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The Contribution of Smoking to Educational Gradients in U.S. Life Expectancy*

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Abstract

Researchers have documented widening educational gradients in mortality in the United States since the 1970s. While smoking has been proposed as a key explanation for this trend, no prior study has quantified the contribution of smoking to increasing education gaps in longevity. We estimate the contribution of smoking to educational gradients in life expectancy using data on white men and women aged 50 and above from the National Longitudinal Mortality Study (N=283,430; 68,644 deaths) and the National Health Interview Survey (N=584,811; 127,226 deaths) in five periods covering the 1980s to 2006. In each period, smoking makes an important contribution to education gaps in longevity for white men and women. Smoking accounts for half the increase in the gap for white women but does not explain the widening gap for white men in the most recent period. Addressing greater initiation and continued smoking among the less educated may reduce mortality inequalities.

Educational differences in life expectancy are sizeable and have grown considerably in recent decades in the United States and other high-income countries (Preston and Elo 1995; Montez and Zajacova 2013a, 2013b). While the causes of widening educational gradients in mortality are not fully understood, factors hypothesized to account for this trend include differences in smoking and other health behaviors; rising inequality in income, employment, and other economic resources; disparities in the quality of and access to health care and other health-enhancing resources; compositional changes in the education distribution; and psychosocial factors (Meara, Richards, and Cutler 2008; Montez and Zajacova 2013b; Pampel, Krueger, and Denney 2010).

Smoking-related diseases are among the largest contributors to educational inequalities in mortality. Several recent studies have identified smoking-related causes of death as key drivers of widening education gaps (Meara et al. 2008; Miech et al. 2011; Montez and Zajacova 2013a, 2013b); however, no prior study has quantified the overall contribution of smoking to this process. Furthermore, the smoking trajectories of men and women have differed strikingly over the course of the twentieth century, reflecting differences in sex role norms and expectations, psychosocial factors, and institutional factors shaping the social

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contexts of smoking (Royce et al. 1997; Waldron 1991). The implications of these differences for trends in educational gradients in mortality, which also vary substantially by gender, have not been fully explored.

In this study, we estimate the mortality burden of smoking by education among white men and women in the United States between the 1980s and 2006. We compare observed educational gradients in life expectancy at age 50 to what they would have been in the absence of smoking in each time period and examine the contribution of smoking to widening life expectancy differentials over time. We evaluate gender differences by comparing how these contributions differ for white men and women. Our findings address one of the key and most commonly proposed explanations for widening educational gradients and have important implications for scholars and policymakers involved in understanding and addressing persistent educational gradients in life expectancy.

BACKGROUND

Educational Gradients in Mortality

Educational gradients in mortality have widened over time, now exceeding those observed between blacks and whites or between men and women. Between 1990 and 2000, the gap in life expectancy at age 25 between those with 13 or more and those with 12 or less years of education increased from 6.2 to 7.8 years for white men and from 3.5 to 5.4 years for white women (Meara et al. 2008). These growing disparities reflect continued life expectancy gains for college graduates alongside stalled mortality declines and even increased mortality for those with less education for some groups (Ibid.; Olshansky et al. 2012).

Unequal access to social and economic resources that promote improved health outcomes, prevent harmful exposures, and buffer individuals from shocks is the most commonly proposed explanation of educational mortality gradients (Link and Phelan 1995). More educated individuals have higher incomes, more stable employment, and greater access to health-promoting institutions; can better afford health-enhancing resources including higher quality health care, health insurance, food, and living conditions; and are more likely to be part of social networks promoting healthy behaviors and diffusion of new health information and innovations. They also have reduced exposure to health-eroding conditions like stress, unstable employment, poor working environments, and social and physical disorder. In addition, education may endow individuals with the ability to more effectively translate health-related information into action.

Health behaviors are an important link between education and health. Cigarette smoking is potentially one of the most powerful proximate determinants of mortality and mortality inequalities. Smoking remains the leading preventable cause of premature death in the United States, and increasingly strong educational gradients have emerged in many dimensions of smoking behavior. Compared to the less educated, the more educated are less likely to be ever smokers, smoke fewer cigarettes per day, are more likely to successfully quit smoking, and are more likely to quit earlier in life (Barbeau et al. 2004; Maralani 2013). Following diagnosis with a chronic condition, more educated individuals are more likely to quit smoking and to adhere to smoking cessation over time (Margolis 2013).

Trends in Smoking by Gender and Education

The role of cigarette smoking in creating and maintaining social boundaries, and thus the practice of smoking by individuals of different genders and education levels, has changed substantially over the twentieth century. Three types of interaction rituals surrounding smoking – elegance, carousing, and relaxation and withdrawal rituals – rose and fell in prominence at different times (Collins 2005). At the beginning of the century, smoking was a glamorous activity practiced by high status individuals and primarily by men since widespread social disapproval surrounded women's smoking (Royce et al. 1997; Waldron 1991; Pampel 2005). Elegance and carousing rituals dominated during this period. Smoking rates and social acceptance of female smoking rose, particularly in the 1930s and 1940s when smoking increased among all birth cohorts of women such that substantial increases in initiation occurred for women in their thirties, forties, and fifties – subsequent to completion of educational attainment and strikingly different from contemporary patterns of smoking initiation, which is concentrated at the adolescent and young adult ages (Burns et al. 1997). This increase has been linked to several interrelated factors, including shifts in the cultural meaning of and social acceptability of women's smoking, women's employment in traditionally male occupations during wartime, and targeted advertising campaigns by tobacco manufacturers. The view of women's smoking as a marker of loose morals, sexual promiscuity, and a lack of respectability was reversed in this period, when smoking was recast as fashionable, stylish, feminine, and a symbol of women's liberation (Amos and Haglund 2000).

Over time, smoking spread rapidly into all social classes, precipitating a decline in the elegance rituals surrounding smoking. The high rates of smoking observed mid-century were due partly to a general diffusion of innovations process but also to the World Wars, during which cigarettes were provided at free or low cost to military personnel and even included in daily rations (Burns et al. 1995). This dramatic increase in cigarette consumption is reflected in the fact that 80% of white men born between 1900 and 1930 were ever smokers by age 30 (Burns et al. 1997). With the rise of the anti-smoking movement in the 1970s and 1980s, the carousing rituals disappeared, smoking prevalence declined (most rapidly for college graduates), and the negative educational gradient in smoking emerged (de Walque 2010). In the most recent period, only smoking's function as a relaxation or withdrawal ritual, a way to "ease away from the pressures and excitements of work and of social life" (Collins 2005, p. 306), remains. Smoking is an increasingly stigmatized behavior, and educational differences in smoking have reached a historical peak.

Educational and Gender Differences in Smoking

Educational differences in cigarette smoking are related to differences in access to a wide array of material resources and health-related information, exposure to stress and coping mechanisms, perceived benefits of smoking, social norms, psychosocial factors, social networks, workplace conditions, and residential contexts. These factors also act to structure smoking behavior differently between men and women, and they impact proximate determinants of educational differences in smoking-related mortality including smoking initiation, number and types of cigarettes smoked, success in quitting, and total number of years spent as a smoker.

Health knowledge and resources—While acceptance of the health risks of smoking is now near universal, most adults in our sample began smoking before the health consequences of smoking were well-known or during the time when educational gradients in this knowledge existed (the youngest members of our sample were born in 1956). Public opinion surveys show that in 1969-1972, only 62.8% of those with less than 12 years of education compared to 84.7% of those with 16 or more years of education believed that smoking causes lung cancer (Link 2008). Once the health risks of smoking became widely known, educational differences in other aspects of health knowledge may have contributed to differences in smoking maintenance and cessation. Individuals with higher levels of education are better informed about health innovations, better at implementing new health technologies, and more likely to have individuals in their social networks with awareness of or access to health-related improvements and information (Glied and Lleras-Muney 2008). More educated individuals may be more successful at translating information about the risks of smoking into quitting and more likely to use effective quitting methods (Cutler and Lleras-Muney 2010). While there is no socioeconomic gradient in attempts to quit smoking, those with higher levels of education, income, and occupational status have greater success in quitting (Barbeau et al. 2004). More educated individuals are better able to afford smoking cessation aids, are more likely to use effective strategies (e.g., nicotine replacement therapy), and have greater access to workplace smoking cessation interventions.

It is generally hypothesized that women may be more responsive to information regarding health, and the timing of smoking cessation among more educated women coincided with the diffusion of the health risks of smoking (Waldron 1991). However, information about the risks of smoking for men has dominated, particularly in the 1960s and 1970s, and women are less likely to report that smoking harmed their health and more likely to report that their tendency to smoke fewer cigarettes per day is protective (Ibid.; Royce et al. 1997).

Perceived benefits—An important dimension of cigarette advertising campaigns targeting women concerns the establishment of the connection between cigarette smoking among women and weight control, which began with Lucky Strike's 1925 "Reach for a Lucky Instead of a Sweet" campaign and continued to play an important role in the development and marketing of women's brands of cigarettes through the 1960s and 1970s (Burns et al. 1995). This has likely contributed to gender differences in the perceived costs and benefits of smoking. Women are more likely to report that they smoke as a method of control weight and to report weight gain as a disadvantage of quitting smoking (Grunberg, Winders, and Wewers 1991; Waldron 1991).

Stress and coping—With the rise of the anti-smoking movement and loss of cultural distinction, smoking's main function remains as a form of relaxation and withdrawal (Collins 2005). Individuals with less education may face high levels of acute and chronic stress stemming from economic deprivation, poor working conditions, discrimination, and poor neighborhood conditions. Less educated individuals may experience low job control, low self-efficacy, and other occupational stressors which may encourage individuals to start, intensify, and continue smoking (Johansson, Johnson, and Hall 1991; Landsbergis et al. 1998). Cigarettes are commonly marketed as stress relieving, and nicotine dependence itself

becomes a source of stress and deterrent to quitting. If smoking among less educated individuals is a response to stressful labor market conditions, stagnation or worsening in employment prospects for those without a college education may contribute to widening education gaps in smoking.

Studies have proposed that men and women experience different levels and sources of stress (e.g., women experience greater stress from multiple social role obligations), and others have suggested that women are more likely to smoke as a coping mechanism (Royce et al. 1997). Women are more likely than men to smoke when upset, in stress-inducing situations, or as a mood regulator. In a 1966 survey of current smokers, women (32.7%) were more likely than men (23.4%) to report that they had not quit smoking because it was relaxing (Waldron 1991).

Social capital and networks—More educated individuals belong to personal and professional networks containing fewer smokers and that discourage or sanction rather than support or perpetuate unhealthy behaviors (Lawlor et al. 2003; Pampel et al. 2010). Stuber, Galea, and Link (2008) found that less educated smokers and smokers living in neighborhoods where all or most individuals smoked perceive lower levels of smoking-related stigma compared to more educated smokers and those in neighborhoods where few or no individuals smoked. Those residing in low SES neighborhoods are exposed to more cigarette advertising because tobacco companies target low SES and minority neighborhoods (Hackbarth, Silvestri, and Cosper 1995; Barbeau et al. 2005). Compared to smokers employed at workplaces with no or weaker smoke-free policies, smokers employed at workplaces with smoke-free policies consume fewer cigarettes per day, are more likely to consider quitting and quit successfully, have lower exposure to environmental tobacco smoke, and may encounter stronger anti-smoking norms (Honjo et al. 2006; Brownson, Hopkins, and Wakefield 2002). More educated individuals are more likely to be employed at workplaces with full smoking bans and to reside in households with full rather than no or partial smoking bans (Pizacani et al. 2004). Smokers living in households with smoking restrictions consume fewer cigarettes, have higher quit rates, and have lower rates of relapse (Farkas et al. 1999). Some studies have documented that women may be more susceptible to social pressures to smoke and lack social support for quitting, particularly when they live with other smokers (Royce et al. 1997).

Social norms—Gendered social norms around tobacco use continue to structure differences in smoking behavior among men and women. Women smoke fewer cigarettes per day and are more likely to smoke low tar and filtered cigarettes, which have slightly lower mortality risks. However, they have lower quit rates than men. This difference may be related to several factors, including gender differences in nicotine dependence, the tighter linkage between weight control and smoking for women, a misperception that cigarettes pose greater health risks to men than women, differential exposure to stress or greater use of smoking as a coping mechanisms among women, and gender differences in social norms surrounding various types of tobacco use (Royce et al. 1997). When quitting cigarette smoking, men are more likely to switch pipes, cigars, and chewing tobacco, which are considered less socially acceptable for women (Grunberg et al. 1991; Waldron 1991).

Smoking and Educational Gradients in Mortality

Smoking is a risk factor for many chronic diseases, particularly cardiovascular diseases, cancer, and respiratory diseases, and a major contributor to premature mortality in the United States (McGinnis and Foege 1993; U.S. DHHS 2010). Smoking-related causes of death are key contributors to widening educational gradients in mortality. For example, chronic obstructive pulmonary disease and lung cancer alone accounted for 21% of the increase in the educational mortality gradient between 1990 and 2000 for non-Hispanic black and white men and women combined, with another 32% of the increase due to heart disease and other cancers (Meara et al. 2008). Montez and Zajacova (2013a) found that widening mortality differences for smoking-related causes of death such as heart disease, lung cancer, chronic lower respiratory disease, and cerebrovascular disease were largely responsible for the widening education gradient in mortality among non-Hispanic white women between 1986 and 2006. In another study, Montez and Zajacova (2013b) found that smoking and employment status were the most important contributors to the widening education gap in mortality among non-Hispanic white women from 1997 to 2006.

While prior studies document that smoking-related causes of death are important contributors to widening education gaps in mortality, they have not provided a comprehensive assessment of the contribution of smoking to educational gradients in life expectancy. Nearly all lung cancer deaths are attributable to smoking, but this is not the case for deaths from cardiovascular disease, stroke, chronic obstructive pulmonary disease, and so on. Smoking behavior changes over the life course, and it is the cumulative damage from smoking taking place over many decades that matters, not just current smoking status at a single point in time. Smoking typically begins in adolescence or early adulthood, but its health consequences may not be observed until later in the life course. The risks of developing and dying from smoking-related diseases are related to lifetime duration of smoking and decrease with time since quitting (Peto et al. 2000). Studies relying on self-reported measures of current smoking status collected at a single point in time are subject to recall bias and social desirability bias, which changed over time with regards to smoking (Warner 1978). They are also limited in their ability to capture smoking history (e.g., years spent as a smoker) and changes in smoking behavior (e.g., number of cigarettes smoked) over the life course. Analyses capturing health behaviors measured at only one point in time tend to underestimate the impact of health behaviors on socioeconomic differences in mortality compared to those measuring health behaviors at multiple points in time (Stringhini et al. 2010).

To address these complexities, this study uses an indirect estimation method to estimate the contribution of smoking to widening educational gradients in life expectancy (Preston, Glei, and Wilmoth 2010). This method captures the cumulative burden of smoking on mortality and does not rely on one-time self-reports of smoking behavior. We are aware of only one other study using indirect estimation methods to study educational mortality disparities in the United States, and this study presents estimates only for males aged 35-69 in 1996 (Jha et al. 2006).

DATA AND METHODS

Data

This study uses data from the third release of the Public Use File of the National Longitudinal Mortality Study (NLMS) and the 1986-2004 waves of the National Health Interview Survey Linked Mortality Files (NHIS). These are annual cross-sectional surveys representative of the U.S. civilian noninstitutionalized population and linked to the National Death Index. NLMS respondents were surveyed in the early 1980s with 11 years of mortality follow-up. The weights are adjusted to reflect the U.S. population on April 1, 1983. NHIS respondents surveyed in 1986-2004 have been linked to mortality follow-up through December 31, 2006. We split the NHIS data into deaths and person-years accumulated during four time periods: 1986-1994, 1995-1998, 1999-2002, and 2003-2006 following Montez and Zajacova (2013a), who found that a longer first period was required to obtain reliable estimates. For a given period, deaths and person-years are confined to those occurring during those years, and survivors from earlier periods are allowed to age into the population at risk in later periods.

Our analytical sample consists of non-Hispanic whites who died or contributed person-years at ages 50 and above in each period. The NLMS sample consists of 283,430 individuals, 68,644 of whom (24%) died over the follow up period. Of these, 4,913 (7%) were lung cancer deaths. The NHIS sample consists of 584,811 individuals and 127,226 (22%) total deaths, of which 10,099 (8%) were lung cancer deaths. We compared life expectancy at age 50 estimates based on the NLMS and NHIS to those from corresponding NCHS official life tables (available upon request).[1] The NLMS and NCHS estimates match closely, whereas the NHIS estimates are somewhat higher than the NCHS estimates (as expected since the NHIS is restricted to the noninstitutionalized population). The differences never exceed 1.3 and 2.4 years for white men and women, respectively.

We focus on non-Hispanic whites since recent studies found larger increases in educational gradients in mortality for these groups than for other racial/ethnic groups (Jemal et al. 2008; Meara et al. 2008; Montez et al. 2011). Non-Hispanic white men and women with less than a high school education were the only groups who appear to have experienced life expectancy declines between 1990 and 2008 (Olshansky et al. 2012). We focus on the comparison between those with a high school degree or less and those with a college degree or more. College graduates have the lowest mortality rates and are often used as the benchmark group in studies of educational mortality gradients. Similar to Meara et al. (2008), we combine high school graduates and those with less than high school education because the latter group has become much smaller and increasingly select over time.[2]

[1]The NCHS does not publish annual life table estimates by education. Thus, we compared our life expectancy at age 50 estimates for non-Hispanic white men and women as a whole (e.g., pooling across education) to the corresponding NCHS life table estimates for white men and women.

[2]For completeness, we estimate and present smoking-attributable mortality for the some college group (individuals with more than a high school degree but less than a college degree). Their smoking behavior is intermediate between the less and more educated groups. Results distinguishing between those with less than high school and high school graduates are available upon request.

In addition to the mortality analysis, we present weighted and age-adjusted current smoking prevalence estimates by sex and education for non-Hispanic white men and women aged 25+, available for select years in 1970-2012 from the NHIS (IHIS 2012). We calculate absolute and relative differences in current smoking prevalence between more and less educated white men and women. These figures illustrate the magnitudes of and trends in educational differences in smoking.

Analytical Approach

We estimate weighted all-cause and lung cancer death rates by sex, five-year age group (50-54, 55-59, …, 85+), and education (high school degree or less, some college, college degree or more) using the NLMS and NHIS. These death rates are used to estimate smoking-attributable mortality for each education group using the indirect method developed by Preston et al. (2010) and adapted by Fenelon and Preston (2012) to the U.S. context. All analyses are performed separately for white men and white women.

Smokers die from a number of underlying causes, including several types of cancers, cardiovascular diseases, and respiratory diseases. The indirect method apportions deaths into those considered attributable to smoking and those not considered attributable to smoking. The fraction of lung cancer deaths attributable to smoking, A_L, is calculated as:

$$A_L = \frac{M_L - \lambda_L^N}{M_L} \quad (1)$$

where M_L is the observed age-sex-education-specific lung cancer death rate in a given period and λ_L^N is the age-sex-specific lung cancer death rate observed among non-smokers in the Cancer Prevention Study II, the largest epidemiological study providing such estimates.

For all other causes of death besides lung cancer, the method uses the statistical relationship between lung cancer mortality and mortality from all other causes of death observed across the 50 U.S. states during a recent period (Fenelon and Preston 2012). The key assumption is that lung cancer mortality is an accurate indicator of the cumulative burden of smoking in a specific population. Using negative binomial regression, mortality from all other causes is modeled separately for males and females as a function of lung cancer mortality, age group, state, year, and a set of lung cancer mortality and age interactions. The model coefficients pertaining to lung cancer mortality are combined in a single set of coefficients $\left(\beta_L'\right)$ which vary by age and sex and reflect the “imprint” of smoking on causes of death other than lung cancer. This application assumes that the expected level of lung cancer mortality among nonsmokers and the effects of smoking on mortality do not vary by education or over time. The implications of these assumptions are further discussed in the limitations section. The fraction of all other deaths attributable to smoking, A_O, is estimated as:

$$A_O = 1 - e^{-\beta_L'\left(M_L - \lambda_L^N\right)} \quad (2)$$

where M_L and λ_L^N are as defined above.

The fraction of all deaths attributable to smoking in a given age-sex-education group is a weighted average of the attributable fractions for lung cancer and for all other causes of death:

$$A=\frac{A_L D_L+A_O D_O}{D} \quad (3)$$

where A_L and A_O are as defined above, D_L is the number of lung cancer deaths, D_O is the number of deaths from all other causes, and D is the total number of deaths. We estimate the fraction of all deaths attributable to smoking above age 50 by sex and education in each period. Using the delta method, we estimate confidence intervals around these fractions which incorporate uncertainty from the Fenelon and Preston (2012) regressions. We estimate death rates in the absence of smoking (i.e., removing smoking-attributable deaths) as:

$$m_i^{-s}=m_i\,(1-A_i) \quad (4)$$

where m_i is the observed age-sex-education specific death rate and A_i is the fraction of deaths in that age-sex-education group attributable to smoking. Finally, life expectancy at age 50 in the presence (using the observed death rates, m_i, the "with smoking" scenario) and absence (using death rates excluding smoking-attributable mortality, m_i^{-s}, the "without smoking" scenario) of smoking is calculated using standard life table methods. The contribution of smoking to educational differences in life expectancy is determined by comparing the two scenarios; the larger the difference, the greater smoking's contribution. We focus on ages 50+ because the bulk of all-cause and smoking-attributable mortality occurred at these ages in this time period. Over 90% of white men and women survived to age 50 according to the 1986 and 2006 U.S. life tables (Arias 2010; NCHS 1988).[3]

We examine the contribution of smoking to educational gradients in each of the five periods and how this contribution has changed over time to assess whether smoking explains widening educational gradients. In the trend analyses, we examine the contribution of smoking to changes in the educational mortality gradient between each of the earlier periods (1980s, 1986-1994, 1995-1998, and 1999-2002) and the most recent period (2003-2006).

RESULTS[4]

Educational Gradients in Smoking

By the 1970s, educational gradients in current smoking emerged and widened over time. Table 1 shows age-adjusted current smoking prevalence by education for white men and

[3]Figures apply to white men and women (including Hispanics) in 1986 and non-Hispanic white men and women in 2006 since Hispanic ethnicity was not reliably reported in earlier years (Arias et al. 2008).

[4]In the results, we focus on contrasting individuals with a high school education or less (referred to as "less educated") and individuals with a college education or more (referred to as "more educated").

women aged 25+. In 1970, 28.0% of white male college graduates were current smokers, compared to 46.1% among those with a high school degree or less, a difference of 18.0%. This difference increased to 26.3% by 2012, when only 8.9% of more educated white men smoked versus 35.2% of less educated white men. Among white women, absolute differences in current smoking grew dramatically from 6.5% to 24.1%, more than tripling between 1970 and 2012. Although absolute differences in current smoking between the more and less educated were initially nearly three times larger among white men than white women, they converged rapidly over time. Relative differences in current smoking (i.e., the ratio of current smoking prevalence among the less versus more educated) by education also increased dramatically over time and converged for white men and women. Among white men, the relative difference in current smoking grew from 1.6 to 4.0 between 1970 and 2012. Less educated white men were four times more likely to be current smokers than more educated white men in the most recent period. Among white women, relative differences in current smoking rose from 1.3 to 3.9 between 1970 and 2012.

These trends reflect the secular declines in cigarette smoking of the latter half of the twentieth century. Both college-educated white men and women experienced the largest declines in current smoking; however, nearly all groups experienced decreases upwards of 10%. The one exception is less educated white women, among whom current smoking remained roughly constant. In each year, just under a third of less educated white women were current smokers.

Educational Gradients in Smoking-Attributable Mortality

Smoking continues to be an important influence on contemporary mortality in the United States. Table 2 shows the level of smoking-attributable mortality (i.e., the percentage of all deaths attributable to smoking) above age 50 among different education groups for non-Hispanic white men and women. In each period, smoking-attributable mortality is greater for less than more educated whites and for white men than white women, reflecting men's historically higher smoking rates.

In the 1980s, smoking accounted for roughly a quarter and a fifth of all deaths over age 50 among less and more educated white men, respectively. Over time, smoking-attributable mortality decreased for all white men but remains high among the less educated. In the most recent period, smoking accounted for 22.3% of deaths above age 50 among less educated white men and only 10.9% of deaths above age 50 among more educated white men. We observe a strong and consistent educational gradient in smoking-attributable mortality for white men in each period: the percentage of deaths attributable to smoking above age 50 decreases monotonically with education. Over time, differences in this percentage between less and more educated white men have remained fairly stable, ranging from 8.2%-12.3%.

In contrast, white women in most education groups experienced increases in smoking-attributable mortality. This is consistent with previous literature documenting their later adoption of smoking and more modest quit rates. Among white women, college graduates always have the lowest fraction of deaths attributable to smoking above age 50. The educational gradient in smoking-attributable mortality was fairly modest in the earliest period, when 8.2% and 11.5% of deaths above age 50 were attributable to smoking among

more and less educated white women, respectively. Over time, smoking-attributable mortality decreased for more educated white women but increased for less educated white women. In the most recent period, educational differences in smoking-attributable mortality among white women were roughly double that of earlier periods (6.3% vs. 2.2%-3.3%).

Contribution of Smoking to Educational Gradients in Longevity

Next, we translate these fractions into implications for life expectancy levels and educational gradients in life expectancy at age 50. For all education groups, life expectancy at age 50 would have been higher in the absence of smoking (Table 3). Consistent with their higher levels of smoking-attributable mortality, less educated whites would experience the greatest life expectancy gains if smoking were eliminated.

In the most recent period, less educated white men had a life expectancy at age 50 of 28.5 years. In the absence of smoking, they could expect to live 31.5 years, an additional 3.0 years. To put this figure in perspective, consider that overall life expectancy at age 50 for white males increased by only 1.7 years in the entire decade between 1996 and 2006 (Anderson 2001; Arias 2010). In 2003-2006, more educated white men stood to gain 1.2 years in life expectancy at age 50 in the absence of smoking (35.1 years versus 33.9 years). These differences are consistent with less educated white men's higher rates of ever and current smoking and lower quit rates over the past four decades. In general, life expectancy gains would be larger for white men (1.2-3.8 years) than white women (0.8-2.2 years). However, due to convergences in smoking behavior between men and women, white women stood to gain nearly as many years in life expectancy in the most recent period as white men if smoking were eliminated. Gains in life expectancy at age 50 would have been 2.2 years among less educated white women (33.0 vs. 35.2 years) and 1.1 years among more educated white women (37.6 vs. 38.7 years) in the absence of smoking.

In each period, smoking is responsible for a large fraction of the educational gradient in mortality among both white men and white women. Table 3 shows the observed difference in life expectancy at age 50 between the less and more educated and what this gap would have been in the absence of smoking in each period. Among white men, the education gap in life expectancy at age 50 would have been 1.6-2.3 years smaller in the absence of smoking. The percent of the gap due to smoking always exceeds a third (33.8% to 54.1%). The education gap in life expectancy at age 50 would also have been smaller (by 0.6-1.1 years) in the absence of smoking among white women. The percent of the gap due to smoking ranges from 17.5% to 24.7%.

Contribution of Smoking to Widening Educational Gradients in Longevity

We also examine whether smoking explains widening educational gradients in longevity. Educational differences in life expectancy at age 50 have increased over time (Table 4, column A). The life expectancy gap between the more and less educated was 1.1 and 2.1 years larger in 2003-2006 than in the 1980s for white men and women, respectively.

We compare the change in the observed education gap between each period and the most recent period and what this change would have been in the absence of smoking. Here, the story is very different for white men than white women. Earlier, we showed that educational

differences in smoking-attributable mortality were substantial but stayed fairly constant over time for white men. Thus, in the absence of smoking (Table 4, column B), very modest changes in the educational gradient would have been observed among white men. In some cases, the widening would have been slightly more pronounced in the absence of smoking. While smoking is an important contributor to educational differences in mortality for white men, it does not explain changes in these differences over time.

In contrast, white women experienced larger increases in the educational gradient in mortality over time, and smoking played an important role in this widening. Between the 1980s and 2006, the gap in life expectancy at age 50 between more and less educated white women increased by 2.1 years. This gap would have increased by only 1.6 years in the absence of smoking. Thus, smoking accounted for a quarter of the widening in the gradient. In more recent periods, smoking accounts for an increasing proportion of widening educational gradients. Between 1999-2002 and 2003-2006, the educational gradient in longevity increased by just under one year. In the absence of smoking, the increase would have been half that – smoking accounted for 50% of the widening educational gradient for white women.

DISCUSSION

Smoking has significantly impacted American mortality over the past century and exhibits strong educational gradients. Recent studies find that smoking contributes substantially to mortality disparities between blacks and whites (Ho and Elo 2013), Hispanic subgroups and non-Hispanic whites (Fenelon 2013a), and men and women (Preston and Wang 2006) and across U.S. geographic regions (Fenelon 2013b). Previous studies have demonstrated that smoking is not responsible for the entirety of education gaps in mortality (Lantz et al. 1998). However, quantifying the overall contribution of smoking to educational gradients in life expectancy, assessing how this contribution has changed over time, and examining how this contribution differs between men and women provide a more comprehensive understanding of educational differences in life expectancy.

We document strong educational gradients in smoking-attributable mortality among white men and white women. In each period, mortality due to smoking is higher among white men than women and higher among less educated than more educated whites. We find that smoking accounts for a third and a quarter of the education gap in life expectancy at age 50 among white men and white women, respectively, in the most recent period. Several studies have suggested that smoking may be responsible for widening educational mortality gradients. Depending on the time period under consideration, we find that smoking accounts for between a quarter and a half of the widening educational gradient for white women, with its contribution increasing over time. Because educational differences in smoking-attributable mortality remained largely stable for white men (rather than increasing as they did for white women), smoking does not account for the widening educational gradient for white men.

These results are driven by divergent smoking histories and educational gradients in smoking initiation and cessation among white men and women, which are in turn related to

several diverse factors. Greater military participation contributed significantly to men's higher smoking rates and may also have flattened their educational gradient in smoking. More educated white men, among the high status innovators, were the first to begin smoking. Without the World Wars, it is likely that they would have begun quitting earlier as smoking diffused to the general public and began losing its cultural distinctiveness. The passage of the G.I. Bill following WWII resulted in substantial gains in college completion among veterans, which would have increased the number of smokers among male college graduates (Bound and Turner 2002). Due to a combination of factors, more educated women had the most favorable smoking histories. They began smoking later than men due to social disapproval of female smoking and quit smoking earlier than more educated men, possibly responding more quickly to the diffusion of information regarding the health risks of smoking (de Walque 2010). The negative relationship between education and smoking emerged sooner and more rapidly among women (for cohorts born after 1930) than among men (for cohorts born after 1950) (Ibid; Pampel 2005). Declines in smoking among male college graduates were faster than for less educated men but did not begin until the late 1970s, well after the health risks of smoking became common knowledge. Less educated women had lower quit rates and were more affected by a second peak in initiation than more educated women. In the 1960s and 1970s, a secondary increase in smoking among young white women coincided with the development and aggressive marketing of brands targeted specifically towards women (e.g., Virginia Slims) (Burns et al. 1995).[5] This increase was greatest among women with less than a college education (1.7 times greater among girls who never attended college than those who did attend college between 1967 and 1973) (Pierce, Lee, and Gilpin 1994). Less educated white women do not appear to have experienced declines in current smoking observed for other groups between 1970 and 2012 (Table 1).

Our estimates are consistent with previous studies attributing between a quarter and a half of widening education gradients to lung cancer and chronic obstructive pulmonary disease among whites (Meara et al. 2008) and non-Hispanic white women (Montez and Zajacova 2013a). The U.S. is not alone in experiencing steepening socioeconomic disparities in mortality. Similar trends have been observed in several European countries. Finland, for example, also experienced increasing socioeconomic disparities in mortality and a smoking epidemic very similar to that of the U.S. Our results are highly consistent with those of Martikainen et al. (2013), who found that while increasing educational gradients in mortality were driven by factors other than smoking among Finnish men, smoking accounted entirely for the increases among Finnish women between 1971-1975 and 2006-2010.

Proposed factors contributing to educational differences in smoking include differences in health knowledge and resources, stress, social capital and networks, occupational factors, and workplace and home environments. Although the causes of these differences are undoubtedly complex, educational divergences in economic well-being are a strong candidate (Montez and Zajacova 2013b). Women without a college degree have experienced deteriorating employment conditions and increasingly struggle to maintain stable

[5]During the same period, smoking initiation showed little change or decreased slightly among young men.

employment in labor markets where employers prefer college degrees. Smoking may represent a coping response to adverse labor force conditions, increased stress, and economic isolation, such that less educated individuals with poorer employment outlooks experience decreased incentives to quit smoking (Pampel et al. 2010; Rosenthal et al. 2012). Links between smoking and mental illness have been documented, particularly among younger cohorts (Murphy et al. 2003). One study estimated that persons with clinically-diagnosed mental illness comprise 40.6% of current smokers in the United States (Lasser et al. 2000). The increasing stigmatization of smoking, accompanied by an ascription of negative social characteristics to smokers, presents barriers to reducing educational disparities in smoking and in life expectancy.

Limitations and Future Research

To the extent that less educated smokers may die at younger ages from smoking-related conditions because of less access to high quality health care and a higher burden of comorbid conditions, these factors are subsumed but cannot be individually identified in our analysis. In addition, we assume that lung cancer mortality rates among non-smokers and the relationship between lung cancer mortality and mortality from all other causes of death do not differ across education groups or over time. It is possible that occupational and residential exposure to asbestos and other toxins that increase lung cancer risk in the absence of smoking may be greater among the less educated. We performed sensitivity analyses assuming 50% higher lung cancer mortality rates among less educated non-smokers that show that the main results are robust. Other studies using the indirect method find that the results are highly similar whether they do or do not incorporate a time trend (Fenelon and Preston 2012; Ho and Elo 2013). Another limitation is that we did not have information on important contextual factors potentially influencing smoking initiation and maintenance over the life course such as parental SES, workplace and home smoking bans, childhood and adult neighborhood environments, social networks, and stress.

In addition, trends in educational gradients in mortality may be influenced by the changing educational makeup of the U.S. (i.e., the less educated have become an increasingly select group) and whether education is measured using absolute or relative levels (Begier, Li, and Maduro 2013; Hendi 2014). Increasing selectivity may partly explain why current smoking has not declined among less educated white women. Given the changing social and economic composition of educational categories over time, widening educational disparities may not exclusively reflect changes in the causal impact of education on health outcomes. A fully comprehensive analysis of widening health differentials by education should account for the effects of compositional change.

Finally, this study focuses on non-Hispanic white men and women. Although the NLMS and the NHIS are the largest population surveys available for such analyses, mortality estimates by education for other racial/ethnic groups are much less reliable due to poorer mortality linkage quality and small sample sizes for some of these subgroups. Given that educational differences in smoking over the life course differ by race and gender, examining how smoking may also contribute to educational gradients for other racial/ethnic groups constitutes a fruitful avenue for future research.

CONCLUSION

Our study demonstrates the contribution of smoking to educational gradients in life expectancy among white men and women and to widening educational gradients among white women above age 50. This process is related to diverging social and economic circumstances and historical differences in smoking by gender and education. Steep educational gradients in smoking currently observed among younger individuals (aged 25-50) foreshadow smoking's continued contribution to future educational gradients in life expectancy. In 2010, just 10% of more educated young white men and women were current smokers compared to over 40% of their less educated counterparts.

Our findings illustrate smoking's changing contribution to life expectancy levels by education and to educational gradients in life expectancy over time. Understanding the circumstances under which smoking contributes to the magnitude of and changes in educational gradients in life expectancy contributes to our knowledge of how health disparities emerge, change, and are maintained over time. While previous studies examined gender differences in smoking or educational differences in smoking, the intersection of these differences and their implications for educational gradients in life expectancy have rarely been considered. We highlight differences in smoking-attributable mortality between white men and women which are likely related to factors including gender differences in social norms surrounding cigarette smoking and other types of tobacco use, military service, stress and coping, and the linkage between smoking and weight control. Determining how much of educational gradients in life expectancy are due to smoking and how this contribution has changed over time also shows that more work is needed to identify non-smoking sources of these gradients, which account for all of the widening in the gradient for white men and half of the widening for white women. Having established the contribution of smoking, our findings provide some idea of the magnitudes of and trends in other, non-smoking-related factors driving steepening educational gradients. Our results reinforce the need for a better understanding of why smoking has persisted among the less educated, particularly less educated white women. Higher levels of smoking and smoking-attributable mortality among the less educated may be traced to disadvantages in multiple domains including material and financial resources, working conditions, psychosocial factors, and stress. Given the strong and universal consensus about the health risks of smoking, documenting the continuing contribution of smoking to mortality inequalities highlights an opportunity for scholars and policymakers to gain a better understanding of and to design more effective interventions addressing educational differences in smoking.

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Table 1

Age-Adjusted Prevalence of Current Cigarette Smoking (%) by Education Level and Absolute and Relative Differences Between the More and Less Educated, Non-Hispanic White Men and Women Aged 25+, Select Years In 1970-2012

	Men					
	Current Smoking Prevalence (%)				Difference Between More and Less Educated	
	High school degree or less	Some college	College-educated	Total	Absolute (%)	Relative
1970	46.1	40.7	28.0	42.1	18.0	1.6
1974	46.0	41.2	28.0	41.4	18.1	1.6
1980	44.0	36.2	27.8	38.5	16.3	1.6
1985	38.2	31.8	19.2	31.6	19.0	2.0
1990	35.7	25.7	13.9	27.2	21.8	2.6
1995	36.2	23.2	13.0	26.1	23.2	2.8
2000	36.1	23.5	11.0	24.8	25.1	3.3
2005	34.8	25.3	9.0	23.1	25.8	3.9
2010	35.4	24.5	8.9	22.4	26.5	4.0
2012	35.2	21.7	8.9	21.7	26.3	4.0
	Women					
	Current Smoking Prevalence (%)				Difference Between More and Less Educated	
	High school degree or less	Some college	College-educated	Total	Absolute (%)	Relative
1970	32.3	31.9	25.8	31.5	6.5	1.3
1974	33.2	30.3	24.8	31.6	8.3	1.3
1980	33.6	30.9	24.0	31.3	9.6	1.4
1985	32.3	26.9	16.1	27.8	16.2	2.0
1990	30.0	21.8	12.8	24.0	17.2	2.3
1995	30.9	22.8	13.8	24.2	17.2	2.3
2000	31.1	21.8	10.4	22.0	20.7	3.0
2005	31.6	20.7	9.4	20.3	22.2	3.4
2010	33.4	23.0	8.8	20.6	24.5	3.8
2012	32.5	21.1	8.4	19.6	24.1	3.9

Note: Less educated refers to those with a high school degree or less, more educated refers to those with a college degree or more.

Source: Integrated Health Interview Series (2012).

Table 2

Percentage of Deaths Attributable to Smoking (95% Confidence Intervals) by Education and Gender, Non-Hispanic White Men and Women Aged 50+, National Longitudinal Mortality Study and National Health Interview Survey, 1980s-2006

		Men			Women		
	Period	**HS & < HS**	**Some Col.**	**Col.+**	**HS & < HS**	**Some Col.**	**Col.+**
NLMS	1980s	27.8 (27.1, 28.4)	23.3 (22.8, 23.9)	17.5 (17.1, 17.9)	11.5 (11.2, 11.8)	13.5 (13.2, 13.9)	8.2 (8.0, 8.4)
NHIS	1986-94	26.8 (26.2, 27.4)	23.9 (23.5, 24.3)	14.5 (14.2, 14.7)	13.6 13.2, 13.9)	13.0 (12.7, 13.3)	11.0 (10.8, 11.2)
	1995-98	23.7 (23.1, 24.2)	21.8 (21.4, 22.2)	15.5 (15.2, 15.8)	14.4 (14.0, 14.7)	14.6 (14.3, 14.9)	12.2 (12.0, 12.4)
	1999-02	23.3 (23.3, 23.4)	19.0 (18.6, 19.4)	11.1 (10.8, 11.3)	13.9 (13.6, 14.3)	17.2 (16.8, 17.7)	10.8 (10.6, 11.0)
	2003-06	22.3 (21.8, 22.9)	16.5 (16.1, 16.9)	10.9 (10.7, 11.1)	15.1 (14.7, 15.5)	14.5 (14.1, 14.8)	8.8 (8.6, 9.1)

Table 3

Life Expectancy at Age 50 With and Without Smoking by Education and Gender, Non-Hispanic Whites, National Longitudinal Mortality Study and National Health Interview Survey, 1980s-2006

	Men								
	With Smoking				Without Smoking				% Gap due to Smoking
Period	HS & < HS	Some Col.	Col.+	Gap	HS & < HS	Some Col.	Col.+	Gap	
1980s	24.2	26.0	28.5	4.3	27.8	28.5	30.2	2.4	44.3
1986-94	26.9	28.9	31.2	4.3	30.7	31.8	32.7	2.0	54.1
1995-98	27.4	29.3	32.0	4.6	30.7	32.0	33.7	3.0	33.8
1999-02	27.7	29.7	32.6	5.0	30.8	32.1	33.8	3.0	40.0
2003-06	28.5	30.4	33.9	5.4	31.5	32.4	35.1	3.6	33.8
	Women								
	With Smoking				Without Smoking				% Gap due to Smoking
Period	HS & < HS	Some Col.	Col.+	Gap	HS & < HS	Some Col.	Col.+	Gap	
1980s	30.6	32.0	33.1	2.5	32.0	33.6	33.9	1.9	24.7
1986-94	33.4	35.8	36.9	3.5	35.4	37.6	38.3	2.9	18.3
1995-98	32.9	35.4	36.7	3.8	34.9	37.2	38.1	3.1	17.5
1999-02	32.4	34.5	36.2	3.8	34.4	36.7	37.5	3.1	18.9
2003-06	33.0	35.5	37.6	4.6	35.2	37.4	38.7	3.5	24.4

Notes: With smoking refers to estimates based on observed all-cause death rates. Without smoking refers to estimates calculated using death rates from which smoking-attributable mortality has been removed. Gap refers to the difference in life expectancy at age 50 between the college-educated and those with a high school education or less.

Table 4

Contribution of Smoking to Widening Educational Differences in Life Expectancy at Age 50, Non-Hispanic White Men and Women, National Longitudinal Mortality Study and National Health Interview Survey, 1980s-2006

	Men			
	Change In Education Mortality Gap Between Period and 2003-2006		Contribution of Smoking to Change in Education Mortality Gap	
Period	With Smoking (A)	Without Smoking (B)	A-B	(A-B)/A
1980s	1.1	1.2	−.1	−8%
1986-94	1.2	1.6	−.5	−41%
1995-98	.8	.5	.3	33%
1999-02	.5	.6	−.2	−35%
	Women			
	Change In Education Mortality Gap Between Period and 2003-2006		Contribution of Smoking to Change in Education Mortality Gap	
Period	With Smoking (A)	Without Smoking (B)	A-B	(A-B)/A
1980s	2.1	1.6	.5	24%
1986-94	1.2	.7	.5	43%
1995-98	.8	.4	.5	55%
1999-02	.9	.4	.4	49%

Notes: Education mortality gap refers to the difference in life expectancy at age 50 between the college-educated and those with a high school education or less. With smoking refers to the gap based on observed all-cause death rates. Without smoking refers to what the gap would have been based on death rates from which smoking-attributable mortality has been removed.