Table 3-1. Weighted Descriptive Characteristics of Wave 1 Current, Established Adult Cigarette Smokers in the Population Assessment of Tobacco and Health (PATH) Study

	Total Sample n=7,290 N[1]=41,001,960 % (CI)	**AMI Symptoms** n=2,249 N=11,823,963 % (CI)	**No AMI Symptoms** n=5,041 N=29,177,997 % (CI)	**p-value[2]**
High Nicotine Dependence[3]				**p<0.01**
Yes	47.2 (45.6, 48.7)	59.9 (57.5, 62.3)	42.0 (40.4, 43.6)	
No	52.8 (51.3, 54.3)	40.1 (37.6, 42.6)	58.1 (56.4, 59.6)	
Number of Days Smoked[4]	26.49 (0.13)	26.47 (0.20)	26.50 (0.16)	0.99
Number of Cigarettes[4] Smoked	10.53 (0.14)	10.73 (0.21)	10.45 (0.17)	0.24
Past 30-Day Other Tobacco Use				**p<0.01**
Yes	41.4 (40.0, 42.7)	48.9 (46.4, 51.3)	37.4 (35.9, 39.0)	
No	58.6 (57.3, 60.0)	51.1 (48.7, 53.6)	62.6 (61.0, 64.1)	
Past 30-Day Alcohol				**p<0.01**
Yes	59.4 (57.9, 61.0)	63.9 (61.3, 66.3)	57.6 (55.9, 59.4)	
No	40.6 (39.1, 42.1)	36.1 (33.7, 38.7)	42.4 (40.6, 44.1)	
Made a Doctor Visit in the Previous 12 Months				**p<0.01**
Yes	72.6 (71.4, 73.9)	76.2 (74.2, 78.0)	71.2 (69.7, 72.7)	
No	27.4 (26.1, 28.6)	23.8 (22.0, 25.8)	28.8 (27.3, 30.3)	
Male	54.7 (53.5, 56.0)	48.7 (46.5, 51.0)	57.2 (55.7, 58.6)	**p<0.01**
Age				**p<0.01**
18-24	14.2 (13.4, 15.1)	21.4 (19.5, 23.4)	11.4 (10.5, 12.3)	
25-34	24.7 (23.7, 25.8)	28.6 (26.7, 30.6)	23.2 (21.9, 24.5)	
35-44	19.2 (18.0, 20.4)	18.8 (17.0, 20.9)	19.3 (18.1, 20.6)	
45-54	20.2 (19.2, 21.3)	17.9 (16.2, 19.9)	21.1 (19.9, 22.4)	
55-64	15.0 (13.9 (16.1)	11.0 (9.60, 12.6)	16.6 (15.3, 18.0)	
65+	6.7 (6.0, 7.5)	2.3 (1.6, 3.2)	8.5 (7.5, 9.5)	
Race/ethnicity				**p<0.01**
Caucasian	69.9 (68.7, 71.1)	71.7 (69.5, 73.8)	69.2 (67.7, 70.7)	
African American	13.3 (12.5, 14.1)	10.6 (9.4, 12.0)	14.4 (13.4, 15.4)	
Hispanic	11.1 (10.4, 11.7)	11.0 (9.6, 12.6)	11.1 (10.3, 11.9)	
Other	5.8 (5.2, 6.43)	6.7 (5.6, 7.8)	5.4 (4.7, 6.1)	
Education				**p<0.01**
High School/GED or less	54.2 (52.9, 55.6)	51.1 (48.8, 53.8)	55.4 (53.9, 56.9)	

	Total Sample n=7,290 N[1]=41,001,960 % (CI)	AMI Symptoms n=2,249 N=11,823,963 % (CI)	No AMI Symptoms n=5,041 N=29,177,997 % (CI)	p-value[2]
Some College	34.4 (33.0, 35.7)	38.7 (36.5, 40.9)	32.6 (31.1, 34.1)	
Bachelor's or higher	11.4 (10.7, 12.2)	10.0 (8.8, 11.4)	12.0 (11.1, 13.0)	
Annual HH Income				**p<0.01**
Less than $10,000	21.2 (19.8, 22.6)	28.4 (26.2, 30.7)	18.2 (16.7, 19.8)	
$10,000-$24,999	28.0 (26.6, 29.6)	29.9 (27.7, 32.2)	27.3 (25.5, 29.1)	
$25,000-$49,999	25.0 (23.9, 26.2)	21.6 (19.6, 23.7)	26.5 (25.0, 28.0)	
$50,000- $99,999	18.6 (17.4, 19.9)	14.2 (12.3, 16.4)	20.5 (19.0, 22.0)	
$100,000+	7.1 (6.4, 8.0)	5.9 (4.8, 7.3)	7.6 (6.7, 8.7)	

[1]N represents the population of U.S. adults to which the sample generalizes, adult All-Wave weights were used for estimates.
[2]Pearson's chi squared tests and t-tests used to determine p-values. Bolded p-values indicate statistical significance <0.05.
[3]Represents Wave 1 nicotine dependence score higher than the median value of 2.83.
[4]All smoking behavior measures refer to past 30-day use; cigarettes smoked refers to average consumption on days smoking in the past 30 days; weighted sample means and standard errors reported.

Table 3-2. Associations Between Any AMI Symptoms, Dependence, and Smoking Behavior (Waves 1-4) Among Wave 1 Current, Established Smokers (n=7290)

	Log Cigarette Consumption (Past 30 Days)[1] β (SE) n=7,020	**Achieving "Non-Smoking" Status** β (SE) n=7,111	**Making a Quit Attempt** β (SE) n=7,072
Any AMI Symptoms + High Dependence[2]	**0.171** (0.071)	**-0.038*** (0.013)	-0.007 (0.022)
High Dependence	**0.202*** (0.052)	**0.027*** (0.009)	-0.018 (0.016)
Past 30-Day Other Tobacco Use	-0.041 (0.030)	**-0.013** (0.006)	**0.021** (0.009)
Past 30-Day Alcohol Use	0.022 (0.036)	**-0.036*** (0.007)	-0.011 (0.011)
Past 12-Month Doctor Visit	-0.032 (0.039)	**0.017*** (0.006)	**0.021** (0.010)
Age			
18-24	Ref	Ref	Ref
25-34	0.006 (0.072)	0.025 (0.012)	0.009 (0.021)
35-44	-0.001 (0.110)	0.031 (0.020)	0.014 (0.035)
45-54	0.043 (0.146)	0.034 (0.027)	-0.017 (0.046)
55-64	0.084 (0.184)	0.032 (0.033)	0.032 (0.056)
65+	0.269 (0.253)	0.027 (0.044)	0.072 (0.075)
Education			
HS/GED or Less	Ref	Ref	Ref
Some College	-0.037 (0.061)	0.006 (0.011)	-0.003 (0.018)
Bachelor's or higher	-0.072 (0.130)	0.033 (0.024)	**0.086** (0.037)
Annual HH Income			
Less than $10,000	Ref	Ref	Ref
$10,000-$24,999	0.093 (0.048)	0.010 (0.007)	0.002 (0.013)
$25,000-$49,999	**0.126** (0.053)	0.014 (0.009)	-0.006 (0.016)
$50,000- $99,999	**0.219** (0.062)	0.012 (0.012)	-0.001 (0.019)
$100,000+	0.161 (0.086)	0.030 (0.018)	-0.005 (0.027)
Time			
Wave 1	Ref	Ref	Ref
Wave 2	**-0.215*** (0.028)	**0.110*** (0.005)	-0.010 (0.008)
Wave 3	**-0.401*** (0.031)	**0.152*** (0.005)	**0.136*** (0.010)
Wave 4	**-0.406*** (0.034)	**0.168*** (0.006)	**0.125*** (0.010)

Bolded p-values indicate statistical significance <0.05, * indicates p<0.01.

[1]Total consumption represents the number of days smoked (past 30 days) multiplied by the average number of cigarettes smoked per day during that period.
[2]Represents participants who experienced any symptoms of AMI during the study period and exhibited an average dependence score>median dependence score per wave.

Table 3-3. Associations Between Internalizing and Externalizing Behaviors, Dependence, and Smoking Behavior (Waves 1-4) Among Wave 1 Current, Established Smokers (n=7290)

	Log Cigarette Consumption (Past 30 Days)[1] β (SE) n=7,020	**Achieving "Non-Smoking" Status** β (SE) n=7,111	**Making a Quit Attempt** β (SE) n=7,072
High Internalizing Symptoms + High Dependence[2]	0.135 (0.084)	**-0.036** (0.016)	0.007 (0.025)
High Externalizing Symptoms + High Dependence[2]	0.051 (0.085)	-0.018 (0.016)	-0.030 (0.026)
High Dependence	**0.213*** (0.040)	**0.029*** (0.009)	-0.015 (0.015)
Past 30-Day Other Tobacco Use	-0.041 (0.030)	**-0.013** (0.006)	**0.022** (0.010)
Past 30-Day Alcohol Use	0.022 (0.038)	**-0.036*** (0.007)	-0.011 (0.011)
Past 12-Month Doctor Visit	-0.032 (0.033)	**0.017*** (0.006)	**0.020** (0.010)
Age			
18-24	Ref	Ref	Ref
25-34	0.007 (0.072)	0.025 (0.014)	0.009 (0.021)
35-44	-0.001 (0.110)	0.031 (0.022)	0.015 (0.035)
45-54	0.045 (0.146)	0.034 (0.029)	-0.017 (0.046)
55-64	0.085 (0.184)	0.032 (0.036)	0.032 (0.056)
65+	0.271 (0.253)	0.027 (0.044)	0.071 (0.075)
Education			
HS/GED or Les	Ref	Ref	Ref
Some College	0.037 (0.061)	0.006 (0.011)	-0.003 (0.018)
Bachelor's or higher	-0.073 (0.130)	0.034 (0.025)	**0.086** (0.037)
Annual HH Income			
Less than $10,000	Ref	Ref	Ref
$10,000-$24,999	0.093 (0.048)	0.010 (0.007)	0.002 (0.014)
$25,000-$49,999	**0.126** (0.053)	0.014 (0.009)	-0.006 (0.016)
$50,000- $99,999	**0.218** (0.062)	0.012 (0.012)	-0.001 (0.019)
$100,000+	0.160 (0.086)	0.030 (0.018)	-0.005 (0.027)
Time			
Wave 1	Ref	Ref	Ref
Wave 2	**-0.214*** (0.028)	**0.110*** (0.005)	-0.010 (0.008)
Wave 3	**-0.400*** (0.031)	**0.151*** (0.005)	**0.137*** (0.010)
Wave 4	**-0.406*** (0.034)	**0.168*** (0.006)	**0.125*** (0.010)

Bolded p-values indicate statistical significance <0.05, * indicates p<0.01.

[1]Total consumption represents the number of days smoked (past 30 days) multiplied by the average number of cigarettes smoked per day during that period.

[2]Represents participants who experienced any symptoms of AMI during the study period and exhibited an average dependence score>median dependence score per wave.

Table 3-4. Associations Between AMI Symptoms and Health Behaviors Among Wave 1 Current, Established Smokers (n=7290)

	Saw a Medical Doctor- Past 12-Months β (SE) n=7,112	**Doctor Advised Quitting Smoking** β (SE) n=5,209	**Used Any Cessation Aid**[1] n=4,220	**Used NRT**[1] n=3,769	**Used Rx Cessation Aid**[1] n=3,241
High Internalizing Symptoms	**0.023** (0.010)	0.020 (0.016)	0.007 (0.019)	**0.051** (0.021)	-0.027 (0.017)
High Externalizing Symptoms	**0.027** (0.011)	0.022 (0.017)	0.026 (0.022)	-0.002 (0.022)	-0.004 (0.014)
High Dependence	0.001 (0.009)	**0.036** (0.014)	0.005 (0.018)	0.028 (0.021)	-0.010 (0.016)
Past 30-Day Other Tobacco Use	0.003 (0.008)	**-0.036*** (0.013)	**0.085*** (0.017)	-0.035 (0.019)	-0.008 (0.014)
Past 30-Day Alcohol Use	-0.012 (0.009)	-0.010 (0.016)	0.022 (0.019)	0.039 (0.022)	0.022 (0.0156)
Age					
18-24	Ref	Ref	Ref	Ref	Ref
25-34	-0.032 (0.020)	-0.046 (0.033)	0.046 (0.038)	**0.093** (0.042)	0.010 (0.021)
35-44	0.002 (0.031)	-0.027 (0.052)	0.122 (0.065)	0.099 (0.070)	0.033 (0.045)
45-54	0.002 (0.042)	0.040 (0.076)	0.153 (0.089)	0.045 (0.101)	0.103 (0.074)
55-64	0.112 (0.050)	0.053 (0.090)	0.045 (0.105)	0.031 (0.122)	-0.013 (0.095)
65+	0.180 (0.060)	0.072 (0.114)	0.078 (0.127)	-0.019 (0.143)	0.026 (0.113)
Education					
HS/GED or Les	Ref	Ref	Ref	Ref	Ref
Some College	0.022 (0.016)	-0.018 (0.027)	-0.052 (0.030)	-0.056 (0.030)	-0.008 (0.019)
Bachelor's or higher	**0.110*** (0.035)	0.050 (0.049)	-0.075 (0.062)	0.050 (0.068)	-0.001 (0.046)
Annual HH Income					
Less than $10,000	Ref	Ref	Ref	Ref	Ref
$10,000-$24,999	-0.018 (0.012)	0.008 (0.022)	0.023 (0.029)	-0.012 (0.028)	-0.011 (0.019)
$25,000-$49,999	-0.016 (0.015)	-0.004 (0.026)	0.028 (0.033)	-0.014 (0.032)	-0.014 (0.021)
$50,000- $99,999	-0.010 (0.018)	0.003 (0.030)	0.046 (0.038)	-0.016 (0.039)	0.010 (0.027)
$100,000+	0.003 (0.024)	-0.006 (0.038)	0.018 (0.050)	**-0.011** (0.053)	-0.040 (0.043)
Time					
Wave 1	Ref	Ref	Ref	Ref	Ref
Wave 2	**-0.052*** (0.008)	-0.027 (0.025)	**-0.067*** (0.015)	**-0.068*** (0.017)	0.018 (0.014)

	Saw a Medical Doctor- Past 12-Months β (SE) n=7,112	**Doctor Advised Quitting Smoking** β (SE) n=5,209	**Used Any Cessation Aid**[1] n=4,220	**Used NRT**[1] n=3,769	**Used Rx Cessation Aid**[1] n=3,241
Wave 3	**-0.038*** (0.008)	-0.028 (0.025)	**-0.145*** (0.018)	**-0.143*** (0.020)	-0.011 (0.015)
Wave 4	**-0.057*** (0.009)	-0.044 (0.026)	**-0.138*** (0.019)	**-0.156*** (0.021)	-0.007 (0.017)

Bolded p-values indicate statistical significance <0.05, * indicates p<0.01.

[1]Participants who attempted quitting smoking during each wave were asked to mark all methods they used to help quit smoking during their most recent quit attempt.

Conclusion and Implications

Despite the success of tobacco prevention policies at reducing smoking prevalence overall among youth and adults, adults with mental illness are at high risk for initiating and continuing cigarette use, and we suffer from a dearth of evidence among this population. This study leveraged the power of longitudinal, nationally representative surveys of cohorts of U.S. adults to investigate whether adults with AMI have responded differently to increases in excise tax rates over time, and whether a unique association between AMI and nicotine dependence may moderate smoking behavior outcomes for highly dependent adult smokers. Our results relying upon historical variation in excise tax rate suggest that, while adults with AMI may be more likely to smoke and to have increased cigarette consumption, they do not appear to respond differently to price policies than adults without AMI. Our investigation of the role of nicotine dependence in predicting successful quit attempts indicates that certain groups of AMI symptoms and disorders may put nicotine-dependent adults at particular disadvantage when attempting to quit or reduce smoking, despite their attempts. Our study relying upon data from contemporary adult participants revealed that exposing participants to theoretical purchase tasks with wider variation in prices than that which we typically observe using excise tax rate predicted that not only would those with AMI still generally self-report higher demand, but that they would also be more reluctant to reduce demand in the face of rising prices. In addition, they were just as likely as those without AMI to substitute one of several lower harm alternative products under certain conditions as the price of their preferred, combustible product increased.

Taken together, our findings imply that adults with AMI have the potential to have more difficulty reducing combustible tobacco use under certain conditions than adults without these symptoms, making it imperative that this population remain a high priority for investigators seeking to reduce a significant disparity in use rates and combustible tobacco-related health consequences. Our results provide cautionary evidence that policymakers should carefully weigh likely responses to increased tobacco prices across subgroups of smokers when assessing how successful price policies may be in reducing smoking. Research related to how best to tailor sustained cessation support to adults with certain classes of AMI symptoms may also prove effective in

turning attempt into success, particularly in light of the fact that these smokers are equally likely to attempt to quit smoking, and to report contact with the healthcare system. Additional areas of focus for future work that could significantly advance our knowledge in this area would include investigating the role specific categories of AMI symptoms play in predicting these outcomes, assessing how severity of symptoms may impact use behaviors in the face of likely policy alternatives, further exploring the role of treatment for mental health in influencing tobacco use behaviors, categorizing the degree to which adults with AMI perceive and respond to tobacco-related harm or risk reduction communication, and expanding these methods to focus on other populations at high risk for initiating and continuing smoking. Without such evidence, there poses a significant risk that some groups of smokers may be omitted from critical policy solutions intended to reduce the substantial public health burden of combustible tobacco use in the U.S.

References

1. Rostron BL, Chang CM, Pechacek TF. Estimation of Cigarette Smoking-Attributable Morbidity in the United States. *JAMA Intern Med*. 2014;174(12):1922. doi:10.1001/jamainternmed.2014.5219
2. Jamal A, King BA, Neff LJ, Whitmill J, Babb SD, Graffunder CM. *Current Cigarette Smoking Among Adults — United States, 2005–2015*. Vol 65.; 2016. doi:10.15585/mmwr.mm6544a2
3. Creamer MR, Wang TW, Babb S, et al. Tobacco Product Use and Cessation Indicators Among Adults — United States, 2018. *MMWR Morb Mortal Wkly Rep*. 2019;68(45):1013-1019. doi:10.15585/mmwr.mm6845a2
4. Gfroerer J, Dube S, BA K, Garrett B, Babb S, McAfee T. Vital Signs: Current Cigarette Smoking Among Adults Aged ≥18 Years with Mental Illness — United States, 2009–2011. *Morb Mortal Wkly Rep*. 2013;62(05):81-87. https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6205a2.htm.
5. Lê Cook B, Wayne GF, Kafali EN, Liu Z, Shu C, Flores M. Trends in smoking among adults with mental illness and association between mental health treatment and smoking cessation. *JAMA - J Am Med Assoc*. 2014;311(2):172-182. doi:10.1001/jama.2013.284985
6. King JL, Reboussin BA, Spangler J, Ross JC, Sutfin EL. Tobacco product use and mental health status among young adults. *Addict Behav*. 2017;77(April 2017):67-72. doi:10.1016/j.addbeh.2017.09.012
7. Pedersen W, Von Soest T. Smoking, nicotine dependence and mental health among young adults: A 13-year population-based longitudinal study. *Addiction*. 2009;104(1):129-137. doi:10.1111/j.1360-0443.2008.02395.x
8. Primack BA, Land SR, Fan J, Kim KH, Rosen D. Associations of Mental Health Problems With Waterpipe Tobacco and Cigarette Smoking Among College Students. *Subst Use Misuse*. 2013;48(3):211-219. doi:10.3109/10826084.2012.750363
9. Krebs P, Rogers E, Smelson D, Fu S, Wang B, Sherman S. Relationship between tobacco cessation and mental health outcomes in a tobacco cessation trial. *J Health Psychol*. 2016:1359105316644974. doi:10.1177/1359105316644974
10. Hu S, Neff L, Agaku I, et al. Tobacco product use among adults - United States, 2012-2013. *Centers Dis Control Prev MMWR Wkly Rep*. 2016;65(27):685-691. doi:http://dx.doi.org/10.15585/mmwr.mm6527a1
11. Babb S, Malarcher A, Schauer G, Asman K, Jamal A. Quitting Smoking Among Adults — United States, 2000–2015. *MMWR Morb Mortal Wkly Rep*. 2017;65(52):1457-1464. doi:10.15585/mmwr.mm6552a1
12. Aditya A, Kaluskar A, Pandya S, Vinay V, Sharma A. Risk of Psychiatric Morbidity in Patients with Tobacco Habits: A Cross-Sectional Study. *J Clin Diagn Res*. 2017;11(7):ZC33-ZC35. doi:10.7860/JCDR/2017/26824.10172
13. Conway KP, Green VR, Kasza KA, et al. Co-occurrence of tobacco product use, substance use, and mental health problems among adults: Findings from Wave 1 (2013 & 2014) of the Population Assessment of Tobacco and Health (PATH) Study. *Drug Alcohol Depend*. 2017;177(February 2017):104-111. doi:10.1016/j.drugalcdep.2017.03.032
14. Lemieux A, Olson L, Nakajima M, Schulberg L, al'Absi M. Life adversity is associated with smoking relapse after a quit attempt. *Addict Behav*. 2016;60:71-77. doi:10.1016/j.addbeh.2016.03.017
15. Zahrani, H., Kamali, A., Ghorbani M. Predictive model of nicotine dependence based on mental health indicators and self-concept. *J Kermanshah Univ Med Sci*. 2014;18(9):539-546.
16. The U.S. Food and Drug Administration (FDA). Statement from FDA Commissioner Scott Gottlieb, M.D., on pivotal public health step to dramatically reduce smoking rates by lowering nicotine in combustible cigarettes to minimally or non-addictive levels. FDA Statement. https://www.fda.gov/newsevents/newsroom/pressannouncements/ucm601039.htm. Published 2018. Accessed June 2, 2018.
17. The U.S. Food and Drug Administration (FDA). The Facts on the FDA's New Tobacco Rule. Consumer Updates. https://www.fda.gov/ForConsumers/ConsumerUpdates/ucm506676.htm. Published 2016. Accessed May 5, 2018.
18. Druss BG, Zhao L, Von Esenwein S, Morrato EH, Marcus SC. Understanding excess mortality in persons with mental illness: 17-year follow up of a nationally representative US survey. *Med Care*.

2011;49(6):599-604. doi:10.1097/MLR.0b013e31820bf86e
19. Center for Disease Control and Prevention. Vital Signs: Current Cigarette Smoking Among Adults Aged ≥18 Years With Mental Illness—United States, 2009–2011. *Morb Mortal Wkly Rep*. 2013;62(05):81-87.
20. Centers for Disease Control: National Center for Chronic Disease and Health Promotion; Office of Smoking and Health. *Vital Signs Fact Sheet: Adult Smoking Focusing on People With Mental Illness, February 2013*.; 2013.
21. Centers for Disease Control and Prevention. Tobacco Use and Quitting Among Individuals With Behavioral Health Conditions. https://www.cdc.gov/tobacco/disparities/mental-illness-substance-use/index.htm. Published 2020.
22. Carter LP, Griffiths RR. Principles of laboratory assessment of drug abuse liability and implications for clinical development. *Drug Alcohol Depend*. 2009;105(SUPPL. 1):14-25. doi:10.1016/j.drugalcdep.2009.04.003
23. Carter LP, Stitzer ML, Henningfield JE, O'Connor RJ, Cummings KM, Hatsukami DK. Abuse liability assessment of tobacco products including potential reduced exposure products. *Cancer Epidemiol Biomarkers Prev*. 2009;18(12):3241-3262. doi:10.1158/1055-9965.EPI-09-0948
24. Prochaska JJ. Smoking and Mental Illness — Breaking the Link. *N Engl J Med*. 2011;365(3):196-198. doi:10.1056/NEJMp1105248
25. National Institute on Drug Abuse. Do people with mental illness and substance use disorders use tobacco more often? https://www.drugabuse.gov/publications/tobacco-nicotine-e-cigarettes/do-people-mental-illness-substance-use-disorders-use-tobacco-more-often. Published 2018. Accessed May 22, 2018.
26. Lindson N, Richards-Doran D, Heath L, Hartmann-Boyce J. Setting research priorities in tobacco control: a stakeholder engagement project. *Addiction*. September 2017. doi:10.1111/add.13940
27. NCI. Tobacco Control Research Priorities for the Next Decade: Working Group Recommendations for 2016 -2025. *Tob Control Res Priorities Work Gr NCI Board Sci Advis*. 2016;(March):24. https://cancercontrol.cancer.gov/pdf/nci-tobacco-control-research-priorities-rpt-feb-2016.pdf.
28. Cochrane Tobacco Addiction Group. Prioritising the unanswered questions in tobacco control. Tobacco Addiction Cochrane Tobacco Addiction Group 20th Anniversary Priority Setting Project (CTAG taps).
29. United States Department of Health and Human Services. The Health Consequences of Smoking—50 Years of Progress A Report of the Surgeon General. *A Rep Surg Gen*. 2014:1081. doi:NBK179276
30. Krugman DM. Understanding the Impact That Marketing, Advertising, and Promotion Have on Adolescent E-cigarette Behavior. *J Adolesc Heal*. 2016;59(6):609-611. doi:10.1016/j.jadohealth.2016.09.016
31. Agaku IT, Ayo-Yusuf O a. The Effect of Exposure to Pro-Tobacco Advertising on Experimentation With Emerging Tobacco Products Among U.S. Adolescents. *Health Educ Behav*. 2013;41(3):275-280. doi:10.1177/1090198113511817
32. Feighery E, Borzekowski DL, Schooler C, Flora J. Seeing, wanting, owning: the relationship between receptivity to tobacco marketing and smoking susceptibility in young people. *Tob Control*. 1998;7(2):123-128. doi:10.1136/tc.7.2.123
33. Gilpin EA, White MM, Messer K, Pierce JP. Receptivity to tobacco advertising and promotions among young adolescents as a predictor of established smoking in young adulthood. *Am J Public Health*. 2007;97(8):1489-1495. doi:10.2105/AJPH.2005.070359
34. Pechmann C, Levine L, Loughlin S, Leslie F. Impulsive and Self-Conscious: Adolescents' Vulnerability to Advertising and Promotion. *J Public Policy Mark*. 2005;24(2):202-221. doi:10.1509/jppm.2005.24.2.202
35. Lawrence D, Mitrou F, Zubrick SR. Non-specific psychological distress, smoking status and smoking cessation: United States National Health Interview Survey 2005. *BMC Public Health*. 2011;11(1):256. doi:10.1186/1471-2458-11-256
36. Institute of Medicine Staff. *Reducing Risks for Mental Disorders: Frontiers for Preventive Intervention Research*. (Mrazek, P.; Haggerty R, ed.). National Academies Press; 1994. https://ebookcentral-proquest-com.proxy.library.vcu.edu/lib/vcu/detail.action?docID=3377478.
37. Johnson EO, Chen LS, Breslau N, et al. Peer smoking and the nicotinic receptor genes: An examination

of genetic and environmental risks for nicotine dependence. *Addiction*. 2010;105(11):2014-2022. doi:10.1111/j.1360-0443.2010.03074.x
38. McClave A, McKnight-Eily L, Davis S, Dube S. Smoking Characteristics of Adults With Selected Lifetime Mental Illnesses: Results From the 2007 National Health Interview Survey. *Am J Public Health*. 2010;100(12):2464-2472.
39. Wetter DW, Smith SS, Kenford SL, et al. Smoking Outcome Expectancies - Factor Structure, Predictive-Validity, and Discriminant Validity. *J Abnorm Psychol*. 1994;103(4):801-811.
40. Lewis-Esquerre JM, Rodrigue JR, Kahler CW. Development and validation of an adolescent smoking consequences questionnaire. *Nicotine Tob Res*. 2005;7(1):81-90. doi:10.1080/14622200412331328475
41. Rohsenow DJ, Abrams DB, Monti PM, Colby SM, Martin R, Niaura RS. The Smoking Effects Questionnaire for adult populations: Development and psychometric properties. *Addict Behav*. 2003;28(7):1257-1270. doi:10.1016/S0306-4603(02)00254-X
42. Tidey JW, Rohsenow DJ. Smoking expectancies and intention to quit in smokers with schizophrenia, schizoaffective disorder and non-psychiatric controls. *Schizophr Res*. 2009;115(2-3):310-316. doi:10.1016/j.schres.2009.09.032
43. Esterberg ML, Compton MT. Smoking behavior in persons with a schizophrenia-spectrum disorder: A qualitative investigation of the transtheoretical model. *Soc Sci Med*. 2005;61(2):293-303. doi:10.1016/j.socscimed.2004.11.057
44. Buckley T, Kamholz B, Mozley S, et al. A Psychometric Evaluation of the Smoking Consequences Questionnaire-Adult in Smokers with Psychiatric Conditions. *Nicotine Tob Res*. 2005;7(5):739-745. doi:https://doi.org/10.1080/14622200500259788
45. Khantzian EJ. The self-medication hypothesis revisited: The dually diagnosed patient. *Prim Psychiatry*. 2003;10(9):47-54.
46. Chaloupka FJ, Warner K. Economics of Smoking. *Natl Bur Econ Res Work Pap Ser*. 1999;(7047). http://www.nber.org/papers/w7047.
47. Benowitz NL. Nicotine Addiction. Schwartz RS, ed. *N Engl J Med*. 2010;362(24):2295-2303. doi:10.1056/NEJMra0809890
48. Tauras JA, Peck RM, Tsipas S, Chaloupka F. Depression, suicide, tobacco control policies, and cigarette smoking among high school students. *J Dual Diagn*. 2009;5(2):197-218. doi:10.1080/15504260902886430
49. Orphanides A, Zervos D. Rational Addiction with Learning and Regret. *J Polit Econ*. 1995;103(4):739-758. http://www.jstor.org.proxy.library.vcu.edu/stable/2138580.
50. Becker GS, Grossman M, Murphy KM. An Empirical Analysis of Cigarette Addiction. *Am Econ Rev*. 1994;84(3):396-418.
51. Huang J, Tauras J, Chaloupka FJ. The impact of price and tobacco control policies on the demand for electronic nicotine delivery systems. *Tob Control*. 2014;23 Suppl 3:iii41-7. doi:10.1136/tobaccocontrol-2013-051515
52. van Baal PHM, Brouwer WBF, Hoogenveen RT, Feenstra TL. Increasing tobacco taxes: A cheap tool to increase public health. *Health Policy (New York)*. 2007;82(2):142-152. doi:10.1016/j.healthpol.2006.09.004
53. Nonnemaker JM, Farrelly MC. Smoking initiation among youth: The role of cigarette excise taxes and prices by race/ethnicity and gender. *J Health Econ*. 2011;30(3):560-567. doi:10.1016/j.jhealeco.2011.03.002
54. Carpenter C, Cook PJ. Cigarette taxes and youth smoking: New evidence from national, state, and local Youth Risk Behavior Surveys. *J Health Econ*. 2008;27(2):287-299. doi:10.1016/j.jhealeco.2007.05.008
55. DeCicca P, Kenkel D, Mathios A. Putting Out the Fires: Will Higher Taxes Reduce the Onset of Youth Smoking? *J Polit Econ*. 2002;110(1):144-169. doi:10.1086/324386
56. Decicca P, Kenkel D, Mathios A, Shin Y-J, Lim J-Y. YOUTH SMOKING, CIGARETTE PRICES, AND ANTI-SMOKING SENTIMENT. *NBER Work Pap Ser*. 2006;(12458).
57. Tauras JA, Huang J, Chaloupka FJ. Differential impact of tobacco control policies on youth sub-populations. *Int J Environ Res Public Health*. 2013;10(9):4306-4322. doi:10.3390/ijerph10094306

58. Levy DT, Mumford E a, Pesin B. Tobacco control policies and reductions in smoking rates and smoking-related deaths. *Expert Rev Pharmacoecon Outcomes Res*. 2003;3(4):457-468. doi:10.1586/14737167.3.4.457
59. Services UD of H and H, U. S. Department of Health and Human Services, U.S. Department of Health and Human Services National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health C for DC and P. Preventing Tobacco Use Among Youth and Young Adults A Report of the Surgeon General. *… , GA US Dep Heal …*. 2012. https://permanent.access.gpo.gov/gpo21718/http___www.surgeongeneral.gov_library_preventing-youth-tobacco-use_full-report.pdf.
60. Gospodinov N, Irvine I. Tobacco taxes and regressivity. *J Health Econ*. 2009;28(2):375-384. doi:10.1016/j.jhealeco.2008.10.010
61. Colman GJ, Remler DK. Vertical equity consequences of very high cigarette tax increases: If the poor are the ones smoking, how could cigarette tax increases be progressive? *J Policy Anal Manag*. 2008;27(2):376-400. doi:10.1002/pam.20329
62. Gruber J, Koszegi B. Tax incidence when individuals are time-inconsistent: The case of cigarette excise taxes. *J Public Econ*. 2004;88(9-10):1959-1987. doi:10.1016/j.jpubeco.2003.06.001
63. Substance Abuse and Mental Health Services Administration. *Key Substance Use and Mental Health Indicators in the United States: Results from the 2018 National Survey on Drug Use and Health*.; 2019. https://www.samhsa.gov/data/sites/default/files/cbhsq-reports/NSDUHNationalFindingsReport2018/NSDUHNationalFindingsReport2018.pdf.
64. Centers for Disease Control and Prevention. *The NSDUH Report Data Spotlight: Adults with Mental Illness or Substance Use Disorder Account for 40 Percent of All Cigarettes Smoked*.; 2013. https://www.samhsa.gov/data/sites/default/files/spot104-cigarettes-mental-illness-substance-use-disorder/spot104-cigarettes-mental-illness-substance-use-disorder.pdf.
65. Lipari R, Van Horn S. *Smoking and Mental Illness Aong Adults in the United States*. Rockville, MD; 2017. https://www.samhsa.gov/data/sites/default/files/report_2738/ShortReport-2738.html.
66. Hitsman B, Moss TG, Montoya ID, George TP. Treatment of Tobacco Dependence in Mental Health and Addictive Disorders. *Can J Psychiatry*. 2009;54(6).
67. Schroeder SA, Morris CD. Confronting a Neglected Epidemic: Tobacco Cessation for Persons with Mental Illnesses and Substance Abuse Problems. *Annu Rev Public Heal*. 2010;31(1):297-314. doi:10.1146/annurev.publhealth.012809.103701
68. Prochaska JJ, Das S, Young-Wolff KC. Smoking, Mental Illness, and Public Health. *Annu Rev Public Health*. 2017;38(1):165-185. doi:10.1146/annurev-publhealth-031816-044618
69. Prochaska JJ, Hall SM, Bero LA. Tobacco use among individuals with schizophrenia: What role has the tobacco industry played? *Schizophr Bull*. 2008;34(3):555-567. doi:10.1093/schbul/sbm117
70. Kalman D, Morissette SB, George TP. Co-Morbidity of Smoking in Patients with Psychiatric and Substance Use Disorders. *Am J Addict*. 2005;14(2):106-123. doi:10.1080/10550490590924728
71. Jones WJ, Silvestri GA. The Master Settlement Agreement and Its Impact on Tobacco Use 10 Years Later. *Chest*. 2010;137(3):692-700. doi:10.1378/chest.09-0982
72. Campaign for Tobacco-Free Kids. *State Excise and Sales Taxes Per Pack of Cigarettes Total Amounts & State Rankings*. https://www.tobaccofreekids.org/assets/factsheets/0202.pdf.
73. Martire KA, Mattick RP, Doran CM, Hall WD. Cigarette tax and public health: What are the implications of financially stressed smokers for the effects of price increases on smoking prevalence? *Addiction*. 2011;106(3):622-630. doi:10.1111/j.1360-0443.2010.03174.x
74. Saffer H, Dave D. Mental illness and the demand for alcohol, cocaine, and cigarettes. *Econ Inq*. 2005;43(2):229-246. doi:10.1093/ei/cbi016
75. Sharbaugh MS, Althouse AD, Thoma FW, Lee JS, Figueredo VM, Mulukutla SR. Impact of cigarette taxes on smoking prevalence from 2001-2015: A report using the Behavioral and Risk Factor Surveillance Survey (BRFSS). *PLoS One*. 2018;13(9):1-10. doi:10.1371/journal.pone.0204416
76. DeCicca P, Kenkel D, Mathios A. Cigarette taxes and the transition from youth to adult smoking: Smoking initiation, cessation, and participation. *J Health Econ*. 2008;27(4):904-917.

doi:10.1016/j.jhealeco.2008.02.008
77. Chaloupka FJ, Peck R, Tauras J a., Xu X, Yurekli A. Cigarette Excise Taxation: The Impact of Tax Structure on Prices, Revenues, and Cigarette Smoking. *Natl Bur Econ Res Work Pap Ser*. 2010;No. 16287. doi:10.3386/w16287
78. Gruber J, Zinman J. *YOUTH SMOKING IN THE U.S.: EVIDENCE AND IMPLICATIONS*. Cambridge, MA; 2000. https://www.nber.org/papers/w7780.pdf.
79. DeCicca P, Kenkel D, Mathios A. Racial Difference in the Determinants of Smoking Onset. *J Risk Uncertain*. 2000;21(2):311-340. doi:10.1023/A:1007819625751
80. Tekin E, Mocan N, Liang L. Do Adolescents with Emotional or Behavioral Problems Respond to Cigarette Prices? *South Econ J*. 2009;76(1):67-85. doi:10.4284/sej.2009.76.1.67
81. Ong MK, Zhou Q, Sung H-Y. Sensitivity to Cigarette Prices Among Individuals With Alcohol, Drug, or Mental Disorders. *Am J Public Health*. 2010;100(7):1243-1245. doi:10.2105/AJPH.2009.159962
82. Chang H-H, Chiang T. Depressive symptoms, smoking, and cigarette price elasticity: results from a population-based survey in Taiwan. *Int J Public Health*. 2009;54(6):421-426. doi:10.1007/s00038-009-0080-4
83. Saffer H, Dave D. MENTAL ILLNESS AND THE DEMAND FOR ALCOHOL, COCAINE, AND CIGARETTES. *Econ Inq*. 2005;43(2):229-246. doi:10.1093/ei/cbi016
84. Steinberg ML, Williams JM, Ziedonis DM. Financial implications of cigarette smoking among individuals with schizophrenia. *Tob Control*. 2004;13(2):206 LP - 206. http://tobaccocontrol.bmj.com/content/13/2/206.1.abstract.
85. U.S. Department of Health & Human Services. *The Health Consequences of Smoking—50 Years of Progress: A Report of the Surgeon General*. Atlanta, GA; 2014.
86. Orzechowski W, Walker R. The tax burden on tobacco. 2012;47:1-363. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:The+Tax+Burden+On+Tobacco#0.
87. El-Shahawy O, Park SH, Duncan DT, et al. Evaluating State-Level Differences in E-cigarette and Cigarette Use Among Adults in the United States Between 2012 and 2014: Findings From the National Adult Tobacco Survey. *Nicotine Tob Res*. 2018;(March):1-10. doi:10.1093/ntr/nty013
88. Decicca P, Kenkel D. Synthesizing Econometric Evidence: The Case of Demand Elasticity Estimates. *Risk Anal*. 2015;35(6):1073-1085. doi:10.1111/risa.12363
89. Gallet CA, List JA. Cigarette demand: A meta-analysis of elasticities. *Health Econ*. 2003;12(10):821-835. doi:10.1002/hec.765
90. Gill SC, Butterworth P, Rodgers B, Mackinnon A. Validity of the mental health component scale of the 12-item Short-Form Health Survey (MCS-12) as measure of common mental disorders in the general population. *Psychiatry Res*. 2007;152(1):63-71. doi:10.1016/j.psychres.2006.11.005
91. Kelly MJ, Dunstan FD, Lloyd K, Fone DL. Evaluating cutpoints for the MHI-5 and MCS using the GHQ-12: a comparison of five different methods. *BMC Psychiatry*. 2008;8:10. doi:10.1186/1471-244X-8-10
92. Bland JM, Altman DG. Statistics notes: Cronbach's alpha. *BMJ*. 1997;314(7080):572-572. doi:10.1136/bmj.314.7080.572
93. U.S. Department of Labor: Bureau of Labor Statistics. Archived Consumer Price Index Supplemental Files: Historical CPI-U, March 2020. https://www.bls.gov/cpi/tables/supplemental-files/home.htm. Published 2020.
94. American Lung Association. State of Tobacco Control (SOTC). https://www.lung.org/research/sotc. Published 2020.
95. Wooldridge D. *Introductory Econometrics: A Modern Approach*. 5th ed. Cengage Learning; 2014.
96. Wooldridge JM. *Econometric Analysis of Cross Section and Panel Data, Second Edition*. 2nd ed. The MIT Press; 2010.
97. Cameron AC, Trivedi P. *Microeconometrics: Methods and Applications*. Cambridge Universuty press; 2005.
98. Chaloupka FJ. *Taxing E-Cigarettes – Options and Potential Public Health Impact*.; 2015.
99. Sheu M, Hu T, Keeler TE, Ong M, Sung H-Y. The effect of a major cigarette price change on smoking

behavior in california: a zero-inflated negative binomial model. *Health Econ*. 2004;13(8):781-791. doi:10.1002/hec.849
100. Goldman TR. *Tobacco Taxes*.; 2016. doi:10.1377/hpb20160919.471471
101. Fleming CB, Kim H, Harachi TW, Catalano RF. Family processes for children in early elementary school as predictors of smoking initiation. *J Adolesc Heal*. 2002;30(3):184-189. doi:10.1016/S1054-139X(01)00327-5
102. Simons-Morton B, Chen R, Abroms L, Haynie DL. Latent Growth Curve Analyses of Peer and Parent Influences on Smoking Progression Among Early Adolescents. *Heal Psychol*. 2004;23(6):612-621. doi:10.1037/0278-6133.23.6.612
103. Prochaska JJ, Hall SM, Tsoh JY, et al. Treating tobacco dependence in clinically depressed smokers: effect of smoking cessation on mental health functioning. *Am J Public Health*. 2008;98(3):446. doi:10.2105/AJPH.2006.101147
104. Yurekli AA, Zhang P. The impact of clean indoor-air laws and cigarette smuggling on demand for cigarettes: An empirical model. *Health Econ*. 2000;9(2):159-170. doi:10.1002/(SICI)1099-1050(200003)9:2<159::AID-HEC499>3.0.CO;2-T
105. U.S. Food and Drug Administration. Products, Ingredients & Components. https://www.fda.gov/tobacco-products/products-guidance-regulations/products-ingredients-components. Published 2020.
106. The U.S. Food and Drug Administration (FDA). FDA permits sale of IQOS Tobacco Heating System through premarket tobacco product application pathway. FDA News Release.
107. Cullen KA, Ambrose BK, Gentzke A, Apelberg BJ, Jamal A, King BA. Notes from the Field: Use of Electronic Cigarettes and Any Tobacco Product Among Middle and High School Students — United States, 2011–2018. MMWR Morb Mortal Wkly Rep. https://www.cdc.gov/mmwr/volumes/67/wr/pdfs/mm6745a5-H.pdf. Published 2018.
108. Foxon F, Selya AS. Electronic Cigarettes, Nicotine Use Trends, and Use Initiation Ages among US Adolescents from 1999–2018. *Addiction*. April 2020:add.15099. doi:10.1111/add.15099
109. Logue JM, Sleiman M, Montesinos VN, et al. Emissions from Electronic Cigarettes: Assessing Vapers' Intake of Toxic Compounds, Secondhand Exposures, and the Associated Health Impacts. *Environ Sci Technol*. 2017;51(16):9271-9279. doi:10.1021/acs.est.7b00710
110. CDC. About Electronic Cigarettes (E-Cigarettes). https://www.cdc.gov/tobacco/basic_information/e-cigarettes/about-e-cigarettes.html. Published 2018.
111. Dai H, Leventhal AM. Prevalence of e-Cigarette Use Among Adults in the United States, 2014-2018. *JAMA*. September 2019. doi:10.1001/jama.2019.15331
112. Vansickel AR, Weaver MF, Eissenberg T. Clinical laboratory assessment of the abuse liability of an electronic cigarette. *Addiction*. 2012;107(8):1493-1500. doi:10.1111/j.1360-0443.2012.03791.x
113. Stein JS, Koffarnus MN, Stepanov I, Hatsukami DK, Bickel WK. Cigarette and e-liquid demand and substitution in e-cigarette-naïve smokers. *Exp Clin Psychopharmacol*. 2018;26(3):233-243. doi:10.1037/pha0000192
114. Johnson MW, Johnson PS, Rass O, Pacek LR. Behavioral economic substitutability of e-cigarettes, tobacco cigarettes, and nicotine gum. *J Psychopharmacol*. 2017;31(7):851-860. doi:10.1177/0269881117711921
115. Barnes AJ, Bono RS, Lester RC, Eissenberg TE, Cobb CO. Effect of Flavors and Modified Risk Messages on E-cigarette Abuse Liability. *Tob Regul Sci*. 2017;3(4):374-387. doi:10.18001/TRS.3.4.1
116. Hursh SR, Roma PG. Behavioral economics and empirical public policy. *J Exp Anal Behav*. 2013;99(1):98-124. doi:10.1002/jeab.7
117. Henningfield JE, Benowitz NL, Slade J, Houston TP, Davis RM, Deitchman SD. Reducing the addictiveness of cigarettes. *Tob Control*. 1998;7(3):281-293. doi:10.1136/tc.7.3.281
118. Gottlieb S. Statement from FDA Commissioner Scott Gottlieb, M.D., on new steps to address epidemic of youth e-cigarette use. *U.S. Food & Drug Administration*. September 2018.
119. Snider SE, Cummings KM, Bickel WK. Behavioral economic substitution between conventional cigarettes and e-cigarettes differs as a function of the frequency of e-cigarette use. *Drug Alcohol Depend*. 2017;177(October 2016):14-22. doi:10.1016/j.drugalcdep.2017.03.017

120. Higgins ST, Heil SH, Sigmon SC, et al. Addiction potential of cigarettes with reduced nicotine content in populations with psychiatric disorders and other vulnerabilities to tobacco addiction. *JAMA Psychiatry*. 2017;74(10):1056-1064. doi:10.1001/jamapsychiatry.2017.2355
121. U.S. Food and Drug Administration: Center for Tobacco products. *Modified Risk Tobacco Product Applications*.; 2020. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/modified-risk-tobacco-product-applications.
122. MacKillop J, Murphy JG, Ray LA, et al. Further Validation of a Cigarette Purchase Task for Assessing the Relative Reinforcing Efficacy of Nicotine in College Smokers. *Exp Clin Psychopharmacol*. 2008;16(1):57-65. doi:10.1037/1064-1297.16.1.57
123. Amlung M, Mccarty KN, Morris DH, Tsai C lin, McCarthy DM. Response to Tucker & Vuchinich (2015): Behavioral economics in the broader context of addiction science. *Addiction*. 2015;110(9):1430-1431. doi:10.1111/add.13015
124. Löwe B, Kroenke K, Gräfe K. Detecting and monitoring depression with a two-item questionnaire (PHQ-2). *J Psychosom Res*. 2005;58(2):163-171. doi:10.1016/j.jpsychores.2004.09.006
125. Fleishman JA, Zuvekas SH, Pincus HA. Screening for Depression Using the PHQ-2: Changes over Time in Conjunction with Mental Health Treatment. *Agency Healthc Res Qual Work Pap*. 2014;(14002). https://meps.ahrq.gov/.
126. Buhrmester MD, Talaifar S, Gosling SD. An Evaluation of Amazon's Mechanical Turk, Its Rapid Rise, and Its Effective Use. *Perspect Psychol Sci*. 2018;13(2):149-154. doi:10.1177/1745691617706516
127. Buhrmester M, Kwang T, Gosling SD. Amazon ' s Mechanical Turk : A New Source of Inexpensive , Yet High-Quality , Data ? *Perspect Psychol Sci*. 2011;6(1):3-5.
128. Chandler J, Shapiro D. Conducting Clinical Research Using Crowdsourced Convenience Samples. *Annu Rev Clin Psychol*. 2016;12(1):53-81. doi:10.1146/annurev-clinpsy-021815-093623
129. Shapiro DN, Chandler J, Mueller PA. Using Mechanical Turk to Study Clinical Populations. *Clin Psychol Sci*. 2013;1(2):213-220. doi:10.1177/2167702612469015
130. Barnes AJ, Bono RS, Lester RC, Eissenberg TE, Cobb CO. Effect of Flavors and Modified Risk Messages on E-cigarette Abuse Liability. *Tob Regul Sci*. 2017;3(4):374-387. doi:10.18001/TRS.3.4.1
131. Stein JS, Koffarnus MN, Snider SE, Quisenberry AJ, Bickel WK. Identification and management of nonsystematic purchase task data: Toward best practice. *Exp Clin Psychopharmacol*. 2015;23(5):377-386. doi:10.1037/pha0000020
132. Kroenke K, Spitzer RL, Williams JBW. The PHQ-9: Validity of a Brief Depression Severity Measure. *J Gen Intern Med*. 2001;16(9):606-613. doi:10.1046/j.1525-1497.2001.016009606.x
133. National Institute of Mental Health. Major Depression.
134. Zuithoff NP, Vergouwe Y, King M, et al. The patient health questionnaire-9 for detection of major depressive disorder in primary care: Consequences of current thresholds in a crosssectional study. *BMC Fam Pract*. 2010;11(1):98. doi:10.1186/1471-2296-11-98
135. Manea L, Gilbody S, McMillan D. Optimal cut-off score for diagnosing depression with the Patient Health Questionnaire (PHQ-9): a meta-analysis. *Can Med Assoc J*. 2012;184(3):E191-E196. doi:10.1503/cmaj.110829
136. Piper ME, McCarthy DE, Bolt DM, et al. Assessing dimensions of nicotine dependence: An evaluation of the Nicotine Dependence Syndrome Scale (NDSS) and the Wisconsin Inventory of Smoking Dependence Motives (WISDM). *Nicotine Tob Res*. 2008;10(6):1009-1020. doi:10.1080/14622200802097563
137. U.S. Department of Health and Human Services, National Institutes of Health. *Why Do You Smoke? (NIH Publication No. 87-1822)*. Bethesda, MD: NIH; 1987.
138. United States Department of Health and Human Services, National Institutes of Health, National Institute on Drug Abuse, U.S. Food and Drug Administration, Center for Tobacco Products. Population Assessment of Tobacco and Health (PATH) Study [United States] Public-Use Files. 2018. doi:10.3886/ICPSR36498.v8
139. Manning C, Gregoire A. Effects of parental mental illness on children. *Psychiatry*. 2006;5(1):10-12. doi:10.1383/psyt.2006.5.1.10

140. National Research Council, Institute of Medicine. Associations Between Depression in Parents and Parenting, Child Health, and Child Psychological Functioning. In: England M, Sim L, eds. *Depression in Parents, Parenting, and Children: Opportunities to Improve Identification, Treatment, and Prevention*. Washington D.C.: National Academies Press; 2009. https://www.ncbi.nlm.nih.gov/books/NBK215128/.
141. National Cancer Institute. NCI Tobacco Control Monograph 22: A Socioecological Approach to Addressing Tobacco-Related Health Disparities. https://cancercontrol.cancer.gov/brp/tcrb/monographs/22/docs/m22_complete.pdf. Published 2017.
142. Centers for Disease Control and Prevention. Tobacco Use Among Adults with Mental Illness and Substance Use Disorders. https://www.cdc.gov/tobacco/disparities/mental-illness-substance-use/index.htm. Published 2019.
143. The U.S. Food and Drug Administration (FDA). How FDA is Regulating E-Cigarettes. https://www.fda.gov/news-events/fda-voices-perspectives-fda-leadership-and-experts/how-fda-regulating-e-cigarettes. Published 2019.
144. Smith TT, Cassidy RN, Tidey JW, et al. Impact of smoking reduced nicotine content cigarettes on sensitivity to cigarette price: further results from a multi-site clinical trial. *Addiction*. 2017;112(2):349-359. doi:10.1111/add.13636
145. O'Brien EK, Nguyen AB, Persoskie A, Hoffman AC. U.S. adults' addiction and harm beliefs about nicotine and low nicotine cigarettes. *Prev Med (Baltim)*. 2017;96:94-100. doi:10.1016/j.ypmed.2016.12.048
146. Healthline. What COVID-19 Is Doing to Our Mental Health. https://www.healthline.com/health-news/what-covid-19-is-doing-to-our-mental-health. Published 2020.
147. Mortensen K, Hughes TL. Comparing Amazon's Mechanical Turk Platform to Conventional Data Collection Methods in the Health and Medical Research Literature. *J Gen Intern Med*. 2018;33(4):533-538. doi:10.1007/s11606-017-4246-0
148. Chaffee BW, Cheng J. Tobacco product initiation is correlated with cross-product changes in tobacco harm perception and susceptibility: Longitudinal analysis of the Population Assessment of Tobacco and Health youth cohort. *Prev Med (Baltim)*. 2018;114(December 2017):72-78. doi:10.1016/j.ypmed.2018.06.008
149. Choi K, Fabian L, Mottey N, Corbett A, Forster J. Young adults' favorable perceptions of snus, dissolvable tobacco products, and electronic cigarettes: Findings from a focus group study. *Am J Public Health*. 2012;102(11):2088-2093. doi:10.2105/AJPH.2011.300525
150. Pepper JK, Brewer NT. Electronic nicotine delivery system (electronic cigarette) awareness, use, reactions and beliefs: a systematic review. *Tob Control*. 2014;23(5):375-384. doi:10.1136/tobaccocontrol-2013-051122
151. Callaghan RC, Veldhuizen S, Jeysingh T, et al. Patterns of tobacco-related mortality among individuals diagnosed with schizophrenia, bipolar disorder, or depression. *J Psychiatr Res*. 2014;48(1):102-110. doi:10.1016/j.jpsychires.2013.09.014
152. Tulloch HE, Pipe AL, Clyde MJ, Reid RD, Els C. The Quit Experience and Concerns of Smokers With Psychiatric Illness. *Am J Prev Med*. 2016;50(6):709-718. doi:10.1016/j.amepre.2015.11.006
153. Substance Abuse and Mental Health Services Administration. Smoking and Mental Illness.
154. Goodwin RD, Sheffer CE, Chartrand H, et al. Drug Use, Abuse, and Dependence and the Persistence of Nicotine Dependence. *Nicotine Tob Res*. 2014;16(12):1606-1612. doi:10.1093/ntr/ntu115
155. Christiansen BA, Carbin J, TerBeek E, Fiore MC. Helping Smokers with Severe Mental Illness Who Do Not Want to Quit. *Subst Use Misuse*. 2018;53(6):949-962. doi:10.1080/10826084.2017.1385635
156. Siru R, Hulse GK, Tait RJ. Assessing motivation to quit smoking in people with mental illness: a review. *Addiction*. 2009;104(5):719-733. doi:10.1111/j.1360-0443.2009.02545.x
157. Secades-Villa R, Weidberg S, González-Roz A, Reed DD, Fernández-Hermida JR. Cigarette demand among smokers with elevated depressive symptoms: an experimental comparison with low depressive symptoms. *Psychopharmacology (Berl)*. 2018;235(3):719-728. doi:10.1007/s00213-017-4788-1
158. Ockene IS, Miller NH. Cigarette Smoking, Cardiovascular Disease, and Stroke: A Statement for Healthcare Professionals From the American Heart Association.

doi:https://doi.org/10.1161/01.CIR.96.9.3243
159. U.S. Department of Health and Human Services. *Population Assessment of Tobacco and Health (PATH) Study [United States] Public-Use Files*.; 2018. doi:10.3886/ICPSR36498.v9
160. Hyland A, Ambrose BK, Conway KP, et al. Design and methods of the Population Assessment of Tobacco and Health (PATH) Study. *Tob Control*. 2016;26(April 2014):tobaccocontrol-2016-052934. doi:10.1136/tobaccocontrol-2016-052934
161. Westat. *PATH Study Public Use Files: User Guide*.; 2019. https://www.icpsr.umich.edu/icpsrweb/NAHDAP/studies/36498/datadocumentation.
162. Huang J, Zheng R, Chaloupka FJ, Fong GT, Jiang Y. Differential responsiveness to cigarette price by education and income among adult urban Chinese smokers: findings from the ITC China Survey. *Tob Control*. 2015;24(Supplement 3):iii76-iii82. doi:10.1136/tobaccocontrol-2014-052091
163. Dennis MLT, Feeney MA, Laverne H, Stevens L, Bedoya BA. GAIN-SS Global Appraisal of Individual Needs– Short Screener (GAIN-SS): Administration and Scoring Manual. 2008;(309). https://dpi.wi.gov/sites/default/files/imce/sspw/pdf/gainssmanual.pdf.
164. Hamilton CM, Strader LC, Pratt JG, et al. The PhenX Toolkit: Get the Most From Your Measures. *Am J Epidemiol*. 2011;174(3):253-260. doi:10.1093/aje/kwr193
165. Dennis ML, Chan Y-F, Funk RR. Development and Validation of the GAIN Short Screener (GSS) for Internalizing, Externalizing and Substance Use Disorders and Crime/Violence Problems Among Adolescents and Adults. *Am J Addict*. 2006;15(s1):80-91. doi:10.1080/10550490601006055
166. Strong DR, Pearson J, Ehlke S, et al. Indicators of dependence for different types of tobacco product users: Descriptive findings from Wave 1 (2013–2014) of the Population Assessment of Tobacco and Health (PATH) study. *Drug Alcohol Depend*. 2017;178(May):257-266. doi:10.1016/j.drugalcdep.2017.05.010
167. Liu G, Wasserman E, Kong L, Foulds J. A comparison of nicotine dependence among exclusive E-cigarette and cigarette users in the PATH study. *Prev Med (Baltim)*. 2017:6-11. doi:10.1016/j.ypmed.2017.04.001
168. Buu A, Hu Y-H, Piper ME, Lin H-C. The association between e-cigarette use characteristics and combustible cigarette consumption and dependence symptoms: Results from a national longitudinal study. *Addict Behav*. 2018;84(March):69-74. doi:10.1016/j.addbeh.2018.03.035
169. Duan N. Smearing Estimate: A Nonparametric Retransformation Method. *J Am Stat Assoc*. 1983;78(383):605-610. doi:10.1080/01621459.1983.10478017
170. Dowd BE, Greene WH, Norton EC. Computation of Standard Errors. *Health Serv Res*. 2014;49(2):731-750. doi:10.1111/1475-6773.12122
171. Wang T, Asman K, Gentzke A, et al. Tobacco Product Use Among Adults — United States, 2017. *MMWR Morb Mortal Wkly Rep*. 2017;67(44). https://www.cdc.gov/mmwr/volumes/66/wr/mm6644a2.htm?s_cid=mm6644a2_w.
172. Hitsman B, Borrelli B, McChargue DE, Spring B, Niaura R. History of depression and smoking cessation outcome: A meta-analysis. *J Consult Clin Psychol*. 2003;71(4):657-663. doi:10.1037/0022-006X.71.4.657
173. National Alliance on Mental Illness (NAMI). Mental Health by the Numbers. https://www.nami.org/learn-more/mental-health-by-the-numbers. Published 2019.
174. National Institute on Drug Abuse. Electronic Cigarettes (E-cigarettes). DrugFacts. doi:10.1097/PRS.0000000000000196
175. Rom O, Pecorelli A, Valacchi G, Reznick AZ. Are E-cigarettes a safe and good alternative to cigarette smoking? *Ann N Y Acad Sci*. 2015;1340(1):65-74. doi:10.1111/nyas.12609
176. Reidel B, Radicioni G, Clapp PW, et al. E-Cigarette Use Causes a Unique Innate Immune Response in the Lung, Involving Increased Neutrophilic Activation and Altered Mucin Secretion. *Am J Respir Crit Care Med*. 2018;197(4):492-501. doi:10.1164/rccm.201708-1590OC
177. Singh T, Marynak K, Arrazola RA, Cox S, Rolle I V, King BA. *Vital Signs: Exposure to Electronic Cigarette Advertising Among Middle School and High School Students - United States, 2014*. Vol 64.; 2016:1403-1408. doi:10.15585/mmwr.mm6452a3

178. Dutra LM, Glantz SA. E-cigarettes and National Adolescent Cigarette Use: 2004–2014. *Pediatrics*. 2017;139(2):2004-2014. doi:10.1542/peds.2016-2450
179. Primack BA, Soneji S, Stoolmiller M, Fine MJ, Sargent JD. Progression to Traditional Cigarette Smoking After Electronic Cigarette Use Among US Adolescents and Young Adults. *JAMA Pediatr*. 2015;169(11):1018-1023. doi:10.1001/jamapediatrics.2015.1742
180. Abbasi J. FDA Extends Authority to e-Cigarettes: Implications for Smoking Cessation? *Jama*. 2016;316(6):572–74. doi:10.1001/jama.2016.8568
181. LaVito A. Tobacco stocks rise as FDA delays plan to cut nicotine levels in cigarettes. *CNBC*. https://www.cnbc.com/2019/11/20/tobacco-stocks-rise-on-report-that-fda-wont-cut-nicotine-levels-in-cigarettes.html. Published November 20, 2019.
182. Moore W, Pedlow S, Krishnamurty P, Wolter K. *National Longitudinal Survey of Youth 1997 (NLSY97) Technical Sampling Report*. Chicago, IL; 2000. https://www.nlsinfo.org/sites/nlsinfo.org/files/attachments/121221/TechnicalSamplingReport.pdf.
183. Centers for Disease Control. Coronavirus Disease 2019 (COVID-19). https://www.cdc.gov/coronavirus/2019-ncov/daily-life-coping/managing-stress-anxiety.html. Published 2020.

Appendices

Appendix 1-A

Sensitivity Analysis for AMI Classification Strategies

1. Smoking Participation

	Threshold: 60 (<60 indicates AMI)	**Threshold: 68** (<68 indicates AMI)	**Threshold: 76** (<76 indicates AMI)
AMI			
No	Ref	Ref	Ref
Yes	**0.02** (0.00, 0.04)	**0.03** (0.01, 0.05)	**0.02** (0.01, 0.04)
AMI * State Excise Tax	0.01 (-0.00, 0.03)	0.00 (-0.01, 0.02)	-0.00 (-0.02, 0.02)
State Excise Tax5	-0.01 (-0.02, 0.00)	-0.01(-0.02, 0.01)	-0.01 (-0.02, 0.01)
Tobacco Control Index	-0.00 (-0.01, 0.01)	-0.00 (-0.01, 0.01)	-0.00 (-0.01, 0.00)

2. Number of Days Smoked Cigarettes (Past 30-Days)

	Threshold: 60 (<60 indicates AMI)	**Threshold: 68** (<68 indicates AMI)	**Threshold: 76** (<76 indicates AMI)
AMI			
No	Ref	Ref	Ref
Yes	**0.05** (0.01, 0.09)	**0.04** (0.00, 0.07)	0.02 (-0.02, 0.06)
AMI * State Excise Tax	-0.01 (-0.04, 0.03)	0.00 (-0.03, 0.04)	0.01 (-0.03, 0.05)
State Excise Tax5	**-0.03** (-0.06, -0.00)	**-0.03**(-0.07, -0.00)	**-0.04** (-0.08, -0.01)
Tobacco Control Index	-0.00 (-0.02, 0.01)	-0.00 (-0.02, 0.01)	-0.00 (-0.02, 0.01)

3. Cigarettes Per Day (Past 30-Days)

	Threshold: 60 (<60 indicates AMI)	**Threshold: 68** (<68 indicates AMI)	**Threshold: 76** (<76 indicates AMI)
AMI			
No	Ref	Ref	Ref
Yes	**0.09** (0.02, 0.16)	0.05 (-0.01, 0.12)	0.05 (-0.01, 0.12)
AMI * State Excise Tax	0.01 (-0.04, 0.06)	-0.00 (-0.05, 0.05)	0.01 (-0.04, 0.07)
State Excise Tax5	-0.03 (-0.07, 0.01)	-0.03(-0.09, 0.02)	-0.04 (-0.10, 0.02)
Tobacco Control Index	-0.01 (-0.03, 0.01)	-0.00 (-0.03, 0.02)	-0.00 (-0.03, 0.02)

4. Total Consumption (Past 30-Days)

	Threshold: 60 (<60 indicates AMI)	**Threshold: 68** (<68 indicates AMI)	**Threshold: 76** (<76 indicates AMI)
AMI			
No	Ref	Ref	Ref
Yes	**0.09** (0.01, 0.16)	0.05 (-0.02, 0.11)	0.05 (-0.02, 0.12)
AMI * State Excise Tax	0.02 (-0.04, 0.07)	-0.01 (-0.05, 0.07)	0.02 (-0.04, 0.08)
State Excise Tax[5]	-0.05 (-0.09, 0.01)	-0.05 (-0.11, 0.02)	-0.06 (-0.12, 0.01)
Tobacco Control Index	-0.01 (-0.04, 0.02)	-0.01 (-0.03, 0.02)	-0.01 (-0.03, 0.02)

Appendix 1-B

Scoring Components of the American Lung Association's State of Tobacco Control Report[94]

Scoring Factor	**Components**
Tobacco Prevention and Control Spending	Total composite score based on each state's spending in the following categories, relative to the state-specific recommendation provided annually by the Centers for Disease Control and Prevention (CDC). 1) State and Community Interventions 2) Health Communication Interventions 3) Cessation Interventions 4) Surveillance and Evaluation 5) Administration and Management
Smokefree Air Laws	Score is a composite based on comprehensiveness of smokefree air requirements across a variety of setting such as schools, private and government-owned workspaces, and entertainment spaces, among others.
Access to Cessation Coverage (2008 and 2010)	Cessation Coverage (available for 2008 and 2010) scores represent each state's coverage of evidence-based cessation support, particularly for low-income and Medicaid-eligible residents.
Youth Access (2002-2006)	Scores are based on factors such as minimum age to purchase, packaging, and enforcement mechanisms for such policies, among others.
Excise Tax Rates (Not included in model results presented in this paper)	Scores are assigned in quintiles based on each state's excise tax rate for cigarettes compared to the mean rate among all states during each survey period.

Appendix 1-C

Sensitivity Analysis for Measurement of Price Variation

Table 1. Associations between Variation in AMI Symptoms, Price, and Smoking Behavior among NLSY97 Participants (2002-2010)

	Smoking Participation n=7,087	**Number of Days Smoked Cigarettes** ß (95% CI) n=2,599	**Cigarettes Per Day** ß (95% CI) n=2,555	**Total Cigarette Consumption** ß (95% CI) n=2,529
Real Cost Per Pack				
AMI				
No	Ref	Ref	Ref	Ref
Yes	0.06 (-0.13, 0.02)	**0.12** (0.01, 0.24)	-0.02 (-0.27, 0.24)	-0.03 (-0.30, 0.25)
AMI * Cost per Pack	**0.06** (0.01, 0.12)	-0.08 (-0.16, 0.01)	0.09 (-0.10, 0.28)	0.10 (-0.11, 0.30)
Average Cost Per Pack	-0.04 (-0.09, 0.01)	**-0.13** (-0.22, -0.04)	-0.15 (-0.36, 0.05)	-0.21 (-0.43, 0.01)
Tobacco Control Index	-0.01 (-0.01, 0.01)	-0.01 (-0.02, 0.01)	-0.01 (-0.03, 0.02)	-0.01 (-0.03, 0.02)
Excise Tax				
AMI				
No	Ref	Ref	Ref	Ref
Yes	**0.04** (0.02, 0.05)	0.01 (-0.01, 0.03)	**0.10** (0.06, 0.15)	**0.11** (0.06, 0.16)
AMI * State Excise Tax	0.01 (-0.01, 0.02)	-0.01 (-0.03, 0.01)	0.01 (-0.04, 0.05)	0.01 (-0.04, 0.07)
State Excise Tax	-0.01 (-0.01, 0.01)	**-0.02** (-0.03, -0.01)	-0.01 (-0.06, 0.03)	-0.03 (-0.07, 0.02)
Tobacco Control Index	-0.01 (-0.01, 0.01)	-0.01 (-0.02, 0.01)	-0.01 (-0.03, 0.02)	-0.01 (-0.03, 0.02)

Bolded p-values indicate statistical significance <0.05.

Notes:

1. Fixed effects Poisson regressions tested associations between smoking behavior, AMI, and state tax rates over time. All models adjusted for sociodemographic and time covariates.
2. Number of days smoked refers to the number of days within the past 30-days a participant smoked cigarettes.
3. Cigarettes per day represents the average number of cigarettes smoked on days smoking in the past 30-days.
4. Total consumption in the past 30-days was constructed by multiplying the number of cigarettes smoked per day by the number of days a participant smoked cigarettes in the past 30 days.
5. Real cost per pack obtained from Orzechowski and Walker's *The Tax Burden on Tobacco, 1970-2018.* (https://chronicdata.cdc.gov/Policy/The-Tax-Burden-on-Tobacco-1970-2018/7nwe-3aj9).
6. State Excise Tax is the tax rate facing each participant during each survey period.

Appendix 1-D

Sensitivity Analysis for Inclusion of Prior Smoking Behavior to Account for Addictive Potential of Cigarettes

Table 1. Associations between Variation in AMI Symptoms, Excise Tax, Prior Smoking, and Smoking Behavior among NLSY97 Participants (2004-2010)

	Smoking Participation ß (95% CI) n=6,998	**Number of Days Smoked Cigarettes** ß (95% CI) n=1,806	**Cigarettes Per Day** ß (95% CI) n=1,783	**Total Cigarette Consumption** ß (95% CI) n=1,744
Prior Tobacco Use				
$Behavior_{t-1}$	**-0.08** (-0.10, -0.06)	**-0.01** (-0.01, -0.01)	**-0.01** (-0.01, -0.01)	**-0.01** (-0.01, -0.01)
AMI				
No	Ref	Ref	Ref	Ref
Yes	**0.03** (0.01, 0.04)	0.20 (-0.01, 0.04)	**0.10** (0.05, 0.16)	**0.10** (0.05, 0.16)
AMI * ln(State Excise Tax)	0.01 (-0.01, 0.02)	0.01 (-0.01, 0.03)	0.04 (-0.02, 0.10)	0.05 (-0.01, 0.12)
ln(State Excise Tax)	-0.01 (-0.02, 0.01)	-0.02 (-0.04, 0.01)	-0.02 (-0.08, 0.03)	-0.04 (-0.10, 0.02)
Tobacco Control Index	-0.01 (-0.01, 0.01)	-0.01 (-0.02, 0.01)	-0.02 (-0.04, 0.01)	-0.02 (-0.05, 0.01)
Without Prior Tobacco Use				
AMI				
No	Ref	Ref	Ref	Ref
Yes	**0.03** (0.01, 0.04)	0.01 (-0.01, 0.03)	**0.11** (0.06, 0.16)	**0.12** (0.06, 0.17)
AMI * State Excise Tax	0.01 (-0.01, 0.02)	-0.01 (-0.03, 0.02)	0.02 (-0.03, 0.07)	0.04 (-0.02, 0.09)
ln State Excise Tax	-0.01 (-0.02, 0.01)	**-0.02** (-0.04, -0.01)	-0.02 (-0.07, 0.02)	-0.04 (-0.09, 0.01)
Tobacco Control Index	-0.01 (-0.01, 0.01)	-0.01 (-0.01, 0.01)	-0.01 (-0.04, 0.02)	-0.01 (-0.04, 0.02)

Bolded p-values indicate statistical significance <0.05.

Notes:

1. Fixed effects linear and Poisson regressions tested associations between smoking behavior, AMI, and state tax rates over time. All models adjusted for sociodemographic and time covariates. Years included in all models were 2004-2010 to allow for congruence between models (2002 not included because no lagged value of behavior available for time period one).
2. Prior tobacco use refers to use in the previous period for each participant.
3. Number of days smoked refers to the number of days within the past 30-days a participant smoked cigarettes.
4. Cigarettes per day represents the average number of cigarettes smoked on days smoking in the past 30-days.
5. Total consumption in the past 30-days was constructed by multiplying the number of cigarettes smoked per day by the number of days a participant smoked cigarettes in the past 30 days.

Appendix 2-A

Electronic Cigarettes

Electronic cigarettes (e-cigarettes), also referred to as electronic vapor products or electronic nicotine delivery systems (ENDS), are battery-operated devices that produce an inhalable aerosol by heating liquid (e-liquid) that frequently contains nicotine, different flavoring alternatives, and many other chemicals. Different designs abound: some e-cigarettes are designed to mimic the look and feel of a conventional cigarette or other combustible product, others are made to resemble items such as pens or devices such as a USB drive, and some users purchase fillable tank systems. Despite variations in design, and whether they are disposable or reusable and refillable, these devices generally all have some type of reservoir (to hold e-liquid), a battery or power source, a heating element, and a mouthpiece. There are currently over 450 e-cigarette brands available to users.[174] Research suggests that e-cigarettes may be less harmful than combustible cigarettes, but that they are not free from risk.[109,175,176] E-cigarettes are increasingly popular among youth and young adults in the U.S.,[177,178] and since they frequently contain nicotine, this has raised concern that initiating e-cigarette use could also lead to later use of combustible products.[179] The U.S. FDA finalized rules in 2016 extending its regulatory authority to electronic vapor products such as e-cigarettes, and continues to evaluate policy options to regulate these products.[17,180]

Low Nicotine Cigarettes

Low nicotine cigarettes are combustible cigarettes in which the nicotine content in the cigarette has been reduced by the manufacturer from levels of nicotine in conventional production. Manufacturers can achieve this outcome by creating tiny ventilation holes to reduce a smoker's intake of nicotine when smoking, or through incorporating lower-nicotine tobacco into their cigarettes.[145] The U.S. FDA is currently considering a policy strategy that would require cigarette manufacturers to reduce the concentration of nicotine in cigarettes to reduce the addictive potential (abuse liability) of combustible cigarettes,[117] though that policy initiative has

recently been postponed.[181] This policy strategy signals to the public that, while addictive regardless of how it is delivered to the user, the methods of ingesting nicotine are not all equal in terms of expected risk from the perspective of the FDA.[16] For example, while a smoker could theoretically choose to consume a specific amount of nicotine each day via consumption of their traditional brand of combustible cigarette, they could also, in theory ingest that same amount of nicotine through use of an electronic vapor product, yet face different risks to their health over the long term. While e-cigarettes, for example, are not without health risk, they are widely considered to be less harmful than combustible cigarettes.[109,175,176] Incorporating combustible cigarettes with lower abuse liability into the market could encourage smokers to switch to less harmful alternatives, however further evidence is required to form expectations about exactly how smokers would respond to such a shift.

Appendix 2-B

Study Screener (restricted to adults ages 18+ who use a U.S-based IP address)

1. Are you over the age of 18?
   a. Yes
   b. No (If no, ineligible)

2. Have you ever smoked a cigarette, even one or two puffs?
   a. Yes
   b. No (If no, ineligible)

3. Do you now smoke cigarettes:
   a. Every Day
   b. Some Days
   c. Not at All (if Not at All, ineligible)

4. How many cigarettes have you smoked in your entire life? A pack usually has 20 cigarettes.
   a. 1 or more puffs but never a whole cigarette
   b. 1-10 cigarettes (less than or equal to half of a pack)
   c. 11-20 cigarettes (1/2 to 1 whole pack)
   d. 21-50 cigarettes
   e. 51-99 cigarettes/100 or more cigarettes (5 packs or more) (if fewer than 100, ineligible)

5. Over the last 2 weeks, how often have you been bothered by any of the following problems?
   a. Little interest or pleasure in doing things
      i. Not at all
      ii. Several days
      iii. More than half the days
      iv. Nearly every day

   b. Little interest or pleasure in doing things
      i. Not at all
      ii. Several days
      iii. More than half the days
      iv. Nearly every day

(Not at all=0 and Nearly every day=3. Generate total score for 4a and 4b, score lower than 3 deemed "No AMI" and score 3 or greater deemed "AMI).[124]

Appendix 2-C

Own Brand Cigarette Purchase Task

Imagine a TYPICAL DAY during which you smoke. The following questions ask how many times you would take 10 puffs of your own brand of cigarettes if they cost various amounts of money. The only available cigarettes are your own brand. Assume that you have the same income/savings that you have now and NO ACCESS to any cigarettes or nicotine products other than those offered at these prices. In addition, assume that you would consume cigarettes that you request on that day; that is, you cannot save or stockpile cigarettes for a later date. Please respond to these questions honestly.

[Please note the following two sentences will be displayed for each of the **X** prices below. Participants will continue on this task until either they make purchases at all of the prices, or they elect to purchase zero on two successive prices]

-If 10 puffs of your own brand of cigarettes cost **X**: How many **times** would you buy 10 puffs to consume in one day?

- You would buy 10 puffs of your own brand of cigarettes **Y times** if they cost **X** each?
1= Yes
2 = Change Answer

Y times you would buy 10 puffs of your own brand cigarette (numeric response by participant)	*X (price)*
	$0 (free)
	$0.01
	$0.02
	$0.04
	$0.08
	$0.16
	$0.32
	$0.64
	$1.28
	$2.56
	$3.84
	$5.12
	$6.40
	$7.68
	$8.96
	$10.24

Appendix 2-D

Cross-product Cigarette Purchase Task: Note-This task was performed four times: once for each of the four alternatives products. The low nicotine combustible cigarette condition is shown below.

Instructions: Now imagine another TYPICAL DAY during which you smoke. The following questions ask how many times you would take 10 puffs of a cigarette or 10 puffs of a cigarette with half the amount of nicotine as your own-brand cigarette if your brand cigarettes cost various amounts of money. The available cigarettes are your own brand. Assume that you have the same income/savings that you have now, but this time, assume that 10 puffs of the low nicotine cigarette are also available at a fixed price of $1. In addition, assume that you would consume the products that you request on that day. That is, you cannot save or stockpile cigarettes or low nicotine cigarettes for a later date. Please respond to these questions honestly.

[Please note the following two sentences will be displayed for each of the **X1/X2** prices below. Participants will continue on this task until either they make purchases at all of the prices, or they elect to purchase zero on two successive prices]

-If 10 puffs of your own brand of cigarettes cost **X1** and 10 puffs of a low nicotine cigarette cost **X2**: How many **times** would you buy 10 own brand puffs and/or 10 puffs of the low nicotine cigarette to consume in one day?

- You would buy 10 puffs of your own brand of cigarettes **Y1 times** if they cost **X1** each and 10 puffs of the low nicotine cigarette puffs **Y2 times** if they cost **X2** each?
1= Yes
2 = Change Answer

Y1 times you would buy 10 puffs of your own brand cigarette (numeric response by participant)	*X1 (own brand price)*	*Y2 times you would buy 10 puffs of a low nicotine cigarette (numeric response by participant)*	*X2 (low nicotine cigarette price)*
	$0 (free)		$1.00
	$0.01		$1.00
	$0.02		$1.00
	$0.04		$1.00
	$0.08		$1.00
	$0.16		$1.00
	$0.32		$1.00
	$0.64		$1.00
	$1.28		$1.00
	$2.56		$1.00
	$3.84		$1.00
	$5.12		$1.00
	$6.40		$1.00
	$7.68		$1.00
	$8.96		$1.00
	$10.24		$1.00

Appendix 3-A

The following tables provide information about the role of model choice in predicting key coefficients of interest in models of smoking behavior.

Table 1. Total Cigarette Consumption

	Pooled OLS	Random Effects	Fixed Effects	Fixed Effects (AMI Time Invariant)
AMI	**-0.15** (-0.24, 0.06)	-0.03 (-0.11, 0.06)	0.05 (-0.05, 0.14)	--
AMI*High Dependence	**0.22** (0.12, 0.33)	**0.12** (0.02, 0.22)	0.06 (-0.05, 0.17)	**0.17** (0.03, 0.31)
High Dependence	**0.68** (0.62, 0.74)	**0.54** (0.48, 0.60)	**0.27** (0.20, 0.35)	**0.20** (0.10, 0.,31)
Internalizing	0.04 (-0.07, 0.14)	0.05 (-0.05, 0.15)	0.03 (-0.08, 0.15)	--
Internalizing * High Dependence	-0.03 (-0.10, 0.15)	0.06 (-0.06, 0.18)	0.10 (-0.03, 0.24)	0.14 (-0.03, 0.30)
Externalizing	**-0.28** (-0.41, -0.16)	**-0.12** (-0.22, -0.01)	0.03, -0.08, 0.15)	--
Externalizing * High Dependence	**0.30** (0.15, 0.44)	0.09 (-0.05, 0.23)	-0.08 (-0.23, 0.08)	0.05 (-0.12, 0.22)
High Dependence	**0.69** (0.63, 0.75)	**0.55** (0.49, 0.61)	**0.28** (0.20, 0.36)	**0.21** (0.11, 0.31)

Regarding total cigarette consumption, the pooled model reveals a significant negative association between experiencing any AMI symptoms and consumption, as well as a positive association for the moderating effect of AMI on the association between high dependence and cigarette consumption, and for high dependence alone (Table 1, Column 1). A random effects model takes into account the panel structure of the data, which reduces the magnitude and statistical significance of the association between AMI and consumption and reduces the magnitude of the significant association between an interaction between AMI and high dependence, and high dependence alone (Column 2). However, a random-effects model uses information from both within and between participants, therefore it does not control for unobservable and time-invariant, individual-level factors that are known to be associated with variation in consumption, such as sex, race/ethnicity, highest educational attainment, cultural attitudes about tobacco use, tobacco policies to which a participant would be subject, and peer and family smoking.

The fixed effects model reveals that once we try to account for time-invariant factors at the participant level, only high dependence is significantly associated with consumption, and the magnitude of that association is reduced again (Column 3). These patterns are similar across the two other smoking behavior outcomes measured in this study, making a quit attempt and achieving self-reported cessation (Tables 2 and 3, below).

The weakness of the fixed effect model is that it relies upon data from those who have experienced a change in their AMI status during the study period, and it relies upon the precision of the instrument measuring AMI to accurately capture the presence or absence of symptoms as they may influence coping behaviors such as smoking. A number of other studies have employed a lifetime measure of AMI, as many individuals who experience symptoms of AMI may do so more than once in their lifetimes, for any extended period of time without or before diagnosis or treatment, and the severity of symptoms may fluctuate. Models summarized in column 4 employed fixed effects and allowed AMI to be ‘fixed’ during the study period for any participant who experienced symptoms during the four time periods during which data were collected. This is more closely aligned with an approach, taken in several previous studies in this area, that would employ lifetime AMI to represent mental health. In doing so, we observed that highly dependent smokers, and highly dependent smokers with AMI smoked more cigarettes than those with low dependence and no AMI symptoms. The

weakness of an approach that employs lifetime AMI, or any AMI during the study period, is that it allows for confusion about temporality under certain conditions, such as those in which a participant who smokes across all waves without AMI symptoms may experiences a stressful life event during Wave 4 data collection and be classified as having AMI during that period, and therefore all periods under this approach.

Of all 3,919 participants who experienced AMI during the four waves of the PATH Study used in this analysis, 357 participants in the sample met this criterion (9%). Of those 357 participants, 51 had reported that they had quit smoking (and not resumed) before Wave 4 data collection, therefore the number of participants for whom this scenario would be a threat to our overall interpretation was relatively small. Finally, in models employing a time carrying measure of AMI, disaggregating internalizing from externalizing symptoms revealed that significant associations between AMI and consumption appeared to be largely driven by experience of externalizing symptoms (impulsivity or behavior disorders), whereas a time-invariant fixed effects model revealed that experience of internalizing symptoms was most significantly associated with reduced success in achieving self-reported cessation.

Table 2. Probability of Making a Quit Attempt

	Pooled OLS	Random Effects	Fixed Effects	Fixed Effects (AMI Time Invariant)
AMI	**-0.06** (-0.04, 0.09)	**0.05** (0.03, 0.07)	0.01 (-0.02, 0.03)	--
AMI*High Dependence	**-0.03** (-0.06, -0.01)	-0.02 (-0.05, 0.01)	-0.00 (-0.04, 0.03)	-0.01 (-0.05, 0.04)
High Dependence	-0.00 (-0.02, 0.01)	-0.01 (-0.02, 0.01)	-0.02 (-0.05, 0.00)	-0.02 (-0.05, 0.01)
Internalizing	**0.03** (0.01, 0.06)	0.02 (-0.01, 0.05)	-0.02 (-0.05, 0.01)	--
Internalizing * High Dependence	-0.02 (-0.05, 0.02)	-0.01 (-0.04, 0.03)	0.02 (-0.02, 0.06)	0.01 (-0.04, 0.06)
Externalizing	**0.07** (0.04, 0.10)	**0.06** (0.03, 0.09)	**0.04** (0.01, 0.07)	--
Externalizing * High Dependence	-0.03 (-0.07, 0.01)	-0.03, -0.07, 0.01)	-0.03 (-0.08, 0.01)	-0.03 (-0.08, 0.02)
High Dependence	-0.00 (-0.02, 0.01)	-0.01 (-0.02, 0.01)	-0.02 (-0.05, 0.00)	-0.01 (-0.04, 0.02)

Table 3. Probability of Achieving Self-Reported Cessation

	Pooled OLS	Random Effects	Fixed Effects	Fixed Effects (AMI Time Invariant)
AMI	**0.02** (0.01, 0.04)	**0.02** (0.01, 0.03)	-0.00 (-0.02, 0.02)	--
AMI*High Dependence	**-0.06** (-0.07, -0.04)	**-0.05** (-0.06, -0.03)	-0.02 (-0.04, 0.00)	**-0.04** (-0.06, -0.01)
High Dependence	**-0.01** (-0.02, -0.01)	**-0.01** (-0.02, -0.01)	0.01 (-0.00, 0.03)	**0.03** (0.01, 0.05)
Internalizing	0.01 (-0.01, 0.03)	0.01 (-0.01, 0.03)	-0.01 (-0.02, 0.02)	--
Internalizing * High Dependence	**-0.04** (-0.06, -0.02)	**-0.04** (-0.06, -0.02)	-0.02 (-0.04, 0.01)	**-0.04** (-0.07, -0.02)
Externalizing	0.02 (-0.00, 0.04)	0.02 (-0.00, 0.03)	0.01 (-0.02, 0.03)	--
Externalizing * High Dependence	**-0.03** (-0.05, -0.01)	**-0.02** (-0.05, -0.00)	-0.01 (-0.04, 0.02)	-0.02 (-0.05, 0.01)
High Dependence	**-0.02** (-0.02, -0.01)	**-0.01** (-0.02, -0.01)	0.,01 (-0.00, 0.03)	**0.03** (0.01, 0.05)