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Rotation Group Bias in Current Smoking Prevalence Estimates Using TUS-CPS

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This paper examined whether the sample rotation scheme of the Current Population Survey (CPS) results in an underestimation of current smoking prevalence in the Tobacco Use Supplement to the Current Population Survey (TUS-CPS). The TUS-CPS has been administered as part of the CPS, which has eight rotation groups of households in each month that are repeatedly interviewed based on a sample rotation scheme. Previous research has found that even though all eight rotation groups in the CPS are independent random samples of the population, some estimates, such as unemployment rates, tend to be significantly higher in the first rotation group than among other rotation groups. The probit regression results of this paper showed that although current smokers are more likely to attrite than nonsmokers in all years of the TUS-CPS, for the six waves of TUS-CPS before 2003 there is no evidence that current smoking prevalence estimates were significantly affected by the rotation scheme of the CPS. For the three waves of TUS-CPS since 2003, however, the results showed that current smoking prevalence has been underestimated likely due to differential panel attrition. It appears that rotation group bias in these waves was caused by the substantially increased number of additional questions current smokers had to answer.

Keywords: rotation group bias; panel attrition; nonresponse

1 Introduction

The adverse health effects from smoking caused more than 480,000 deaths, or nearly one of every five deaths, each year from 2005 to 2009 in the United States (Kochanek, Xu, Murphy, Miniño, & Kung, 2012; U.S. Department of Health and Human Services, 2014). In an effort to curtail this public health problem, decreasing the prevalence of current cigarette smoking among adults to less than 12% has been one of the national health objectives for 2020 (U.S. Department of Health and Human Services, 2013). To assess progress toward this objective, it is essential to accurately measure current smoking prevalence in the U.S. adult population.

One survey often used to provide such estimates is the Tobacco Use Supplement to the Current Population Survey (TUS-CPS). The Current Population Survey (CPS) is a monthly labor force survey conducted by the U.S. Census Bureau for the Bureau of Labor Statistics and is the source of official government statistics on employment and unemployment. The TUS-CPS, sponsored by the National Cancer Institute, has been collected from respondents after completing the regular part of the CPS in select months since 1992 (U.S. Census Bureau, 2006a). Because it is based on a large, nationally representative sample, over 220,000 respondents when data from adjacent periods are pooled, the TUS-CPS has also been extensively used in tobacco research for small geographic regions, such as states (Biener, Garrett, Gilpin, Roman, & Currivan, 2004; Shopland et al., 1996), and small groups, such as those defined by immigrant status, employment status, age, education, and race/ethnicity (Acevedo-Garcia, Pan, Jun, Osypuk, & Emmons, 2005; Baluja, Park, & Myers, 2003; Fagan, Shavers, Lawrence, Gibson, & Ponder, 2007; Green et al., 2007; Shavers, Lawrence, Fagan, & Gibson, 2005).[1]

The CPS is based on a sample of household addresses and is designed to follow a 4–8–4 sample rotation scheme: the household at that address is interviewed for 4 consecutive months, not surveyed for 8 consecutive months, and then re-interviewed for 4 consecutive months before the address is finally dropped from the survey.[2] Each month a new group of

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[1] In comparison, the National Health Interview Survey, another data set commonly used to measure smoking prevalence in the U.S. adult population by the Centers for Disease Control and Prevention, is based on only about 31,000 respondents.

[2] This rotation scheme was introduced as a way to reduce re-

household addresses enters the sample for the first time and another group of household addresses retires from the sample permanently. In any particular month, as a result, there are eight groups of household addresses and the number of times each household's address has been in the sample varies from 1 (Rotation Group 1 or Month In Sample (MIS) 1) to 8 (Rotation Group 8 or MIS 8). Typically, most CPS interviews for the first and the fifth rotation groups are conducted in person because the CPS sample is strictly a sample of addresses and the U.S. Census Bureau needs to confirm that the respondents are, in fact, residing in the sample household address. However, if the respondent requests during the initial personal contact, telephone interviews are conducted even for these rotation groups. Most interviews for the remaining rotation groups are conducted over the telephone, with the approval of the respondent, because it is much more time and cost efficient. In the interests of timeliness and efficiency, the CPS also allows proxy responses: any knowledgeable adult household member 15 years of age or older can be the respondent for other household members and the respondent can change from interview to interview. Yet the majority of the CPS data is collected from the respondent themselves (U.S. Census Bureau, 2006a).

Because each rotation group in the CPS is an independent random sample of the population, it is possible to get eight separate estimates of the population characteristic of interest for a given month, and these estimates from different rotation groups supposedly should not differ systematically. However, some estimates, such as unemployment rates, tend to be significantly higher in the first rotation group than among other rotation groups (Bailar, 1975; Brooks & Bailar, 1978; M. H. Hansen, Hurwitz, Nisselson, & Steinberg, 1955; McCarthy, 1978; Shack-Marquez, 1986; Solon, 1986; U.S. Census Bureau, 2006a; Williams & Mallows, 1970). Such systematic differences in estimates by rotation group are called rotation group bias. Some factors have been suggested for why responses may vary systematically by rotation group in the CPS (McCarthy, 1978): differences in the lengths and contents of the questionnaire among rotation groups (the first interview is longer than others because demographic information about all members of the household has to be obtained); differences in the mode of interview (personal vs. telephone interview); differences in the respondents for the household (self vs. proxy response); conditioning of respondents by repeated interviews[3] and differences in the characteristics of nonrespondents among rotation groups.

Given that the TUS-CPS is based on the CPS, it is natural to suspect that current smoking prevalence estimates based on the TUS-CPS will exhibit rotation group bias. The effects of survey mode (telephone or in-person) and respondent type (self or proxy) on the estimates of current smoking prevalence have received extensive attention in the literature (Baron-Epel, Haviv-Messika, Green, & Kalutzki, 2004; Beland & St-Pierre, 2008; Caraballo, Giovino, Pechacek, & Mowery, 2001; Donovan, Corti, & Jalleh, 1997; Gilpin et al., 1994; Harakeh, Engels, De Vries, & Scholte, 2006; Hyland, Cummings, Lynn, Corle, & Giffen, 1997; Navarro, 1999; Simile, Stussman, & Dahlhamer, 2006; Soulakova, Davis, Hartman, & Gibson, 2009). In particular, Soulakova et al. (2009) investigated whether survey mode and respondent type affect the current smoking prevalence estimates in the 1992 through 2003 TUS-CPS. After controlling for various sociodemographic characteristics, they found that the current smoking prevalence obtained from proxy-responses is lower than that obtained from self-responses, and the current smoking prevalence obtained from telephone responses underestimates the current smoking rate by 3 percentage points.

Controlling for the effects of survey mode and respondent type, this paper investigates if rotation group bias can be attributed to differences in the characteristics–in particular, smoking status–of nonrespondents among rotation groups (differential panel attrition). Tobacco users are more likely to attrite in longitudinal surveys (Cunradi, Moore, Killoran, & Ames, 2005; Goldberg, Chastang, Zins, Niedhammer, & Leclerc, 2006; Gray, Campanelli, Deepchand, & Prescott-Clarke, 1996; Morrison et al., 1997; Young, Powers, & Bell, 2006). Cunradi et al. (2005) suggested two explanations for the higher attrition of smokers: first, it is because smokers are more likely to develop health problems that would decrease their ability to respond to follow-up surveys, and second, some characteristics associated with smoking may also be associated with less likelihood of participation in survey follow-up. For example, smokers are more impulsive

sponse burden and also as a compromise between a permanent sample (from which a high response rate would be difficult to maintain) and a completely new sample each month (which results in more variable estimates of change) (U.S. Census Bureau, 2006a).

[3]Panel conditioning is the phenomenon where responding to questions in the baseline survey influences respondents' answers to questions on subsequent surveys (Halpern-Manners & Warren, 2012; Warren & Halpern-Manners, 2012). In the CPS, respondents are asked multiple follow-up questions depending on whether they respond as employed, unemployed, or out of the labor force. Panel conditioning may arise in the CPS if respondents feel these questions are rather lengthy or burdensome and may believe, although incorrectly, that they could have shortened the survey length had they responded differently. Halpern-Manners and Warren (2012) showed evidence for panel conditioning effects in the CPS by comparing unemployment rates between otherwise identically selected people who differ only with respect to whether they were interviewed for the first time or second time in the CPS. They also noted that panel conditioning effects are frequently observed when survey waves are separated by 1 month or less, such as the basic monthly CPS survey, but fewer panel conditioning effects are expected when surveys are separated by longer periods of time. Except for a few months, respondents in general participate in the TUS-CPS only once and thus the TUS-CPS is less likely to be subject to panel conditioning.

than nonsmokers in that they choose small but immediate rewards over large but delayed rewards (Bickel, Odum, & Madden, 1999; Khwaja, Sloan, & Salm, 2006; Lahiri & J. G. Song, 2000; Odum, Madden, & Bickel, 2002; Reynolds, Richards, Horn, & Karraker, 2004); have substantially less education (Levine, Gustafson, & Velenchik, 1997), lower wages (Grafova & Stafford, 2009; Munasinghe & Sicherman, 2006), are less likely to vote at election time than nonsmokers (Denny & Doyle, 2007; Kelleher, Timoney, Friel, & McKeown, 2002); and spend more time on activities that provide immediate gratification, such as watching television, but less time on activities that provide long-term returns, such as exercising and education, than nonsmokers (Y. Song, 2011). Regardless of the reasons, the higher attrition of smokers in panel surveys found in previous literature suggests that the successive rotation groups in the TUS-CPS could be subject to the same problem.

2 Descriptive Analysis of Rotation Group Bias

The national level estimates of current smoking prevalence for the population 18 years and older by the National Cancer Institute are based on three TUS-CPS data sets pooled from adjacent periods (National Cancer Institute, 2017; U.S. Census Bureau, 1994, 1998, 2001, 2003, 2004, 2006b, 2008, 2012): 1992–93 (September 1992, January 1993, and May 1993), 1995–96 (September 1995, January 1996, and May 1996), 1998–99 (September 1998, January 1999, and May 1999), 2000 (January 2000 and May 2000)[4], 2001–02 (June 2001, November 2001, and February 2002), 2003 (February 2003, June 2003, and November 2003), 2006–07 (May 2006, August 2006, and January 2007), and 2010–11 (May 2010, August 2010, and January 2011). I first estimated current smoking prevalence for 18 years and older by rotation group for each year of the TUS-CPS using pooled data. In the TUS-CPS, respondents 15 years and older were asked a) "Have you smoked at least 100 cigarettes in your entire life?" and b) "Do you now smoke cigarettes every day, some days, or not at all?" Based on the responses to these questions, current smokers are defined as those who now smoke cigarettes every day (everyday smokers) or some days (some-days smokers) (National Cancer Institute, 2017). Nonsmokers are those who have never smoked at least 100 cigarettes in their entire life (never smokers) or those who had smoked at least 100 cigarettes, but who were no longer smoking at the time of the interview (former smokers). All estimates are weighted using the TUS-CPS nonresponse weights (PWNRWGT)[5] and standard errors have been estimated using the balanced repeated replication method in Stata/SE.[6]

Table 1 provides estimates of current smokers for each year of the TUS-CPS by rotation group. It shows evidence that estimates of current smokers based on the TUS-CPS vary by rotation group and the estimate for the first rotation group is higher than the estimates for other rotation groups. This is clearly demonstrated by means of a rotation group index: the ratio of the estimate based on a particular rotation group to the average estimate over all eight rotation groups, multiplied by 100 (Bailar, 1975; U.S. Census Bureau, 2006a). If an equal percentage of current smokers are present in each rotation group, the index for each rotation group would be 100. In Table 1, hence, the index of 105.39 for the first rotation group in the 1992–93 TUS-CPS indicates that the rotation group in the sample for the first time gave an estimate significantly higher by 5.39% than the average for all rotation groups. Table 1 also shows that the rotation group indices for the first rotation group are significantly higher than 100 for all years, except 2000 when an abbreviated version of the TUS-CPS was conducted, while the rotation group indices for all other rotation groups do not show consistent and significant patterns. Therefore, the remainder of this paper is focusing on analyzing the difference in current smoking prevalence between the first rotation group and all other rotation groups. Finally, it is important to point out that Table 1 clearly illustrates that the difference in current smoking prevalence between the first rotation group and the overall group became substantially larger since 2003: between 1992–2002, the rotation group indices for respondents in their first month in the sample are about 105, but between 2003–2011, they are about 110.

3 Regression Analysis of Rotation Group Bias

The significantly larger rotation group indices for the first rotation group found in the above analysis could also be due to differences in characteristics of the respondents across rotation groups, because, as shown in various studies, current smoking status is also associated with demographic characteristics, such as age, gender, race/ethnicity, and education of the respondents, that can certainly vary across rotation groups in random sampling. Younger people are more likely

[4]In 2000, an abbreviated version of the TUS-CPS was conducted for only two months.

[5]The TUS-CPS nonresponse weight adjusts the CPS household weight to account for occupied sample households that responded to and completed the CPS, but not the TUS-CPS. The CPS household weight adjusts for household nonresponse so that the weighted sample results can match independently derived estimates of the civilian noninstitutional population of the United States by age, sex, and race/Hispanic origin (U.S. Census Bureau, 2008). Even if unweighted, the patterns of rotation group bias reported in Tables 1 and 2 remain more or less unchanged, suggesting that the TUS-CPS nonresponse weight is not designed to correct for rotation group bias.

[6]Recent replicate weight files are retrieved from https://thedataweb.rm.census.gov/ftp/cps_ftp.html#cpsrepwgt. Other replicate weight files obtained from DataFerrett Help-Census/DSD/SMPB (dsd_ferrett@census.gov).

Table 1
Current Smokers: Percentage Estimates and Rotation Group Indices, U.S. Household Population, 18 Years and Over, 1992–2011 TUS-CPS

	Month in sample								Sample Size
	1	2	3	4	5	6	7	8	
1992–93 TUS-CPS									277,703
Percentage estimate	25.03	23.63	23.31	23.37	24.35	23.11	23.84	23.32	
	(0.38)	(0.40)	(0.39)	(0.33)	(0.30)	(0.37)	(0.34)	(0.35)	
Rotation group index	**105.39**	99.49	98.15	98.40	102.53	97.31	100.38	98.19	
	(1.60)	(1.68)	(1.64)	(1.39)	(1.26)	(1.56)	(1.43)	(1.47)	
1995–96 TUS-CPS									233,737
Percentage estimate	24.03	23.17	22.65	23.13	23.53	23.31	22.15	22.69	
	(0.36)	(0.36)	(0.35)	(0.35)	(0.36)	(0.36)	(0.34)	(0.36)	
Rotation group index	**104.12**	100.39	98.14	100.22	101.95	101.00	**95.97**	98.31	
	(1.56)	(1.56)	(1.52)	(1.52)	(1.56)	(1.56)	(1.47)	(1.56)	
1998–99 TUS-CPS									224,902
Percentage estimate	22.71	21.64	20.73	21.43	21.97	21.10	20.73	21.17	
	(0.34)	(0.32)	(0.34)	(0.34)	(0.35)	(0.32)	(0.35)	(0.37)	
Rotation group index	**105.97**	100.98	**96.73**	100.00	102.52	98.46	96.73	98.79	
	(1.59)	(1.49)	(1.59)	(1.59)	(1.63)	(1.49)	(1.63)	(1.73)	
2000 TUS-CPS									156,764
Percentage estimate	22.09	20.96	21.37	21.30	21.91	20.82	20.89	21.32	
	(0.40)	(0.45)	(0.41)	(0.38)	(0.41)	(0.34)	(0.41)	(0.43)	
Rotation group index	103.08	97.81	99.72	99.39	102.24	97.15	97.48	99.49	
	(1.87)	(2.10)	(1.91)	(1.77)	(1.91)	(1.59)	(1.91)	(2.01)	
2001–02 TUS-CPS									234,227
Percentage estimate	21.74	20.73	19.98	20.19	21.08	20.04	19.57	20.10	
	(0.35)	(0.34)	(0.29)	(0.4)	(0.31)	(0.35)	(0.33)	(0.43)	
Rotation group index	**106.26**	101.32	97.65	98.68	103.03	97.95	**95.65**	98.24	
	(1.71)	(1.66)	(1.42)	(1.96)	(1.52)	(1.71)	(1.61)	(2.10)	
2003 TUS-CPS									234,274
Percentage estimate	20.17	18.59	18.16	18.05	18.39	17.84	17.79	17.50	
	(0.29)	(0.34)	(0.30)	(0.38)	(0.30)	(0.28)	(0.34)	(0.40)	
Rotation group index	**109.74**	101.14	98.80	98.20	100.05	97.06	96.79	**95.21**	
	(1.58)	(1.85)	(1.63)	(2.07)	(1.63)	(1.52)	(1.85)	(2.18)	
2006–07 TUS-CPS									227,428
Percentage estimate	19.54	17.67	17.89	17.79	17.84	17.31	16.68	16.49	
	(0.31)	(0.29)	(0.32)	(0.38)	(0.33)	(0.32)	(0.31)	(0.34)	
Rotation group index	**110.27**	99.72	100.96	100.40	100.68	97.69	**94.13**	**93.06**	
	(1.75)	(1.64)	(1.81)	(2.14)	(1.86)	(1.81)	(1.75)	(1.92)	
2010–11 TUS-CPS									227,722
Percentage estimate	17.00	15.09	15.09	15.61	15.28	14.82	14.72	15.37	
	(0.31)	(0.32)	(0.27)	(0.34)	(0.28)	(0.3)	(0.28)	(0.35)	
Rotation group index	**110.68**	98.24	98.24	101.63	99.48	96.48	**95.83**	100.07	
	(2.02)	(2.08)	(1.76)	(2.21)	(1.82)	(1.95)	(1.82)	(2.28)	

Note: Standard errors are in parentheses. Rotation group indices that are significantly different from 100 based on the 95% two-sided confidence intervals are in bold. The results are weighted using the Tobacco Use Supplement to the Current Population Survey nonresponse weight (PWNRWGT) and standard errors have been estimated using the balanced repeated replication method.

Table 2
Marginal Effects of Rotation Group 1 in Probit Regression on Current Smokers, U.S. Household Population, 18 Years and Over, 1992–2011 TUS-CPS

Dependent variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Current smoker indicator	1992–93	1995–96	1998–99	2000	2001–02	2003	2006–07	2010–11
Panel A, No Control								
Rotation group 1	0.015***	0.011***	0.014***	0.009*	0.015***	0.020***	0.021***	0.019***
	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
Number of observations	277,703	233,737	224,902	156,764	234,227	234,274	227,428	227,722
Mean of the dependent variable	0.237	0.231	0.214	0.213	0.205	0.184	0.177	0.154
Panel B, Full Control								
Rotation group 1	−0.001	−0.001	−0.000	−0.002	0.004	0.016***	0.011***	0.009***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Mean of the dependent variable for rotation group 1	0.250	0.240	0.227	0.221	0.217	0.202	0.195	0.170
Difference	−0.013	−0.009	−0.013	−0.008	−0.012	−0.018	−0.018	−0.016

Note: Standard errors in parentheses. The results are weighted using the Tobacco Use Supplement to the Current Population Survey nonresponse weight (PWNRWGT) and standard errors have been estimated using the balanced repeated replication method. The probit marginal effects of the full model of Panel B are reported in Appendix Table A2.
* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

to smoke than older people (Barbeau, Krieger, & Soobader, 2004; Jha, Ranson, Nguyen, & Yach, 2002). Men are more likely to smoke than women (Barbeau et al., 2004; Blackwell, Lucas, & Clarke, 2014; Jha et al., 2002). American Indians and Alaska Natives have the highest rate of current smoking, while Asians and Pacific Islanders have the lowest rate (Barbeau et al., 2004; Shavers et al., 2005; U.S. Department of Health and Human Services, 1998). More educated people are less likely to smoke (Cavelaars et al., 2000; de Walque, 2007; Huisman, Kunst, & Mackenbach, 2005; Laaksonen, Rahkonen, Karvonen, & Lahelma, 2005; Lantz et al., 1998). The unemployed have a higher rate of current smoking than the employed (Hammarström & Janlert, 2002; Lawrence, Fagan, Backinger, Gibson, & Hartman, 2007; Waldron & Lye, 1989). Married people are less likely to smoke (Nystedt, 2006). Current smoking prevalence estimates are higher among people with lower household income (Huisman et al., 2005; Laaksonen et al., 2005; Lantz et al., 1998). Home ownership is negatively correlated with current smoking (Balabanova, Bobak, & McKee, 1998; Laaksonen et al., 2005). Current smoking prevalence estimates are higher in urban areas than in nonurban areas (Idris et al., 2007). And current smoking prevalence estimates are higher in the southern states and lower in the western states than the rest of the United States (Shopland et al. 1996). Furthermore, other factors–such as the mode of interview and respondents for the household–vary across rotation groups (McCarthy 1978). To control for all these differences, I conducted probit analysis for each period. The dependent variable was an indicator variable for current smokers. In addition to an indicator for the first rotation group, the following variables are included as the dummy independent variables: three age categories; female; five race/ethnicity categories; three education categories; two employment status categories; three indicators for marital status; indicators for family income levels (missing, $5,000-7,499, $7,500-9,999, $10,000-12,499, $12,500-14,999, $15,000-19,999, $20,000-24,999, $25,000-29,999, $30,000-34,999, $40,000-49,999, $50,000-59,999, $60,000-74,999, and $75,000 or more; the reference group being less than $5,000)[7]; an indicator for home owner; two indicators for metropolitan areas (non metropolitan area and not identified[8]; the reference group being metropolitan area); three region indicators; indicators for TUS-CPS month in each period; an indicator for self-response (the reference group being proxy response)[9]; and two indicators for survey mode (personal and unknown[10]; the reference group being telephone interview). Appendix Table A1 reports the means of all these control variables for each of the TUS-CPS.

Table 2 presents the probit marginal effects of the indicator for the first rotation group, which shows how much current smoking prevalence estimates differ for the first rotation group compared to the reference category, Rotation Groups 2 through 8. For comparison, Panel A of Table 2 reports the results where the only control variable is the indicator for the first rotation group, whereas Panel B of Table 2 reports the probit marginal effects of the indicator for the first rotation group from the model that includes the above-mentioned full control variables.[11] Similar to the findings in Table 1, in Panel A of Table 2 the prevalence estimates of current smoking are 0.9 to 2.1 percentage points higher for the first rotation group than for Rotation Groups 2 through 8. And the differences became larger since 2003.[12] In Panel B of Table 2, when other variables are fully controlled for, the gaps in current smoking prevalence became smaller for all periods but still remained statistically significant for the years 2003, 2006–07, and 2010–11. In sum, the findings in Panels A and B of Table 2 indicated that for the years 1992–93, 1995–96, 1998–99, 2000, and 2001–02, rotation group bias observed in Panel A could be explained by the differences in characteristics of the respondents, the modes of interview and respondent types between the first rotation group and other rotation groups. For the years 2003, 2006–07, and

[7]In the TUS-CPS, family income is reported as a categorical variable. For 2003, 2006-07, and 2010-11 TUS-CPS, the following indicators are included instead of $75,000 or more: $75,000-99,999, $100,000-149,999, and $150,000 or more.

[8]For metropolitan areas, the not-identified code was recorded in the CPS when geographic identification would have violated confidentiality requirements.

[9]For the 1992–93 TUS-CPS, an indicator for the unknown respondent type is also included for 227 observations.

[10]In each of the TUS-CPS, except for the 1992–93 TUS-CPS, there are two variables for the method of interview–PES81A and HRMODE. Based on e-mail exchanges with Anne Hartman at the National Cancer Institute and Todd Gibson at Information Management Services, who are coauthors of Soulakova et al. (2009), I have coded a small number of TUS-CPS respondents who have -1 for PES81A and 1 for HRMODE as the unknown survey mode. Soulakova et al. (2009) have excluded these respondents from their sample in their analysis of the impact of survey modes on current smoking prevalence estimates using the 1992–2003 TUS-CPS, but the national level estimates of current smoking prevalence by the National Cancer Institute (2017) have included them in their sample. Therefore, I have included them in my analysis after coding them as the unknown survey mode. For the 1992–93 TUS-CPS, I have coded TUS-CPS respondents who have values other than telephone or personal visit for A-S81A as the unknown survey mode.

[11]The probit marginal effects of the full model of Panel B of Table 2 are reported in Appendix Table A2, which show almost all of the control variables are statistically significant, with the patterns consistent with the findings in previous literature described above. The overall results are similar even if unweighted.

[12]Considering that estimates of current smoking prevalence–the means of the dependent variable reported in Panel B of Table 2–have been monotonically decreasing between 1992 and 2011, the magnitudes of the difference between the first rotation group and the seven other rotation groups as a fraction of the estimates of current smoking prevalence have also become larger in recent years.

Table 3
Marginal Effects of Current Smoking in Probit Regressions of Matching and the Fitted Probabilities of Matching for Nonsmokers

Years	Proportion of current smokers in MIS 1	(1) MIS 2	(2) MIS 3	(3) MIS 4	(4) MIS 5	(5) MIS 6	(6) MIS 7	(7) MIS 8	Sample size
1992–93	0.2503	−0.000 (0.005) [0.913]	−0.009* (0.005) [0.888]	−0.014** (0.006) [0.862]	−0.027*** (0.007) [0.727]	−0.021*** (0.007) [0.717]	−0.028*** (0.007) [0.710]	−0.025*** (0.007) [0.701]	34,325
1995–96	0.2403	−0.002 (0.004) [0.951]	−0.007 (0.005) [0.924]	−0.008 (0.005) [0.903]	−0.036*** (0.006) [0.748]	−0.037*** (0.006) [0.742]	−0.036*** (0.005) [0.730]	−0.037*** (0.006) [0.729]	29,754
1998–99	0.2271	−0.004 (0.004) [0.952]	−0.014*** (0.004) [0.919]	−0.010** (0.005) [0.900]	−0.038*** (0.007) [0.766]	−0.033*** (0.008) [0.759]	−0.033*** (0.008) [0.746]	−0.034*** (0.008) [0.743]	28,823
2000	0.2209	0.002 (0.005) [0.949]	−0.007 (0.006) [0.917]	−0.002 (0.006) [0.897]	−0.010 (0.010) [0.764]	−0.011 (0.009) [0.754]	−0.023** (0.009) [0.746]	−0.021** (0.009) [0.735]	19,424
2001–02	0.2174	−0.004 (0.004) [0.952]	−0.012** (0.005) [0.917]	−0.018*** (0.006) [0.883]	−0.032*** (0.007) [0.735]	−0.035*** (0.008) [0.730]	−0.035*** (0.008) [0.718]	−0.036*** (0.008) [0.711]	33,308
2003	0.2017	0.002 (0.004) [0.949]	−0.000 (0.005) [0.924]	−0.009* (0.005) [0.900]	−0.031*** (0.007) [0.711]	−0.029*** (0.008) [0.699]	−0.030*** (0.008) [0.694]	−0.030*** (0.007) [0.683]	32,733
2006–07	0.1954	−0.010** (0.004) [0.943]	−0.010* (0.005) [0.914]	−0.011** (0.005) [0.896]	−0.026*** (0.008) [0.732]	−0.022*** (0.008) [0.726]	−0.023*** (0.007) [0.715]	−0.026*** (0.008) [0.711]	32,293
2010–11	0.1700	−0.008* (0.004) [0.948]	−0.013** (0.006) [0.920]	−0.019*** (0.005) [0.902]	−0.037*** (0.008) [0.750]	−0.040*** (0.008) [0.736]	−0.038*** (0.008) [0.728]	−0.044*** (0.008) [0.725]	31,874

Sample: The first rotation groups in the 1992 through 2011 TUS-CPS and the subsequent basic CPS
Dependent variable: Successful matching indicator
Note: MIS stands for Month In Sample. Standard errors in parentheses. Fitted probabilities of matching for nonsmokers are in brackets. The results are weighted using the Tobacco Use Supplement to the Current Population Survey nonresponse weight (PWNRWGT) and standard errors have been estimated using the balanced repeated replication method.
* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

2010–11, in contrast, these differences do not fully account for the difference between the first rotation group and other rotation groups. If only Rotation Group 1 was used, rather than using all rotation groups, to estimate current smoking prevalence, the calculations in Panel B of Table 2 show that the estimates would have been higher by 1.6 to 1.8 percentage points, which means about 3.6 to 3.9 million more current smokers, for the years 2003, 2006–07, and 2010–11.

4 Panel Attrition in the TUS-CPS

To examine if rotation group bias is due to higher attrition rates of current smokers in the successive rotation groups in the CPS, using the rotation scheme of the CPS, I matched Rotation Group 1 (or MIS 1) from all the TUS-CPS to the subsequent CPS and tested if current smokers are less likely to be interviewed in the subsequent rotation groups in the CPS. For example, Rotation Group 1 from the January 2007 TUS-CPS can be matched to Rotation Group 2 in the February 2007

CPS, Rotation Group 3 in the March 2007 CPS, and so on. Similar to the matching process used in Y. Song (2011), I followed the guidelines from the U.S. Bureau of Labor Statistics (2010) and linked observations from Rotation Group 1 in each of the TUS-CPS to Rotation Groups 2 through 8 in the subsequent CPS by using a set of household and individual identification variables.[13] Although these identification variables produce unique matches, one also needs to check sex, race, and age because the CPS is a sample of housing addresses and not a sample of individuals. Successful matches should have the same values for sex and race, and acceptable ranges of age difference between the two surveys (Madrian & Lefgren, 2000). [14] By using the first rotation groups in each of the TUS-CPS, I examined whether the rate of successful match varied by smoking status. To control for the differences in other characteristics that may affect matching, I also conducted probit analysis of matching. A set of control variables similar to those used in Panel B of Table 2 plus an indicator for availability of a telephone in the house are included as independent variables (Abraham, Maitland, & Bianchi, 2006).

Table 3 reports the marginal effects of current smoking on matching and the fitted probabilities of matching for nonsmokers from these probit regressions. Consistent with the findings in the previous literature (Cunradi et al., 2005; Goldberg et al., 2006; Gray et al., 1996; Morrison et al., 1997; Young et al., 2006), current smokers are less likely to be matched to the subsequent CPS in almost all years. For example, the marginal effect of -0.025 in the first row of column 7 indicates that current smokers in Rotation Group 1 from the 1992–93 TUS-CPS (September 1992, January 1993, and May 1993) are, on average, 2.5 percentage points less likely to participate in the subsequent CPS surveys 15 months later as Rotation Group 8 (December 1993, April 1994, and August 1994 CPS) than nonsmokers, whose fitted probability of matching is 0.701. [15]

To investigate how the higher attrition rates of current smokers than nonsmokers in matching to the successive rotation groups in the CPS found in Table 3 could explain the pattern of rotation group bias observed in Panel B of Table 2, it is helpful to first look at a numerical example. Suppose there are 10,000 respondents in round 1 of a panel survey, and 25 percent of them, 2,500 respondents, are current smokers and the remaining 7,500 respondents are nonsmokers. If only 85 percent of the nonsmokers are re-interviewed in the next round of the panel survey, there will be 6,375 nonsmokers left ($= 7,500 \cdot 0.85$) in round 2. Furthermore, if current smokers are 5 percentage points less likely to be re-interviewed than nonsmokers in round 2, current smokers' probability of re-interview is 0.80 and there will be 2,000 current smokers left ($= 2,500 \cdot 0.80$) in round 2. Then in round 2, the percentage of current smokers will be 23.9 percent $\left(\frac{2,000}{2,000+6,375} \cdot 100\right)$. Overall, this example demonstrates that given the probability of re-interview for nonsmokers of 0.85 and the 5 percentage-point shortfall in probability of re-interview for current smokers, the proportion of current smokers in round 2 is decreased by 0.011 to 0.239, from 0.25 in round 1.

In fact, given the proportion of current smokers in round 1 of S_1, the probability of re-interview in round 2 for nonsmokers of R_{ns}, and the shortfall in probability of re-interview for current smokers of ΔR_s in round 2, one can write the proportion of current smokers in round 2, S_2, as follows. [16]

$$S_2 = \frac{S_1 \cdot (R_{ns} - \Delta R_s)}{R_{ns} - S_1 \cdot \Delta R_s} \tag{1}$$

One can show that holding other things equal, as R_{ns} increases, S_2 increases, and as ΔR_sincreases, S_2 decreases. Therefore, S_2 becomes the smallest with the smallest value of R_{ns} and the largest value of ΔR_s.

In Table 4, based on Equation 1, the maximum differences in the estimates of current smoking prevalence for each of the TUS-CPS are calculated between Rotation Group 1 and two groups: the subsamples matched to Rotation Groups 2 through 4 (MIS 2–4) and the subsamples matched to Rotation Groups 5 through 8 (MIS 5–8).[17] Column 1 of Table 4

[13]The CPS basic monthly data used here are retrieved from http://www.nber.org/data/cps_basic.html.

[14]Due to the changes, race categories beginning in 2003 are not comparable to race categories before 2003. Therefore, in linking the 2001–02 TUS-CPS to the 2003 CPS, race was not used in determining successful matches.

[15]Table 3 also shows that in all years the marginal effects of current smoking on matching are usually larger in absolute terms in matching to Rotation Groups 5 through 8 than in matching to Rotation Groups 2 through 4, and in all years the fitted probabilities of matching for nonsmokers drop from around 0.86–0.95 in matching to Rotation Groups 2 through 4 to around 0.68–0.77 in matching to Rotation Groups 5 through 8. These patterns are understandable because the interviews as Rotation Groups 2 through 4 are occurring only 1 to 3 months after the initial interview as Rotation Group 1 in the TUS-CPS, while the interviews as Rotation Groups 5 through 8 are occurring 12 to 15 months after the initial interview.

[16]If there are N respondents in round 1, the number of nonsmokers re-interviewed in round 2 is $N \cdot (1 - S_1) \cdot R_{ns}$ and the number of current smokers re-interviewed in round 2 is $N \cdot S_1 \cdot (R_{ns} - \Delta R_s)$. Then the proportion of current smokers in round 2 is

$$\begin{aligned} &\frac{N \cdot S_1 \cdot (R_{ns} - \Delta R_s)}{N \cdot (1 - S_1) \cdot R_{ns} + N \cdot S_1 \cdot (R_{ns} - \Delta R_s)} \\ &= \frac{S_1 \cdot (R_{ns} - \Delta R_s)}{(1 - S_1) \cdot R_{ns} + S_1 \cdot (R_{ns} - \Delta R_s)} \\ &= \frac{S_1 \cdot (R_{ns} - \Delta R_s)}{R_{ns} - S_1 \cdot \Delta R_s} \quad . \end{aligned}$$

[17]Although Equation 1 is specifically referring to round 2, it can be generalized to any subsequent rounds.

Table 4
Maximum Differences in the Estimates of Current Smoking Prevalence between Rotation Group 1 and the Sample Matched to Other Rotation Groups

		(1) Proportion of current smokers in MIS 1	(2) Nonsmoker matching probability	(3) Shortfall in matching probability for current smokers	(4) Proportion of current smokers in subsequent MIS	(5) Difference in proportions of current smokers	(6) Weighted average difference
		S_1	R_{ns}	ΔR_s	S_2	$S_1 - S_2$	
1992–93	MIS2–4	0.2503	0.862	0.014	0.2472	0.0031	0.0056
	MIS5–8	0.2503	0.701	0.028	0.2427	0.0076	
1995–96	MIS2–4	0.2403	0.903	0.008	0.2387	0.0016	0.0061
	MIS5–8	0.2403	0.729	0.037	0.2309	0.0094	
1998–99	MIS2–4	0.2271	0.900	0.014	0.2244	0.0027	0.0064
	MIS5–8	0.2271	0.743	0.038	0.2180	0.0091	
2000	MIS2–4	0.2209	0.897	0.007	0.2196	0.0013	0.0037
	MIS5–8	0.2209	0.735	0.023	0.2155	0.0054	
2001–02	MIS2–4	0.2174	0.883	0.018	0.2139	0.0035	0.0065
	MIS5–8	0.2174	0.711	0.036	0.2087	0.0087	
2003	MIS2–4	0.2017	0.900	0.009	0.2001	0.0016	0.0049
	MIS5–8	0.2017	0.683	0.031	0.1943	0.0074	
2006–07	MIS2–4	0.1954	0.896	0.011	0.1935	0.0019	0.0041
	MIS5–8	0.1954	0.711	0.026	0.1896	0.0058	
2010–11	MIS2–4	0.1700	0.902	0.019	0.1670	0.0030	0.0062
	MIS5–8	0.1700	0.725	0.044	0.1613	0.0087	

Note: MIS stands for Month In Sample. Column 6 is calculated for each year as 3/7 times the difference in the proportions of current smokers in column 5 for MIS2–4 plus 4/7 times the difference in the proportions of current smokers in column 5 for MIS5–8.

reports the proportion of current smokers in Rotation Group 1, S_1, of each of the TUS-CPS from Table 3.[18] Column 2 of Table 4 displays the smallest fitted probabilities of matching for nonsmokers, R_{ns}, found in Table 3 for each of the two groups for each year. For example, 0.862 reported for MIS 2–4 for 1992–93 is the smallest fitted probability of matching for nonsmokers among columns 1 through 3 for 1992–93 in Table 3. Column 3 of Table 4 displays the largest marginal effects (in absolute terms) of current smoking on matching, ΔR_s, found in Table 3 for each of the two groups for each year. For example, 0.028 reported for MIS5–8 for 1992–93 is the largest marginal effect of current smoking on matching among columns 4 through 7 for 1992–93 in Table 3. Column 4 of Table 4 is the proportion of current smokers in subsequent MIS, S_2, calculated based on Equation 1 using the values reported in columns 1 through 3. Column 5 of Table 4 is the difference in the proportions of current smokers between columns 1 and 4.

Finally, column 6 of Table 4 shows the weighted averages of the two differences in the proportions of current smokers reported in column 5 for each year.[19] Because I used the smallest fitted probability of matching for nonsmokers and the largest marginal effect of current smoking on matching in columns 2 and 3, respectively, 0.0056 is the maximum difference in the proportions of current smokers between Rotation Group 1 and the subsamples matched to all other rotation

[18]The same estimates are reported in percentages in Table 1 for the first rotation group of each of the TUS-CPS.

[19]The weights are 3/7 for the difference in column 5 reported for MIS 2–4 and 4/7 for the difference in column 5 reported for MIS 5–8. For example, 0.0056 reported in column 6 for 1992–93 is calculated as $0.0031 \cdot (3/7) + 0.0076 \cdot (4/7)$.

groups for 1992–93.

Overall, the maximum differences reported in column 6 of Table 4 range from 0.0037 in 2000 to 0.0065 in 2001–02, which suggest that higher attrition rates of current smokers in the successive rotation groups in the CPS could cause the differences in the estimates for current smoking prevalence between Rotation Group 1 and all other rotation groups observed in Table 2.[20] However, the magnitudes of the maximum differences observed in column 6 of Table 4 for the years 2003, 2006–07, and 2010–11 range from 0.0041 to 0.0062, which are substantially smaller than the magnitudes of the marginal effects of Rotation Group 1 of 0.009 to 0.016 observed in columns 6 through 8 in Panel B of Table 2. Therefore, the results reported in Tables 3 and 4 offer some support for the argument that the pattern of rotation group bias observed in Panel B of Table 2 could be due to differential panel attrition, but fail to provide convincing evidence that this pattern of rotation group bias is due mostly to differential panel attrition.

It is important to recall, however, that Table 3 only shows that current smokers are more likely to attrite in subsequent rotation groups in the basic CPS, not in the TUS-CPS. Because the TUS-CPS is a supplement to the CPS, some of those who responded to the basic CPS questionnaires did not respond to the TUS-CPS questionnaires.[21]. Then, rotation group bias in the TUS-CPS may be observed not because current smokers are less likely to participate in the basic CPS but because they are less likely to respond to the TUS-CPS. To examine this possibility, I matched two TUS-CPS data a year apart and examined whether the probability of a successful match varied by smoking status.

There are three pairs of TUS-CPS monthly data that can be matched. Rotation Groups 1, 2, 3, and 4 from the January and May 1999 TUS-CPS can be matched to Rotation Groups 5, 6, 7, and 8 from the January and May 2000 TUS-CPS; and Rotation Groups 1, 2, and 3 from the February 2002 TUS-CPS can be matched to Rotation Groups 5, 6, and 7 from the February 2003 TUS-CPS.[22] Following the same matching procedure used for matching the TUS-CPS to the basic CPS, I matched Rotation Group 1 from the January, May 1999 and February 2002 TUS-CPS to Rotation Group 5 in the January, May 2000 and February 2003 TUS-CPS and ran probit analysis of matching, including the same set of control variables used in Table 3.

Table 5 reports the marginal effects of smoking on matching and the fitted probabilities of matching for nonsmokers from these probit regressions. The first row of Table 5 shows that in matching Rotation Group 1 in the January and May 1999 TUS-CPS to Rotation Group 5 in the January and May 2000 Basic CPS, current smokers are 3.09 percentage points less likely to be matched than nonsmokers. And in Column 2 the magnitude of the negative marginal effect of smoking does not change substantially in matching Rotation Group 1 in the January and May 1999 TUS-CPS to Rotation Group 5 in the January and May 2000 TUS-CPS. In the second row of Table 5, the magnitude of the negative marginal effect of smoking becomes substantially larger in matching Rotation Group 1 in the February 2002 TUS-CPS to Rotation Group 5 in the February 2003 CPS than those observed in row 1 of Table 5. Furthermore, the magnitude of the negative marginal effect of smoking becomes even larger in matching Rotation Group 1 in the February 2002 TUS-CPS to Rotation Group 5 in the February 2003 TUS-CPS than in matching to the February 2003 Basic CPS. And the fitted probabilities of matching for nonsmokers substantially decrease between columns 1 and 2 for both rows in Table 5.

Table 6 uses the marginal effects of current smoking on matching and the fitted probabilities of matching for nonsmokers in Table 5 to calculate the differences in the estimates of current smoking prevalence between Rotation Group 1 and the subsample matched to Rotation Group 5. This is to investigate if the substantially higher attrition rates of current smokers than nonsmokers in matching rotation Group 1 in the February 2002 TUS-CPS to Rotation Group 5 in the February 2003 TUS-CPS observed in column 2 of Table 5 could generate the magnitudes of the marginal effects of Rotation Group 1 of 0.9 to 1.6 percentage points observed in columns 6 through 8 in Panel B of Table 2. The columns in Table 6 are defined similarly as those in Table 4, except that the values in columns 2 and 3 in Table 6 are the corresponding values in Table 5 and there is no column 6 in Table 6.

The results in column 5 of Table 6 indicate that the difference in the proportions of current smokers between Rotation Group 1 from the 1999 TUS-CPS and the subsample matched to the 2000 TUS-CPS, 0.0079, is similar to the difference in the proportions of current smokers between Rotation Group 1 from the 1999 TUS-CPS and the subsample matched to the 2000 Basic CPS, 0.0071, although the differences are slightly higher than those reported in column 6 of Table 4 for 1998–99. However, the difference in the proportions of current smokers between Rotation Group 1

[20]For comparison, by using the largest fitted probability of matching for nonsmokers and the smallest marginal effect of current smoking on matching, one can get the following minimum differences in the proportions of current smokers between Rotation Group 1 and the subsamples matched to all other rotation groups for each year: 1992–93: 0.0031, 1995–96: 0.0007, 1998–99: 0.0047, 2000: 0.0014, 2001–02: 0.0046, 2003: 0.0036, 2006–07: 0.0036, and 2010–11: 0.0045.

[21]For example, the household nonresponse rates for May and August 2006, and January 2007 on the basic CPS ranged from 7.6 to 9.1%, whereas the person nonresponse rates for the May and August 2006, and January 2007 TUS-CPS range from 14.8 to 19.3% (U.S. Census Bureau, 2008)

[22]Rotation Group 4 was interviewed for the basic CPS but not for the Tobacco Use Supplement in February 2002.

Table 5
Marginal Effects of Current Smoking in Probit Regressions of Matching and the Fitted Probabilities of Matching for Nonsmokers.

	Proportion of current smokers	(1) Basic CPS	(2) TUS-CPS	Sample size
January and May 1999	0.2273	−0.0309*** (0.0100) [0.769]	−0.0312*** (0.0118) [0.698]	19,058
February 2002	0.2068	−0.0547*** (0.0115) [0.754]	−0.0684*** (0.0130) [0.660]	11,027

Sample: The first rotation groups in the January and May 1999 and February 2002 TUS-CPS and fifth rotation groups in the January and May 2000 and February 2003 basic CPS and TUS-CPS
Dependent variable: Successful matching indicator
Note: Standard errors in parentheses. Fitted probabilities of matching for nonsmokers are in brackets. The results are weighted using the Tobacco Use Supplement to the Current Population Survey nonresponse weight (PWNRWGT) and standard errors have been estimated using the balanced repeated replication method.
* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

Table 6
Differences in the Estimates of Current Smoking Prevalence between Rotation Group 1 and the Sample Matched to Rotation Group 5

		(1) Proportion of current smokers in MIS 1	(2) Nonsmoker matching probability	(3) Shortfall in matching probability for current smokers	(4) Proportion of current smokers in subsequent MIS	(5) Difference in proportions of current smokers
		S_1	R_{ns}	ΔR_s	S_2	$S_1 - S_2$
1999	Basic CPS	0.2273	0.769	0.0309	0.2202	0.0071
	TUS-CPS	0.2273	0.698	0.0312	0.2194	0.0079
2002	Basic CPS	0.2068	0.754	0.0547	0.1947	0.0121
	TUS-CPS	0.2068	0.660	0.0684	0.1894	0.0174

Note: MIS stands for Month In Sample.

from the 2002 TUS-CPS and the subsample matched to the 2003 TUS-CPS, 0.0174, has increased substantially compared with the difference in the proportions of current smokers between Rotation Group 1 from the 2002 TUS-CPS and the subsample matched to the 2003 Basic CPS, 0.0121. And the magnitude of 0.0174 is very similar to the magnitude of the marginal effect of 0.016 observed in column 6 of Panel B of Table 2. Thus, the analysis in Table 6 provide evidence that the magnitude of rotation group bias observed for 2003 in columns 6 of Panel B of Table 2 could be due mostly to differential panel attrition by smoking status.

5 Changes in the TUS-CPS

Given the findings above, the natural question to ask is why the rate of differential panel attrition for current smokers substantially increased in 2003, and perhaps as well in 2006–07 and 2010–11, resulting in the pattern of rotation group bias observed in Panel B of Table 2. The reason is likely to be due to the dramatic increase in the number of questions for current smokers in the TUS-CPS beginning 2003.[23]

[23] Considering that the attrition rate of current smokers in matching the 2002 TUS-CPS to the 2003 Basic CPS was already higher than the attrition rate observed in matching the 1999 TUS-CPS to the 2000 Basic CPS, one cannot ignore that there might be other reasons, although it is hard to point out.

Previous research has shown that increasing the length of telephone interview surveys decreases response rates (Collins, Sykes, Wilson, & Blackshaw, 1988; K. M. Hansen, 2007; McGonagle, 2013).[24] For example, in the Panel Study of Income Dynamics, McGonagle (2013) found that longer computer-assisted telephone interview surveys are more likely to cause breakoffs, which could result in nonresponse. In the TUS-CPS, breakoffs during the interview usually result in item-level nonresponses for those questions not yet reached, with the exception that item nonresponses to either of the following two key questions become a complete nonresponse: "Have you smoked at least 100 cigarettes in your entire life?" and "Have you ever used a pipe, cigar, chewing tobacco or snuff even one time?"[25] The question about ever smoking at least 100 cigarettes has always been the first question in all of the TUS-CPS questionnaires. Those who answered in the negative to this question were categorized as never smokers and were directly routed to the question about a pipe, cigar, chewing tobacco or snuff. However, those who answered in the affirmative to the first key question were asked, prior to the question about a pipe, cigar, chewing tobacco or snuff, various follow-up questions. And the number of follow-up questions varied depending on whether these respondents were categorized, based on the responses to the subsequent question described in section 2, as everyday smokers, some-days smokers, and former smokers. Table 7 shows that current smokers – everyday smokers and some-days smokers – have always been asked more follow-up questions between these two key questions than nonsmokersformer smokers and never smokers.

According to National Cancer Institute (2017), all TUS-CPS contain generally the same information, covering current cigarette smoking status and amount smoked; smoking history, quit attempts, and intention to quit; medical/dental advice to quit; and cigar, pipe, and smokeless tobacco use. Since 2003, however, the following information was additionally collected from current smokers and former smokers: use of menthol cigarettes; level of nicotine dependence; products, treatments and methods used to quit cigarette; cost of cigarettes and purchase location; and use of new harm reduction and emerging products.[26] As a result, as shown in Table 7, the number of questions asked to current smokers between these two key questions has dramatically increased since 2003: from 22 in 2001–02 to 87 in 2003 for everyday smokers, from 23 in 2001–02 to 114 in 2010–11 for some-days smokers. Although the number of follow-up questions asked to former smokers has also increased since 2003, the number of follow-up questions asked to never smokers has always been 0. Therefore, the length of interview disproportionately increased for current smokers than for nonsmokers since 2003.[27]

The last column of Table 7 shows that the person nonresponse rates to the monthly TUS-CPS data have not increased substantially since 2003.[28] Nevertheless, these changes in survey questions since 2003 are likely to have put more burdens on individuals who respond as current smokers, causing more breakoffs before the key question about a pipe, cigar, chewing tobacco or snuff, eventually resulting in more overall nonresponses for current smokers. Therefore, the increase in the number of questions for current smokers in the TUS-CPS since 2003 is likely to have further amplified differential attrition of smokers in the successive rotation groups.

6 Conclusions

In order to properly monitor progress towards the objective of reducing the prevalence of current cigarette smoking among U.S. adult population to less than 12% by 2020, it is important to have accurate measurements of current smoking prevalence. The main goal of this paper is to examine if the sampling rotation scheme used in the CPS results in an underestimation of current smoking prevalence in the TUS-CPS, one of the surveys regularly used to estimate current smoking prevalence in the U.S. adult population. The analysis reported in this paper showed that although current smokers are more likely to attrite in subsequent rotation groups in all years, for the six waves of TUS-CPS before 2003 there is no evidence that current smoking prevalence estimates were significantly affected by the rotation scheme of the CPS. For

[24] Collins et al. (1988) found that increasing the announced interview time from 20 to 40 minutes increased refusal rates from 9 percent to 14 percent in telephone interview surveys in the United Kingdom. In a computer-assisted telephone interview study of political opinions in Denmark, K. M. Hansen (2007) found that an increase of 5 minutes in the announced interview time from 15 to 20 minutes decreased the number of completed interviews by 20 percent. But according to e-mail exchanges with Karen Woods at the U.S. Census Bureau, there were no letters given to respondents that provided the expected length of the TUS-CPS interview.

[25] It is based on e-mail exchanges with Karen Woods at the U.S. Census Bureau.

[26] See National Cancer Institute (2017) for more detailed changes over time.

[27] In contrast, the number of variables in the basic CPS has only slightly increased over the same period in Table 7. Because the basic CPS questionnaire is not available in the CPS codebook, the number of variables is reported, instead of the number of questions. The number of variables in the TUS-CPS increased in tandem with the number of questions in the TUS-CPS.

[28] It is also noteworthy in Table 7 that the person nonresponse rates to the monthly TUS-CPS reached the minimum in 2000 when the number of questions in the TUS-CPS is the smallest. Furthermore, in 2000, the numbers of questions asked prior to the key question about a pipe, cigar, chewing tobacco or snuff are the same for current smokers and former smokers at the smallest value of 3. This could be the reason why no significant rotation group bias is observed in the 2000 TUS-CPS even in Table 1.

Table 7
Number of Follow-up Questions by Smoking Status and Monthly Nonresponse Rates in the TUS-CPS Over Time

	Number of questions between "Have you smoked at least 100 cigarettes in your entire life?" and "Have you ever used a pipe, cigar, chewing tobacco or snuff even one time?"						
	Current smokers		Nonsmokers				
	Everyday smokers	Some-days smokers	Former smokers	Never smokers	Number of questions in TUS-CPS	Number of variables in the basic CPS	Monthly TUS-CPS person nonresponse rate
1992–93	16	15	10	0	41	240	N/A
1995–96	22	23	13	0	59	350	14.8; 15.6; 13.1
1998–99	22	23	13	0	61	360	13.0; 15.4; 18.0
2000	3	3	3	0	9	362	12.0; 12.9
2001–02	22	23	13	0	53	362	18.4; 17.7; 16.3
2003	87	89	56	0	234	364	16.4; 18.3; 16.8
2006–07	57	63	31	0	159	371	19.3; 18.3; 14.8*
2010–11	109	114	85	0	306	384	17.8; 17.9; 18.4*

Source: Author's counting, codebooks for each of the Tobacco Use Supplement to the Current Population Survey. Note: In 2000, an abbreviated version of the TUS-CPS was conducted for only two months. The person nonresponse rates are listed for each month of the TUS-CPS. * The rates for 2006–07 and 2010–11 are for individuals at least 18 years old, whereas the rates before 2006 are for those 15 years and older.

the three waves of TUS-CPS since 2003, however, the results showed that current smoking prevalence has been underestimated likely due to higher attrition rates of current smokers than nonsmokers. It appears that rotation group bias in these waves was caused by the substantially increased number of additional questions current smokers have to answer, which is consistent with the findings in the literature on the length of telephone interviews and nonresponse (Collins et al., 1988; K. M. Hansen, 2007; McGonagle, 2013). Therefore, one way to reduce the effect of rotation group bias in the future waves of the TUS-CPS would be to alleviate the burden on respondents by reducing the number of questions for current smokers.

The findings in this paper remind researchers of the risk of adding extensive supplemental questions to an existing panel survey: the effort to collect extra information may introduce bias into the very statistics researchers are after. By asking extra questions, the researchers are likely to further increase the probability of nonresponse among the respondents who are already at higher risk of attrition in panel surveys, such as smokers (Cunradi et al., 2005; Goldberg et al., 2006; Gray et al., 1996; Morrison et al., 1997; Young et al., 2006), drug users (Cunradi et al., 2005) and alcohol users (Goldberg et al., 2006; Morrison et al., 1997). It is important for researchers to carefully consider the costs of collecting extensive and specialized information before they add additional questions to panel surveys.

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Appendix
Table

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Table A1
Sample Mean of TUS-CPS Variables, Unweighted

VARIABLES	(1) 1992–93	(2) 1995–96	(3) 1998–99	(4) 2000	(5) 2001–02	(6) 2003	(7) 2006–07	(8) 2010–11
Rotation group 1	.124	.127	.128	.124	.142	.140	.142	.140
Age 18–24	.122	.113	.112	.117	.113	.113	.112	.109
Age 25–44	.434	.426	.409	.402	.389	.377	.355	.342
Age 45–64	.267	.283	.302	.308	.320	.334	.354	.364
Age 65 or older (ref group)	.177	.177	.177	.173	.177	.177	.179	.185
Female	.538	.540	.532	.529	.530	.530	.530	.530
White (ref group)	.804	.794	.780	.765	.777	.763	.747	.725
Black	.089	.091	.091	.095	.089	.085	.085	.093
Hispanic	.066	.073	.083	.091	.084	.095	.103	.113
American Indian/ Alaskan Native	.009	.010	.011	.011	.012	.009	.008	.009
Asian/Pacific Islander	.030	.031	.036	.038	.037	.035	.041	.047
Other	.001						.015	.014
Less than high school (ref group)	.191	.178	.166	.164	.155	.148	.141	.124
High school	.354	.337	.331	.329	.324	.322	.314	.303
Some college	.251	.263	.265	.268	.272	.273	.276	.283
College	.204	.221	.238	.239	.249	.258	.269	.289
Employed (ref group)	.622	.636	.652	.656	.651	.641	.649	.609
Unemployed	.044	.035	.028	.027	.033	.038	.030	.058
Not in labor force	.334	.329	.320	.318	.317	.321	.322	.333
Married	.606	.602	.593	.589	.585	.586	.577	.558
Widowed	.077	.076	.073	.071	.072	.070	.068	.067
Divorced/Separated	.111	.118	.121	.121	.124	.124	.129	.131
Never married (ref group)	.206	.204	.212	.219	.219	.220	.226	.243
Family income								
Missing	.054	.086	.093	.119	.120	.131	.130	
Less than $5,000 (ref group)	.042	.036	.026	.022	.020	.021	.020	.025
$5,000–7,499	.045	.037	.027	.023	.022	.021	.017	.017
$7,500–9,999	.043	.035	.027	.023	.022	.022	.018	.023
$10,000–12,499	.052	.045	.036	.033	.031	.029	.025	.031
$12,500–14,999	.051	.042	.035	.031	.028	.027	.024	.029
$15,000–19,999	.079	.064	.057	.051	.047	.045	.040	.047
$20,000–24,999	.087	.078	.070	.065	.061	.058	.051	.061
$25,000–29,999	.077	.072	.069	.064	.060	.058	.052	.061
$30,000–34,999	.076	.069	.065	.062	.058	.058	.056	.061
$35,000–39,999	.069	.063	.061	.058	.056	.051	.050	.055
$40,000–49,999	.096	.098	.096	.091	.087	.084	.081	.089
$50,000–59,999	.077	.082	.087	.084	.087	.084	.082	.088
$60,000–74,999	.064	.072	.085	.087	.091	.091	.099	.106
$75,000 or more	.088	.120	.167	.188	.210			
$75,000–99,999 (from 2003)						.179	.107	.122
$100,000–149,999						.026	.091	.112
$150,000 or more						.016	.060	.075

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VARIABLES	(1) 1992–93	(2) 1995–96	(3) 1998–99	(4) 2000	(5) 2001–02	(6) 2003	(7) 2006–07	(8) 2010–11
Metropolitan (ref group)	.715	.749	.752	.758	.742	.744	.768	.779
Non Metropolitan	.268	.248	.245	.239	.253	.251	.223	.212
Metropolitan status not identified	.017	.003	.003	.003	.005	.004	.010	.009
Home owner	.703	.708	.723	.724	.731	.739	.745	.719
Northeast (ref group)	.239	.224	.210	.209	.220	.218	.201	.205
Midwest	.250	.243	.237	.238	.251	.250	.238	.236
South	.302	.307	.307	.311	.288	.288	.313	.315
West	.210	.226	.246	.242	.241	.245	.248	.244
TUS-CPS month 1 (ref group)	.337	.356	.344	.505	.359	.277	.355	.367
TUS-CPS month 2	.337	.320	.334	.495	.366	.360	.273	.273
TUS-CPS month 3	.325	.325	.322		.275	.364	.372	.361
Self-response	.822	.799	.782	.792	.790	.781	.75	.749
Respondent type unknown	.001							
Personal interview	.245	.281	.302	.313	.339	.333	.354	.350
Survey mode unknown	.015	.001	.002	.0002	.002	.003	.004	.005
Telephone interview (ref group)	.740	.718	.696	.687	.659	.664	.643	.645
Number of observations	277,703	233,737	224,902	156,764	234,227	234,274	227,428	227,722

Table A2
Marginal Effects in Probit Regression on Current Smokers, U.S. Household Population, 18 Years and Over, 1992–2011 TUS-CPS

VARIABLES	(1) 1992–93	(2) 1995–96	(3) 1998–99	(4) 2000	(5) 2001–02	(6) 2003	(7) 2006–07	(8) 2010–11
Rotation group 1	−0.001	−0.001	−0.000	−0.002	0.004	0.016***	0.011***	0.009***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Age 18–24	0.130***	0.141***	0.133***	0.149***	0.139***	0.118***	0.088***	0.056***
	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)
Age 25–44	0.205***	0.205***	0.191***	0.196***	0.188***	0.169***	0.157***	0.131***
	(0.005)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)	(0.003)
Age 45–64	0.173***	0.181***	0.170***	0.177***	0.164***	0.157***	0.148***	0.127***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
Female	−0.058***	−0.056***	−0.053***	−0.053***	−0.050***	−0.046***	−0.046***	−0.041***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Black	−0.071***	−0.088***	−0.085***	−0.084***	−0.086***	−0.083***	−0.094***	−0.081***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.003)	(0.003)
Hispanic	−0.151***	−0.153***	−0.153***	−0.146***	−0.144***	−0.146***	−0.145***	−0.128***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
American Indian/ Alaskan Native	0.050***	0.050***	0.027**	0.026	0.026**	0.033**	0.012	0.019
	(0.016)	(0.012)	(0.011)	(0.016)	(0.012)	(0.014)	(0.017)	(0.013)
Asian/ Pacific Islander	−0.090***	−0.102***	−0.092***	−0.090***	−0.087***	−0.089***	−0.083***	−0.079***
	(0.007)	(0.008)	(0.007)	(0.007)	(0.006)	(0.007)	(0.006)	(0.005)
Other	−0.124***					0.033***	0.029***	0.016**
	(0.032)					(0.008)	(0.007)	(0.007)
High school	−0.038***	−0.032***	−0.027***	−0.027***	−0.024***	−0.019***	−0.023***	−0.019***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Some college	−0.093***	−0.085***	−0.084***	−0.082***	−0.074***	−0.061***	−0.064***	−0.055***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.002)
College	−0.211***	−0.206***	−0.198***	−0.192***	−0.188***	−0.165***	−0.171***	−0.156***
	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)
Unemployed	0.066***	0.063***	0.061***	0.072***	0.060***	0.066***	0.071***	0.055***
	(0.005)	(0.006)	(0.006)	(0.006)	(0.005)	(0.004)	(0.005)	(0.003)
Not in labor force	−0.015***	−0.012***	−0.025***	−0.025***	−0.022***	−0.015***	−0.011***	−0.003
	(0.004)	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)
Married	−0.011***	−0.018***	−0.032***	−0.027***	−0.033***	−0.032***	−0.036***	−0.036***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.002)
Widowed	0.008	0.012**	−0.002	−0.003	−0.001	−0.002	−0.022***	−0.017***
	(0.005)	(0.006)	(0.005)	(0.008)	(0.006)	(0.005)	(0.005)	(0.005)
Divorced/Separated	0.096***	0.088***	0.068***	0.071***	0.067***	0.061***	0.050***	0.039***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)

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VARIABLES	(1) 1992–93	(2) 1995–96	(3) 1998–99	(4) 2000	(5) 2001–02	(6) 2003	(7) 2006–07	(8) 2010–11
Family income								
Missing	−0.052***	−0.067***	−0.053***	−0.055***	−0.068***	−0.070***	−0.078***	
	(0.007)	(0.006)	(0.007)	(0.008)	(0.009)	(0.007)	(0.007)	
$5,000–7,499	0.007	0.001	0.015*	0.011	−0.011	0.007	0.005	0.012
	(0.006)	(0.006)	(0.008)	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)
$7,500–9,999	−0.004	−0.014**	0.016*	0.010	0.003	−0.014	−0.001	0.010
	(0.006)	(0.006)	(0.008)	(0.010)	(0.011)	(0.010)	(0.009)	(0.008)
$10,000–12,499	−0.015**	−0.013**	−0.003	−0.005	−0.017*	−0.008	−0.019**	0.003
	(0.006)	(0.006)	(0.009)	(0.010)	(0.009)	(0.008)	(0.009)	(0.007)
$12,500–14,999	−0.016**	−0.025***	−0.001	−0.009	−0.017*	−0.017**	−0.018**	0.002
	(0.006)	(0.007)	(0.007)	(0.010)	(0.009)	(0.008)	(0.008)	(0.007)
$15,000–19,999	−0.024***	−0.021***	−0.010	−0.004	−0.018**	−0.015*	−0.022***	−0.005
	(0.005)	(0.006)	(0.008)	(0.009)	(0.009)	(0.008)	(0.008)	(0.006)
$20,000–24,999	−0.028***	−0.023***	−0.021***	−0.016*	−0.019**	−0.028***	−0.029***	−0.007
	(0.007)	(0.006)	(0.008)	(0.009)	(0.009)	(0.007)	(0.007)	(0.007)
$25,000–29,999	−0.043***	−0.031***	−0.014**	−0.026***	−0.032***	−0.028***	−0.033***	−0.018***
	(0.006)	(0.006)	(0.006)	(0.010)	(0.009)	(0.007)	(0.007)	(0.006)
$30,000–34,999	−0.041***	−0.033***	−0.023***	−0.027***	−0.026***	−0.032***	−0.035***	−0.007
	(0.007)	(0.006)	(0.007)	(0.010)	(0.009)	(0.008)	(0.007)	(0.006)
$35,000–39,999	−0.047***	−0.045***	−0.026***	−0.026***	−0.032***	−0.029***	−0.035***	−0.019***
	(0.007)	(0.006)	(0.008)	(0.009)	(0.009)	(0.008)	(0.008)	(0.006)
$40,000–49,999	−0.057***	−0.061***	−0.031***	−0.045***	−0.044***	−0.041***	−0.044***	−0.024***
	(0.006)	(0.005)	(0.007)	(0.009)	(0.009)	(0.007)	(0.007)	(0.006)
$50,000–59,999	−0.063***	−0.070***	−0.047***	−0.053***	−0.049***	−0.052***	−0.051***	−0.037***
	(0.007)	(0.007)	(0.007)	(0.009)	(0.008)	(0.007)	(0.007)	(0.006)
$60,000–74,999	−0.072***	−0.076***	−0.055***	−0.065***	−0.058***	−0.064***	−0.065***	−0.044***
	(0.007)	(0.006)	(0.006)	(0.009)	(0.009)	(0.007)	(0.007)	(0.006)
$75,000 or more	−0.091***	−0.100***	−0.073***	−0.081***	−0.087***	−0.080***	−0.073***	−0.056***
$75,000–99,999 (from 2003)	(0.008)	(0.006)	(0.007)	(0.009)	(0.009)	(0.007)	(0.007)	(0.006)
$100,000–149,999						−0.090***	−0.097***	−0.065***
						(0.010)	(0.007)	(0.006)
$150,000 or more						−0.108***	−0.115***	−0.092***
						(0.011)	(0.008)	(0.007)
Home owner	−0.058***	−0.050***	−0.056***	−0.053***	−0.053***	−0.053***	−0.054***	−0.042***
	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
Non Metropolitan	−0.005	−0.008**	−0.003	−0.001	0.006*	0.005*	0.009***	0.003
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Metropolitan status not identified	−0.014	−0.003	0.005	0.029	0.025	0.021	0.005	0.010
	(0.009)	(0.016)	(0.017)	(0.028)	(0.019)	(0.020)	(0.011)	(0.018)

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Midwest	0.016***	0.020***	0.012***	0.017***	0.020***	0.023***	0.025***	0.027***
	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
South	0.018***	0.015***	0.007**	0.017***	0.015***	0.016***	0.018***	0.023***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)
West	−0.010***	−0.014***	−0.023***	−0.020***	−0.021***	−0.014***	−0.012***	−0.008**
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.003)
TUS-CPS month 2	−0.006**	−0.003	−0.010***	0.005*	−0.004	0.000	−0.000	−0.005***
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
TUS-CPS month 3	−0.005	−0.006**	−0.008***		−0.011***	0.002	−0.006***	−0.005**
	(0.002)	(0.002)	(0.003)		(0.003)	(0.003)	(0.002)	(0.002)
Self-response	0.028***	0.011***	0.013***	0.009***	0.007***	0.005*	0.011***	0.011***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Respondent type unknown	−0.162***							
	(0.032)							
Personal interview	0.023***	0.018***	0.022***	0.020***	0.017***	0.006**	0.016***	0.016***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)
Survey mode unknown	0.024***	0.074***	0.036*	0.041	0.044*	0.232***	0.140***	0.137***
	(0.009)	(0.026)	(0.020)	(0.083)	(0.023)	(0.015)	(0.013)	(0.010)
Observations	277,703	233,737	224,902	156,764	234,227	234,274	227,428	227,722

Note: Standard errors in parentheses. The results are weighted using the Tobacco Use Supplement to the Current Population Survey nonresponse weight (PWNRWGT) and standard errors have been estimated using the balanced repeated replication method. *** p<0.01, ** p<0.05, * p<0.1. Other race/ethnicity category does not exist in the CPS-TUS for 1995–96, 1998–99, 2000, and 2001–02.