Nicotine & Tobacco Research, 2018, 1–8
doi:10.1093/ntr/nty120
Original investigation
Received September 8, 2017; Editorial Decision June 7, 2018; Accepted June 14, 2018
Advance Access publication June 16, 2018

Original investigation

Socioeconomic Disparities in Electronic Cigarette Use and Transitions from Smoking

Abigail S. Friedman PhD[1], Samantha J.L. Horn MA[2]

[1]Department of Health Policy and Management, Yale School of Public Health, New Haven, CT; [2]Global Poverty Research Lab, Northwestern University, Evanston, IL

Corresponding Author: Abigail S. Friedman, PhD, Department of Health Policy and Management, Yale School of Public Health, 60 College Street, Rm. 303, New Haven, CT 06520-8034, USA. Telephone: 203-785-5760; E-mail: abigail.friedman@yale.edu

Abstract

Introduction: Socioeconomic disparities have been established for conventional cigarette use, but not for electronic cigarettes. This study estimates socioeconomic gradients in exclusive use of conventional cigarettes, electronic cigarettes, and dual use (ie, use of both products) among adults in the United States.

Methods: Analyses consider nationally representative data on 25- to 54-year-old respondents to the 2014–2016 National Health Interview Surveys (N = 50 306). Demographically adjusted seemingly unrelated regression models estimate how two socioeconomic status measures—respondent education and household income—relate to current exclusive use of conventional cigarettes, electronic cigarettes, and dual use.

Results: Conventional cigarette use exhibits negative education and income gradients, consistent with existing research: −12.9 percentage points (confidence interval [CI]: −14.0, −11.8) if college educated, and −9.5 percentage points (CI: −10.9, −8.1) if household income exceeds 400% of the federal poverty level. These gradients are flatter for dual use (−1.4 [CI: −1.8, −0.9] and −1.9 [CI: −2.5, −1.2]), and statistically insignificant for electronic cigarette use (−0.03 [CI: −0.5, 0.4] and −0.3 [CI: −0.8, −0.2]). Limiting the sample to ever-smokers, higher education is associated with a 0.9 percentage point increase in likelihood of exclusive electronic cigarette use at interview (CI: 0.0, 1.9).

Conclusions: Education and income gradients in exclusive electronic cigarette use are small and statistically insignificant, contrasting with strong negative gradients in exclusive conventional cigarette use. Furthermore, more educated smokers are more likely to switch to exclusive e-cigarette use than less educated smokers. Such differential switching may exacerbate socioeconomic disparities in smoking-related morbidity and mortality, but lower the burden of tobacco-related disease.

Implications: Research has not yet established whether socioeconomic disparities in electronic cigarette (e-cigarette) use resemble those observed for conventional cigarettes. This article uses nationally representative data on US adults aged 25–54 to estimate income and education gradients in exclusive use of conventional cigarettes, e-cigarettes, and dual use. Both gradients are steep and negative for conventional cigarette use, but flat and statistically insignificant for e-cigarette use. Repeating the analysis among ever-smokers indicates that more educated smokers are more likely to transition toward exclusive e-cigarette use than less educated smokers. Such differential substitution may exacerbate disparities in smoking-related morbidity and mortality.

Introduction

Socioeconomic disparities in conventional cigarette use are well documented, and a potential driver of inequities in life expectancy within the US population,[1,2] as well as morbidity differentials in tobacco-related diseases.[3,4] However, socioeconomic disparities in use of electronic cigarettes (e-cigarettes), as well as that product's impact on disparities in conventional cigarette use, remain unclear.[5] This information is critical for public health and policy, as such effects could have substantive implications for disparities in tobacco-related morbidity and mortality.

As current research finds substantially lower health risks from vaping (e-cigarette use) than smoking (conventional cigarette use),[6–9] smokers who substitute away from conventional cigarettes toward e-cigarettes would be expected to face lower health risks than those who continue smoking.[10,11] Moreover, e-cigarettes generally deliver lower doses of nicotine than conventional cigarettes, and studies assessing second-hand exposure to e-cigarette vapor find lower health risks (if any) compared with second-hand smoke.[6] Consequently, socioeconomic disparities in substitution from conventional to electronic cigarettes could shift existing disparities in tobacco-related diseases and mortality.

Relationships between socioeconomic status (SES) and health behaviors are long established and well documented.[1,12–14] Such studies have measured SES in terms of occupation, education, income, and status differences, depending on the analysis. Here, we focus on education and income, as both have shown strong and persistent associations with smoking rates,[15–17] and are well measured in our data: the 2014–2016 National Health Interview Surveys (NHIS).

Using 2015 NHIS data, Jamal et al. observe smoking rates of 19.8% for high school graduates, compared with 7.6% for those with an undergraduate degree.[17] Heterogeneity is also evident by income level: current smoking rates for individuals below the federal poverty threshold were nearly twice as high as for individuals above the threshold.[17] Considering a variety of different datasets, Cutler and Lleras-Muney estimate that differences in economic resources account for about 20% of smoking's education gradient.[1] Thus, it is particularly important that analyses of either education or income disparities in tobacco use consider both differentials, in order to separate these associations.

Research has not yet established whether e-cigarette use exhibits similar income and education disparities to those observed for conventional cigarettes. Hartwell et al.'s systematic review of sociodemographic differences in e-cigarette use internationally finds 13 studies considering education gradients in current e-cigarette use and 7 considering gradients by income or affluence.[5] Findings are mixed. While awareness of e-cigarettes appears more common in higher educated groups, studies focusing on current e-cigarette use varied: positive, negative, and nonsignificant gradients by educational attainment were evinced, depending on the analysis. Considering studies of disparities by income/affluence, the authors conclude that "no clear pattern emerged."

Focusing on the US context, this study uses the three most recent years of annual, repeated cross-section data from the nationally representative National Health Interview Surveys (2014–2016), on adults aged 25–54. First, seemingly unrelated regression analyses estimate the education and income gradients in exclusive use of conventional cigarettes, e-cigarettes, and dual use (ie, use of both products) among US adults, adjusting for demographic differences. Second, these regressions are repeated in a subsample limited to ever-smokers. As, in our data, the vast majority of ever-smokers who now use e-cigarettes tried conventional cigarettes before e-cigarettes became available on the US market, estimating SES differentials in e-cigarette use among the subsample of ever-smokers allows us to test for SES disparities in transitions from smoking to exclusive e-cigarette use. Results clarify the latter product's implications for SES disparities in adult conventional cigarette use, as well as tobacco-related morbidity and mortality. While the analyses presented here are not causal and cannot pinpoint the mechanisms behind the SES differentials they identify, their results provide critical information to researchers and policymakers interested in understanding how electronic cigarettes may contribute to or mitigate existing tobacco-related health inequalities, given differential patterns of use.

Methods

Data come from the three most recent National Health Interview Surveys (NHIS 2014, 2015, and 2016), the only years in which survey questions asked about e-cigarette use thus far. These nationally representative datasets are repeated cross-sections, each of which covers approximately 35,000 US households. The survey collects self-reported information on health status, access, and behaviors, as well as household demographics. Analyses restrict consideration to adults aged 25–54, with the lower age cut-off defined to ensure that our education measure captures completed education and the upper age cut-off set to reduce the likelihood of differential mortality due to tobacco use in our sample. This leaves an analytic sample of 50,306 respondents.

Measures

Dependent variables

Three binary outcome variables are considered: (1) current use of conventional cigarettes only, (2) current use of e-cigarettes only, and (3) current use of both conventional cigarettes and e-cigarettes (ie, dual use). Respondents are classified as current conventional cigarette users if they report having used at least 100 cigarettes in their lifetime and report now using some days or daily. Respondents are classified as current e-cigarette users if they now use e-cigarettes some days or daily. (The NHIS lacks a minimum lifetime consumption question for e-cigarettes.) Thus, the respective outcome variables equal one if the respondent qualifies as (1) a current conventional cigarette user but not a current e-cigarette user (17.2% of our sample), (2) a current e-cigarette user but not a current conventional cigarette user (1.4% of our sample), or (3) both a current conventional cigarette user and a current e-cigarette user (2.7% of our sample).

Socioeconomic status

SES is captured through both education and income indicators. For ease of interpretation, a binary education variable is used, indicating whether an individual has completed one or more years of college. Income measures are based on each household's prior year income as a percent of the federal poverty level (FPL) for their state and number of household members. This measure adjusts the raw income data for both household size and variation in purchasing power between Alaska, Hawaii, and the contiguous 48 states. To allow for the possibility of a nonlinear relationship between income and tobacco use, percent-of-poverty indicators are defined as a series of dummy variables, indicating whether the respondent's household is within 0%<100%, 100%<200%, 200%<400%, or ≥400% of the FPL.

Additional independent variables

Additional controls include binary indicators for sex, 5-year age groups, US citizenship status, race (White, Black, Asian, Other race), ethnicity, veteran status, survey year, whether the respondent has health insurance, and poor mental health. The latter signifies a score of 13 or higher on the Kessler Psychological Distress Scale (K6), a six-item scale addressing levels of mental distress in the 30 days prior to the survey. The K6 cut-off of 13+ has been validated as indicative of having a DSM-IV nonsubstance abuse disorder.[18] While regressions often do not include veteran status, US citizenship, insurance coverage, and poor mental health as demographic controls, these variables are each related to socioeconomic status as well as conventional cigarette use, including through differentials in incentives for early smoking initiation as well as access to smoking cessation aids. Including these controls does not allow a causal interpretation of the education and income indicators. It does, however, remove some of the more obvious sources of confounding.

Statistical Analysis

We begin by calculating the prevalence of each of the aforementioned socioeconomic and demographic characteristics, in the full sample and by product choice. Next, seemingly unrelated regression techniques are used to simultaneously estimate three linear probability models, which test how each of the three outcome variables is associated with both income and education, adjusting for all of the aforementioned independent variables to account for demographic differences in product choice.[19,20] The seemingly unrelated regression method allows for correlation in the error terms across equations. Consistent with the goal of estimating SES gradients for the US adult population, this approach tells us how the SES measures relate to each outcome variable, taking all population members who do not use that product as the comparison group. A multinomial choice approach is not used, as it takes individuals who engage in none of the choice-behaviors as the comparison group instead of all remaining population members (ie, its SES coefficients would not reflect the full population's SES gradient in each behavior, and one could shift the estimates simply by adding more outcomes to the model in a manner that changes the comparison group).

Cluster-robust SE address heteroskedasticity concerns related to the use of linear models with binary outcome variables. Moreover, with all independent variables specified as binary indicators, our regressions avoid imposing the same linearity restrictions as a linear probability model with continuous independent variables.[21] Wald tests are used to compare coefficients across regressions.

Given broad differences in the rates of exclusive smoking, exclusive vaping, and dual use, further adjustments are needed to understand these coefficients' implications. To this end, we use the regression equations to estimate the likelihood of each choice-outcome under two counterfactual scenarios: (1) as if all respondents were low education and (2) as if all respondents were in the lowest income group, with all other characteristics unchanged. Specifically, data on each respondent are input into the estimated regression equation to generate predicted-y-values, with the only change being that, for all individuals, the education indicator is set to 0 (counterfactual scenario 1) or the income indicators are set to 0 (counterfactual scenario 2). A sample-weighted average of the resulting estimates is taken across all respondents, to estimate the average likelihood of each outcome under the corresponding counterfactual. Dividing the education (income) coefficient by the choice-outcome's likelihood in the low education (low income) scenario yields an estimate of the percent change in the average population-member's likelihood of using that product, associated with going from low to high education (income). These percent change estimates can be more reasonably compared across outcomes, as they account for the different rates of each behavior in the population.

Finally, the aforementioned regressions are repeated in a subsample limited to ever-smokers; that is, those respondents who report having smoked at least 100 conventional cigarettes in their lifetime. Critically, the vast majority of adult e-cigarette users in the United States are ever-smokers (93.3% in our sample), and, in our data, most adult ever-smokers who report using e-cigarettes at interview initiated smoking before e-cigarettes became available on the US market in late 2006/early 2007 (89.2%). While order of initiation cannot be established for those who began smoking in 2006 or later (because the NHIS asks about age at first conventional cigarette use but not age at first e-cigarette use), US e-cigarette consumption only began to climb markedly in 2012, such that many of those adults who began smoking post-2005 are also expected to have tried conventional cigarettes before e-cigarettes.[22] Thus, within the ever-smoker subsample, the exclusive e-cigarette use regression's education and income coefficients can help clarify whether SES differentials are present in smokers' transitions to exclusive e-cigarette use.

NHIS sampling weights are applied in all regressions to ensure representativeness, with SE clustered according to the sampling units provided by the NHIS.[23] All analyses are conducted using Stata 14.

The Yale Institutional Review Board deemed this research exempt from IRB review.

Results

Table 1 provides summary statistics with separate columns for the full sample, conventional cigarette users only, e-cigarette users only, and dual users. 65.8% of the sample is college educated (ie, has completed at least 1 year of college), and 28.3% of individuals live in households with incomes below 200% of the FPL. Education and income levels appear higher for exclusive e-cigarette users (67.3% college educated, 30.7% with incomes below 200% FPL) than dual users (53.7% college educated, 42.7% with incomes below 200% FPL), and higher for dual users than exclusive conventional cigarette users (45.9% college educated, 43.0% with incomes below 200% FPL). E-cigarette use is highest for current smokers (13.7%), and previous smokers (7.3%), but very low for never smokers (0.4%; results not shown).

Regression results for the full analytic sample are reported in Table 2. Reassuringly, findings for exclusive conventional cigarette use are consistent with the current literature[17]: more educated, higher income individuals are significantly less likely to smoke (−12.9 percentage points if college educated [CI: −14.0, −11.8]; −4.4 percentage points for households with income at 200% to <400% of poverty [CI: −5.9, −2.9]; and −9.5 percentage points for household incomes greater than or equal to 400% FPL [CI: −10.9, −8.1]). However, patterns for exclusive e-cigarette use do not match those for conventional cigarettes: neither being higher income nor having completed at least a year of college yield statistically significant reductions in the likelihood of current e-cigarette use, with point estimates close to zero (−0.3 and −0.03 percentage points, respectively). For both college education and the two highest income brackets, the e-cigarette-only and conventional cigarette-only coefficients differ significantly, with p-values below 0.001 (see Table 3, column 1).

Table 1. Summary Statistics by Type of Current Tobacco Product Usage

	Full sample	Conventional cigarette use only	Electronic cigarette use only	Dual use
Age	39.55 (8.76)	39.68 (9.17)	37.25 (8.05)	39.63 (9.32)
Female	50.87	45.95	38.42	45.83
Socioeconomic characteristics				
College educated	65.84	45.90	67.30	53.70
Poverty ratio: 0 to <100%	11.55	20.00	9.43	19.03
Poverty ratio: 100 to <200%	16.76	23.03	21.29	23.70
Poverty ratio: 200 to <400%	27.47	29.08	31.51	26.85
Poverty ratio: ≥400%	38.66	23.50	33.29	25.65
Poverty ratio: Unknown	0.87	1.04	0.57	1.64
Race/ethnicity				
White	76.68	78.01	81.72	85.20
Black	13.08	14.27	8.41	6.76
Asian	1.02	1.31	1.84	1.38
Other race	9.21	6.41	8.03	6.67
Hispanic	18.50	12.35	9.20	6.44
Other characteristics				
Non-US citizen	12.00	7.40	5.65	2.14
Veteran	5.63	7.19	12.43	11.13
Insured	84.45	75.25	82.57	77.48
Poor mental health	7.23	12.10	6.15	12.40
N	50306	8642	688	1338

Data are on 25- to 54-year-old respondents to the 2014, 2015, and 2016 National Health Interview Surveys. This table presents the mean of each variable for the full sample and by type of (current) cigarette use. Poor mental health is a binary indicator for having a Kessler score of 13 or higher, a score indicative of having a DSM-IV nonsubstance abuse disorder. Summary statistics for missing entries are not included. For the full sample, the percentage missing by variable are as follows: education level (0.47%), US citizen status (0.15%), veteran status (0.02%), insurance status (0.57%), Kessler score (3.73%), current conventional cigarette use (0.40%), and current e-cigarette use (2.53%).

These coefficients are used to estimate the percent change in the average adult's likelihood of using a given product associated with going from low to high SES. Acquiring a college education is associated with a 53% drop in one's likelihood of being an exclusive-smoker, as opposed to a 2% drop in the likelihood of exclusive vaping. Similarly, household incomes of 200% to <400% FPL are associated with a 21% drop in exclusive smoking but 13% increase in exclusive vaping, while those amounting to 400% or more of FPL show a 45% and 20% drops, respectively (results not shown). Thus, among US adults, the SES gradients in exclusive smoking appear steeper and more negative than those observed in exclusive vaping.

As with conventional cigarettes, college education and higher incomes are both associated with a reduced likelihood of dual use. Having completed at least 1 year of college is associated with a 1.4 percentage point (CI: −1.8, −0.9) reduction in the likelihood of dual use. Household incomes of 200%<400% and ≥400% of FPL yield reductions of 1.1 (CI: −1.7, −0.5) and 1.9 (CI: −2.5, −1.2) percentage points, respectively. In all three cases, these coefficients' magnitudes are significantly smaller than those seen with conventional cigarettes and significantly larger than those seen with e-cigarettes (see Table 3). However, percent change comparisons are less clear-cut. While acquiring a college education is associated with a statistically significant 39% drop in the average adult's likelihood of being a dual user (as compared to 53% for exclusive smoking and 2% for exclusive vaping), the household income indicators for 200% to <400% and ≥400% FPL show larger percent changes for dual use (32% and 53%, respectively) than exclusive smoking (21% and 45%) (results not shown).

In terms of demographics, the results show significantly lower likelihoods of conventional and electronic cigarette use among women relative to men (−2.5 [CI: −3.3, −1.6] and −0.6 [CI: −1.0, −0.3] percentage points, respectively). There are also sizable differences in smoking rates across races and ethnicities. Compared to white, non-Hispanic respondents, being Black or Hispanic is associated with significantly lower likelihoods for any type of cigarette use, consistent with current evidence on racial disparities in smoking.

While having insurance coverage is associated with a statistically significant reduced likelihood of smoking (−8.6 percentage points [CI: −10.1, −7.2]) and dual use (−1.3 percentage points [CI: −1.9, −0.6]), this coefficient is statistically insignificant and quite small for exclusive e-cigarette use (−0.4 percentage points [CI: −1.0, 0.2]). This could represent selection into insurance, a direct effect of being insured, or an effect of differential access to care. Veteran status is associated with significantly higher rates of all types of cigarette use (+4.1 percentage points for conventional cigarettes [CI: 2.1, 6.0], +2.4 percentage points for dual use [CI: 0.4, 4.5], and +1.8 percentage points for e-cigarettes [CI: 0.8, 2.8]).

Poor mental health is associated with a higher likelihood of both conventional cigarette use only and dual use: +16.0 percentage points (CI: 13.1, 18.8) for conventional cigarettes and +4.2 percentage points (CI: 2.5, 6.0) for dual use. However, the effect is not significant for e-cigarette use (+0.8 percentage points [CI: −0.3, 1.8]). These coefficients are statistically different from each other (see Table 3). Moreover, for conventional cigarette use as well as dual use, the mental health coefficient is substantially larger than the same analysis's coefficients for high education and income brackets.

Table 4 repeats the Table 2 regressions, now limiting the sample to those respondents who have smoked at least 100 cigarettes in their lifetime (ie, current and former smokers). As, among adults, the vast majority of ever-smokers who use e-cigarettes having initiated smoking prior to e-cigarettes' entry on the US market, the e-cigarette-only

Table 2. Seemingly Unrelated Regression Model of Tobacco Product Use, Coefficients/(SE)

	(1)	(2)	(3)
	Conventional cigarette use only	E-cigarette use only	Dual use
College educated	−0.129**	−0.0003	−0.014**
	(0.006)	(0.002)	(0.003)
Poverty ratio: 100 to <200%	−0.007	0.006	0.002
	(0.008)	(0.003)	(0.004)
Poverty ratio: 200 to <400%	−0.044**	0.002	−0.011**
	(0.008)	(0.002)	(0.003)
Poverty ratio: ≥400%	−0.095**	−0.003	−0.019**
	(0.007)	(0.002)	(0.003)
Female	−0.025**	−0.006**	−0.003
	(0.004)	(0.002)	(0.002)
Black	−0.034**	−0.009**	−0.024**
	(0.007)	(0.002)	(0.002)
Asian	0.010	0.012	0.003
	(0.022)	(0.009)	(0.012)
Other race	−0.031**	−0.003	−0.006
	(0.007)	(0.003)	(0.003)
Hispanic	−0.118**	−0.012**	−0.026**
	(0.005)	(0.002)	(0.002)
Insured	−0.086**	−0.004	−0.013**
	(0.007)	(0.003)	(0.003)
Non-US citizen	−0.089**	−0.006	−0.022**
	(0.007)	(0.003)	(0.002)
Veteran	0.041**	0.018**	0.024*
	(0.010)	(0.005)	(0.010)
Poor mental health	0.160**	0.008	0.042**
	(0.014)	(0.005)	(0.009)
Constant	0.404**	0.029**	0.072**
	(0.011)	(0.004)	(0.005)
Age group fixed effects	Yes	Yes	Yes
Observations	50 303	50 303	50 303
Number of users	8642	688	1338

Data are on 25- to 54-year-old respondents to the 2014, 2015, and 2016 National Health Interview Surveys. The dependent variable is current usage of the cigarette type referenced, with "dual use" referring to those who use both conventional cigarettes and e-cigarettes. The reference category is non-college-educated, white, non-Hispanic males with a poverty ratio of 0%<100% who are citizens and not veterans between ages 25 and 29. Regressions are weighted according to the survey weights; SE are clustered according to survey strata and primary sampling units. Controls not listed above include fixed effects for 5-year age groups and survey year fixed effects, as well as binary missing-observation indicators (for education, US citizen status, veteran status, poverty ratio, insurance status, and Kessler score). Poor mental health is a binary indicator for having a Kessler score of 13 or higher, a score indicative of having a DSM-IV nonsubstance abuse disorder.

*Statistical significance at 5 pc.

**Statistical significance at 1 pc.

results can help clarify whether SES differentials exist in rates of transition from smoking to exclusive e-cigarette use (Table 4, column 2). Indeed, ever-smokers who are college educated are 0.9 percentage points more likely to be exclusive e-cigarette users at interview (CI: 0.0, 1.9), relative to those with zero years of college education. All income coefficients are positive but statistically insignificant, as is the indicator for poor mental health. Thus, more educated smokers are more likely to switch to exclusive e-cigarette use than less educated smokers, but the same conclusion cannot be drawn with confidence for those with higher incomes or better mental health. Black and Hispanic ever-smokers, however, exhibit reduced likelihoods of exclusive vaping (−2.0 percentage points [CI: −2.8, −1.2] and −1.6 percentage points [CI: −2.7, −0.5], respectively), suggesting that these groups are less likely to switch to exclusive e-cigarette use than white, non-Hispanic smokers.

Discussion

A myriad of studies has documented SES disparities in conventional cigarette use, particularly in terms of education and income. Considering whether these disparities extend to e-cigarette use and dual use, this article finds that SES differentials for both exclusive e-cigarette use and dual use differ significantly from those for conventional cigarette use. Specifically, we find no statistically significant differences in exclusive e-cigarette use by education or high household income, contrary to decades of evidence for such differentials in smoking. Education gradients are steepest for exclusive conventional cigarette use, flatter for dual use, and flattest (and close to zero) for exclusive e-cigarette use, whether measured as regression coefficients or the percent change in the average adult's likelihood of engaging in each behavior associated with going from low to high education. Income gradients are also flattest for exclusive e-cigarette use, though the relative size of the dual use and exclusive smoking gradients depends on how these are measured.

As limiting consideration to ever-smokers ensures that the vast majority of e-cigarette users in that subsample tried conventional cigarettes before e-cigarettes, the income and education coefficients from the ever-smoker sample's exclusive e-cigarette use regression should capture SES differentials in transitions from smoking to exclusive vaping. Results indicate that having any college education increases an ever-smoker's likelihood of being an exclusive e-cigarette user at interview by 0.9 percentage points. This positive relationship between education and vaping contrasts sharply with smoking's strongly negative education gradient, whether calculated relative to the general population or ever-smokers. While the same distinction was not evident for higher income indicators, the ever-smoker analysis also showed a reduced likelihood of exclusive vaping associated with Black race and Hispanic ethnicity.

Overall, these findings suggest that more educated smokers are more likely to transition to exclusive e-cigarette use than less educated smokers. Such differential take-up has the potential to exacerbate education disparities in smoking, as well as smoking-related morbidity and mortality. Similarly, as non-Hispanic white ever-smokers are more likely to have quit smoking than Black ever-smokers, reduced take-up of exclusive e-cigarette use in the latter group could further aggravate racial disparities in smoking-related morbidity and mortality.[24] However, as the sample under consideration here did not typically have access to e-cigarettes in their youth, more work is needed to ascertain whether these patterns persist among those who had access to e-cigarettes as teenagers, once that cohort matures.

The observed gradients in product use by mental health status, as measured by the Kessler Psychological Distress Scale, may also have substantive implications for disparities in tobacco-related illness. While poor mental health is associated with higher likelihoods of both conventional cigarette and dual use, we do not find a statistically significant association with exclusive e-cigarette use in either the full sample analysis (Table 2) or the subsample limited to ever-smokers (Table 4). As those suffering from mental illness exhibit particularly high smoking rates and relatively low cessation rates,

Table 3. Results from Wald Tests of Equality of Coefficients across Equations

	(1)	(2)	(3)
	p Value: CC use only – EC use only	*p* Value: CC use only – dual use	*p* Value: EC use only – dual use
College educated	<.001	<.001	<.001
Poverty ratio: 100 to <200%	.119	.325	.409
Poverty ratio: 200 to <400%	<.001	<.001	.001
Poverty ratio: ≥400%	<.001	<.001	<.001
Female	<.001	<.001	.198
Black	<.001	.188	<.001
Asian	.950	.783	.563
Other race	<.001	.002	.450
Hispanic	<.001	<.001	<.001
Insured	<.001	<.001	.053
Non-US citizen	<.001	<.001	<.001
Veteran	.045	.305	.589
Poor mental health	<.001	<.001	.001

Wald tests are for equality of coefficients across Table 2's regressions, which use data on 25- to 54-year-old respondents to the 2014–2016 National Health Interview Surveys (see footnotes in Table 2). CC refers to conventional cigarettes, EC to e-cigarettes, and "dual use" to those who use both conventional cigarettes and e-cigarettes. Poor mental health is a binary indicator for having a Kessler score of 13 or higher, a score indicative of having a DSM-IV nonsubstance abuse disorder.

finding ways to facilitate substitution toward exclusive e-cigarette use among such individuals could improve their long-run health.

The mechanisms behind the observed SES differentials cannot be identified from this analysis. Prominent hypotheses on the causes of SES gradients in addictive behavior include differences in underlying traits, such as time preferences—an individual's relative valuation of the present compared to the future—or impulsivity[25,26]; varying knowledge of health risks[27,28]; a relationship between education and cognitive ability or health literacy that allows more educated/higher income individuals to better process complex health information, or more effectively adapt their behavior to available health information[29–31]; effects of poverty on cognitive capacity that lead to different processing of health information or implementation of health behaviors[32]; and differences in the return on or cost of investment in long run health outcomes.[33]

SES differences in either product knowledge or perceptions of product risk could predict both a steep, negative SES gradient in conventional cigarette use and no such gradient in exclusive e-cigarette use. Indeed, King et al. and Adkison et al. both find that education levels and income are positively correlated with awareness of the existence of e-cigarettes.[34,35] This pattern could facilitate greater e-cigarette take-up among more educated and higher income smokers. Similarly, Viscusi finds that, while both smokers and non-smokers associate e-cigarette use with lower risks of lung cancer and total mortality than conventional cigarette use, there is significant heterogeneity in these views.[36] In particular, education (but not income) is associated with lower perceived risks from e-cigarette use relative to conventional cigarette use. This difference in perceptions would suggest a greater likelihood of e-cigarette take-up among more educated smokers.

Further work is needed to pinpoint the exact driver of these differentials. Indeed, the aforementioned hypotheses are still actively debated in the context of conventional cigarette use, where they remain an area of ongoing research. Considering such questions in the context of electronic cigarettes is a particularly important area for future research, as results may inform interventions to nudge smokers toward lower risk tobacco products, with substantive impacts on tobacco-related morbidity and mortality, as well as disparities therein.

Limitations

This study has several limitations. First, the cross-sectional nature of our data prohibits analysis of within-respondent patterns of product use over time. In particular, we cannot pin down the exact subset of respondents who tried conventional cigarettes before trying e-cigarettes. As this directionality is explicit for 89.2% of those ever-smokers who use e-cigarettes at interview, and the overall percentage trying conventional cigarettes first is likely to be even higher given delays in the e-cigarette market's growth into 2012, we are confident that the vast majority of our sample's e-cigarette users who ever-smoked initiated conventional cigarettes before e-cigarettes. Further analyses of transitions between these products would require either nationally representative longitudinal data or nationally representative panel data with recalled information on initiation and cessation ages for both electronic and conventional cigarettes.

Second, given the nascence of the e-cigarette market, recent data may not represent a steady state. Patterns of cessation may shift as technology evolves, or as cohorts who had greater access to e-cigarettes in their youths age. We look forward to future research on these issues as the current generation of teenagers matures. Third, since the outcome variable for e-cigarette use is defined as any current use, the data cannot distinguish experimenters from committed users. However, tobacco experimentation is generally more common at younger ages, with habitual use typically established by one's early 20s.[37] Thus, our sample limitation to those aged 25 and above attenuates this concern. Of course, this sample restriction does mean that our results may not generalize to youths.

Finally, our finding that poor mental health is a substantive predictor of conventional cigarette and dual use, but not exclusive e-cigarette use, opens a broader question about mental health disparities in tobacco use. Understanding transitions from conventional cigarette to e-cigarette use among those with mental illness may prove central to reducing the burden of tobacco-related disease in this subgroup. Indeed, differentials in e-cigarette use and experimentation by mental health status have been observed in other US samples.[38] Future studies should consider the particular relationship between e-cigarette access and conventional cigarette cessation among those with mental health conditions, as well as group-specific costs and

Table 4. Seemingly Unrelated Regression Model of Tobacco Product Use, Ever-Smokers Only, Coefficients/(SE)

	(1) Conventional cigarette use only	(2) E-cigarette use only	(3) Dual use
College educated	−0.152**	0.009*	−0.007
	(0.010)	(0.005)	(0.006)
Poverty ratio: 100 to <200%	−0.038*	0.004	−0.001
	(0.015)	(0.006)	(0.009)
Poverty ratio: 200 to <400%	−0.063**	0.006	−0.021**
	(0.015)	(0.005)	(0.008)
Poverty ratio: ≥400%	−0.140**	0.005	−0.029**
	(0.015)	(0.006)	(0.008)
Female	0.023*	−0.009*	0.001
	(0.010)	(0.004)	(0.005)
Black	0.136**	−0.020**	−0.039**
	(0.015)	(0.004)	(0.007)
Asian	−0.022	0.002	0.0005
	(0.044)	(0.014)	(0.028)
Other race	0.030	0.004	0.005
	(0.019)	(0.010)	(0.012)
Hispanic	−0.078**	−0.016**	−0.038**
	(0.015)	(0.006)	(0.007)
Insured	−0.115**	−0.003	−0.017*
	(0.013)	(0.006)	(0.007)
Non-US citizen	−0.026	−0.010	−0.043**
	(0.022)	(0.008)	(0.008)
Veteran	−0.012	0.020*	0.030
	(0.017)	(0.009)	(0.019)
Poor mental health	0.109**	0.004	0.045**
	(0.020)	(0.008)	(0.014)
Constant	0.738**	0.040**	0.143**
	(0.021)	(0.009)	(0.012)
Age group fixed effects	Yes	Yes	Yes
Observations	18 608	18 608	18 608
Number of users	8628	565	1334

Data are from the 2014–2016 National Health Interview Surveys, with the sample limited to 25- to 54-year-old respondents who have smoked at least 100 cigarettes in their lifetime. The dependent variable is current use of the cigarette type referenced. The reference category is noncollege-educated, white, non-Hispanic males with a poverty ratio of 0%<100% who are citizens and not veterans between ages 25 and 29. Regressions use NHIS survey weights with SE clustered according to survey strata and primary sampling units. Controls not listed above include fixed effects for 5-year age groups and survey year, as well as binary missing-observation indicators (for education, US citizen status, veteran status, poverty ratio, insurance status, and Kessler score). Poor mental health is a binary indicator for having a Kessler score of 13 or higher, indicative of having a DSM-IV nonsubstance abuse disorder.
*Statistical significance at 5 pc.
**Statistical significance at 1 pc.

benefits of encouraging such substitution. Accounting for more nuanced measures of mental illness would also add value.

Conclusions

This analysis finds marked, negative education and income gradients in both exclusive conventional cigarette use and dual use, but not in exclusive e-cigarette use. Limiting the analytic sample to ever-smokers, findings suggest that more educated smokers are more likely to transition to exclusive e-cigarette use than those who are less educated. While smokers' substitution toward e-cigarettes could reduce the overall health burden of tobacco use, the observed differentials in e-cigarette take-up could also exacerbate SES disparities in conventional cigarette use, and thus in smoking-related morbidity and mortality, over the long run. Understanding why such substitution occurs in some groups more so than others, and ways to encourage it among smokers who are otherwise unlikely to quit conventional cigarettes, may have great potential to both reduce the burden of tobacco-related morbidity and mortality overall and shrink disparities therein.

Funding

This work was not supported by outside funding.

Declaration of Interests

Neither author has any conflicts of interest related to this research, financial or otherwise.

Acknowledgments

The authors would like to thank Trace Kershaw and Jody Sindelar for helpful feedback on the manuscript.

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