

THE POLICY ISSUE

Tobacco use damages health, which creates large private and social costs. E-cigarettes and heated tobacco (collectively, electronic nicotine delivery systems, or ENDS) have become popular with some smokers trying to quit smoking. While ENDS are not risk-free, they are almost certainly much less harmful to health than smoking. Whether public policy should encourage smokers to use ENDS to quit smoking—the *harm reduction* approach—remains an unsettled issue. Some public health officials, such as those in South Korea, discourage smokers from using ENDS for cessation. In a highly publicized statement in 2015, the Korean government health ministry implied that ENDS were just as dangerous as smoking and that ENDS “cannot be used for cessation.”

However, smoking among remains high in Korea (over one-third of adult men smoked in 2018) and the overall adult smoking prevalence (21%) did not decrease between 2015 and 2018 (see Figure 1). Therefore, if ENDS *can* aid cessation from smoking (as has been found to be the case in numerous RCTs) and reduce health harms, failure to incorporate ENDS into the toolkit of public health efforts to promote cessation is misguided and represents a massive lost opportunity.

THE ECONOMETRIC ISSUE

ENDS use and smoking are positively correlated in Korea, hence the government’s opposition to using ENDS for cessation. Such correlation does not imply that ENDS use causally decreases the chance of successful cessation, however, due to selection bias. Heavier smokers and others finding it more difficult to quit may be more likely to use ENDS (dual use). Thus, econometric estimation of the causal treatment effect of ENDS use on smoking must grapple with selection bias in the use of ENDS.

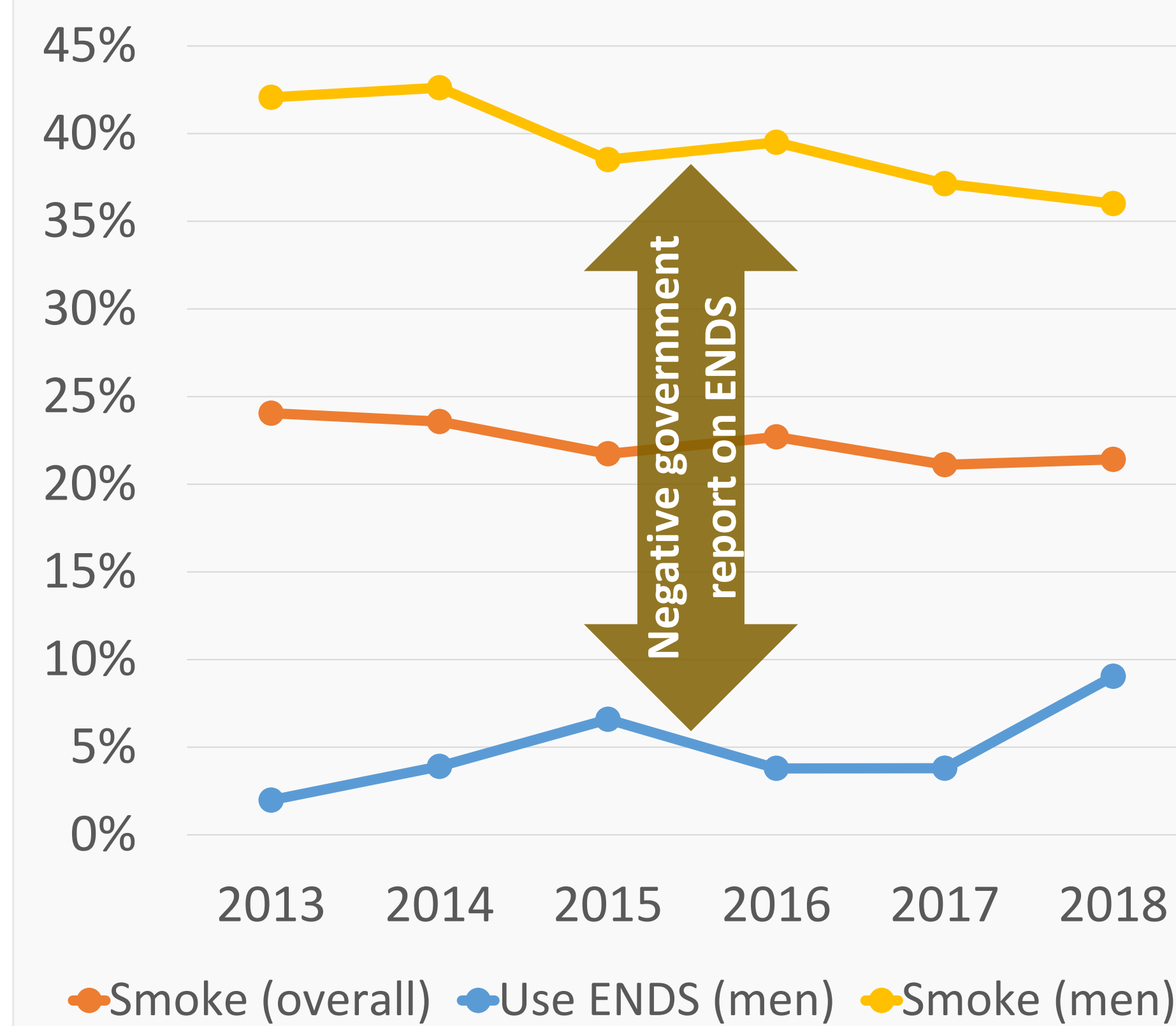
The goal here is to estimate the average treatment effect on the treated (ATET): the increase in the probability of cessation due to ENDS use, among those who choose to use ENDS. Three features of the data limit which methods to correct for selection bias are available: 1) the data are observational; 2) the data are (repeated) cross-sections (not longitudinal), and 3) both the selection variable (ENDS use) and the outcome variable (cessation) are binary. Applicable estimators inescapably rely on parametric assumptions. Therefore, several different models are estimated to assess the robustness of the results. The models investigated are: 1) bivariate recursive probit, 2) copulas to bind marginal distributions of the selection and outcome variables, and 3) Wooldridge’s (2014) moment-based control function estimator.

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DESCRIPTIVE EMPIRICAL RESULTS

Figure 1: Current smoking and use of ENDS among adult males in Korea



Data are from KNHANES, 2013-2018.

Table 1: Evidence for selection effects from changes in estimated effect of ENDS on smoking after the governments negative ENDS report

	Effect of ever-use of ENDS on the probability of current smoking	
	Probit estimation	Propensity score matching estimation
2014	0.245 (s.e. = 0.034)	0.219 (s.e. = 0.039)
2016	0.314 (s.e. = 0.027)	0.304 (s.e. = 0.032)
Difference	0.070 (s.e. = 0.044)	0.129 (s.e. = 0.053)
95% CI:	(-0.017, 0.155)	(0.025, 0.233)

Probit results are from estimations controlling for sex, age, marital status, metro/small city/rural region, education, home ownership, occupation, insurance status, and income. The PSM estimators match on similar covariates (for details, see paper). Data are from KNHANES.

CAUSAL EMPIRICAL RESULTS

Results below are for the recursive bivariate model for ENDS use D_i (the selection or treatment equation) and cessation Y_i (the outcome equation), where D_i is a regressor in the equation for Y_i . Negative association of the error terms (measured by Pearson’s ρ or Kendall’s τ) indicates selection bias consistent with the existence of latent factors making individuals more likely to use ENDS and less likely to quit smoking/maintain cessation.

Table 2: The causal impact (ATET) of ENDS use on cessation: Comparison of models for selection bias

Regression model	ATET	Pearson correlation ρ	Kendall’s τ	dAIC
Simple specifications				
Probit (exogeneity assumed) (S1)	-0.147***	0 (fixed)	0 (fixed)	16,769.9
Bivariate probit (S1)	0.046	-0.39	-0.26*	16,769.6
Frank copula (S1)	0.126***	-0.60***	-0.31	16,766.0
Clayton copula (270° rotation) (S1)	0.165***	-0.81***	-0.64***	16,766.4
Frank copula (S2)	0.109***	-0.54***	-0.29	16,713.7
Clayton copula (270° rotation) (S2)	0.162***	-0.78***	-0.61***	16,711.2†
Potential outcome specifications				
Bivariate probit (S3)	0.150***	-0.76*	-0.55**	16,794.8
Frank copula (S3)	0.091	-0.49	-0.29	16,803.4
Clayton copula (270° rotation) (S3)	0.155***	-0.73***	-0.55***	16,796.1
Clayton copula (270° rotation) (S4)	0.159***	-0.76***	-0.58***	16,719.3†‡
Control function model (GMM) (S3’)	0.169***	NA	NA	NA

$p < 0.1$; ** $p < 0.05$; *** $p < 0.01$ †Best model among likelihood-based models per dAIC, within the set of simple or potential outcome specifications. ‡Best model among likelihood-based models per dAIC, across all regression specifications.

Notes: The sample is limited to current and past male smokers. The data are from the 2013–2018 KNHANES. The dAIC statistic is Lumley & Scott’s (2015) design-based, bias-corrected AIC; lower values indicate less divergence from the true parametric model for the population.

EVIDENCE FOR SELECTION BIAS

Indirect evidence

- Changes in the composition of the treated after officials make a recommendation regarding a health activity can constitute evidence for selection bias. The announcement by the Korean government in 2015 cautioning against using ENDS likely changed the type of person using ENDS. Indeed, the characteristics of ENDS users changed between 2014 and 2016. The profile of ENDS users shifted toward lower income, less education, older individuals, more binge drinking, and worse health, all of which are associated with lower chances for cessation. The change in observables is consistent with a shift in unobservables among ENDS users toward who are less likely to use them for cessation (a selection effect).
- Changes in the regression coefficients in the smoking equation after the 2015 report about ENDS could also constitute evidence for selection bias (Oster 2020). Table 1 (to the left) shows that the apparent effect of using ENDS on smoking increased substantially after the announcement (whether observables are controlled for by regression or matching). This is further evidence consistent with a shift in unobservables among ENDS users that worsens the selection bias in the association between ENDS use and smoking.

Direct evidence

The causal empirical results are shown in Table 2 (to the left). The recursive bivariate models are for ever-ENDS use and cessation within the past 8 years among ever-smoking adult males in Korea. All but the naïve bivariate probit show that there is negative correlation between the errors (and thus selection bias). Among the simple specifications, the preferred estimate of ATET is 16.2 p.p. Among the potential outcome specifications, the preferred estimate of ATET is 15.9 p.p. among likelihood-based models and 16.9 p.p. from the control-function model.

DISCUSSION

The preferred estimates for the treatment effect of ever-use of ENDS on smoking cessation, an ATET of 16-17 percentage points, are sizeable but not unreasonably large. As with evidence from RCTs, these treatment effects are lower than those from pharmacotherapy for cessation but higher than most other cessation aids and methods. Thus:

- The Korean government’s discouragement of ENDS use by smokers creates a massive lost opportunity to reduce smoking and improve public health at a time when smoking’s decline has slowed.
- The government’s attitude runs the danger of creating a self-fulfilling prophecy.
 - Smokers who use ENDS for smoking cessation have higher rates of quitting cigarettes than those who use ENDS for other reasons (Vickerman, et al. (2017).
 - Thus if public misperception about ENDS causes ENDS use only for reasons other than cessation, then ENDS will in fact be less helpful for cessation.