




BMJ Open Impact of an e-cigarette tax on cigarette and e-cigarette use in a middle-income country: a study from Indonesia using a pre-post design

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ABSTRACT

Objectives Indonesia implemented its first e-cigarette regulation in 2018, a 57% tax on the retail price of e-cigarette liquid (e-liquid), exceeding the 40% average tax on cigarettes. Economic research suggests that this tax could unintentionally increase cigarette smoking among dual users, but this has not been examined in a low-income or middle-income country. We therefore investigated the effects of the e-liquid tax among adults in Indonesia.

Design Pre-post study.

Setting Indonesia.

Participants Adults who currently used e-cigarettes and either currently or occasionally smoked cigarettes or recently quit were recruited using Facebook and Instagram ads. Our follow-up response rate was 79%. A final sample of 1039 adults participated.

Primary outcome measures E-cigarette and cigarette use.

Results Following the e-liquid tax, participants reported paying a 4.4% higher price for e-liquid ($p=0.02$). Participants also reported an average 0.5-day decrease in the number of days they used e-cigarettes in the past week ($p<0.001$), and the proportion of daily e-cigarette users decreased (75.9% to 63.6%; $p<0.001$). Overall, reported use of cigarettes also declined, on average, by nine cigarettes per week. Participants who reported decreasing their e-cigarette use had higher odds of reporting increasing their cigarette use rather than reporting no change (adjusted OR: 2.99; 95% CI: 1.95 to 4.59). Further, as participants reported using e-cigarettes less frequently, they reported using cigarettes more frequently ($\beta=-2.41$, $p=0.007$).

Conclusions Following an e-liquid tax in Indonesia, prices of e-liquid increased slightly, e-cigarette and cigarette use declined, and people who reported decreasing their e-cigarette use reported increasing their cigarette use. To avoid encouraging cigarette use, a prudent approach would be to raise cigarette taxes concurrently with e-cigarette taxes.

INTRODUCTION

Indonesia has the third largest population of smokers (over 60 million) and the highest male smoking prevalence in the world, with

Strengths and limitations of this study

- ⇒ This is the first paper examining the impact of an e-cigarette tax on substitution of e-cigarettes and cigarettes in a low-income or middle-income country.
- ⇒ Our study includes participants from across Indonesia (32 out of Indonesia's 34 provinces).
- ⇒ Our study did not include a control group/country, so we cannot be certain the effects we observed are due strictly to the tax.
- ⇒ We only assessed tobacco use behaviours over a period of 2–3 months and it is possible that the novelty of the tax triggered short-term changes in tobacco use that might not be sustained over a longer time period.
- ⇒ We had a relatively high response rate, but some participants were lost to follow-up.

67% of males smoking tobacco.¹ While the majority of tobacco users in Indonesia smoke cigarettes, particularly clove cigarettes known as *kretek*, use of e-cigarettes is growing, with 2.8% of males and 2.7% of females over the age of 10 years reporting current use as of 2018.² Social media posts, sales data and audits have also shown increasing interest in e-cigarettes and growing availability online and in vape shops.³ For instance, in 2017, Indonesia had the second highest number of Instagram posts about e-cigarettes (following only the USA).⁴ In addition, recent research suggests that the prevalence of dual use in Indonesia is high (ie, the majority of people who use e-cigarettes also smoke cigarettes).⁵

Research from laboratory experiments^{6–8} and real-world economic studies^{9–14} in the USA, European Union, and New Zealand have shown that e-cigarettes and cigarettes can serve as substitutes for one another. Thus, any policy that targets one tobacco product can affect use of other tobacco products (cross-substitution).¹⁵ For example, increases

in cigarette prices can lead to increased demand for e-cigarettes,^{9 11} and increases in e-cigarette prices can lead to increased use and demand for cigarettes.^{10–13} In this context, any public policy targeting e-cigarette use, for example, through a tax increase, may result in unintended consequences, such as increased cigarette smoking. Effects may be even more pronounced if there are differential tax rates for various tobacco products, such as a higher tax for e-cigarettes compared with cigarettes.¹⁶

On 1 October 2018, Indonesia implemented its first e-cigarette regulation, a 57% ad-valorem tax on the retail price of e-cigarette liquid (e-liquid) applied at the manufacturer level, which would exceed the 40% average tax on cigarettes.¹⁷ While previous studies have examined how increases in e-cigarette prices can lead to increased use and demand for cigarettes,^{10–13} to our knowledge no studies have been conducted in low-income or middle-income countries. Therefore, we sought to learn the effect of the Indonesian e-liquid tax on e-cigarette and cigarette use. Specifically, our goals were to: (1) examine if the e-liquid tax is associated with changes in e-cigarette use, (2) examine if the e-liquid tax is associated with changes in cigarette use and (3) examine if changes in e-cigarette use are associated with changes in cigarette use. We hypothesised that following the e-liquid tax: (1) e-cigarette use would decline, (2) cigarette use would increase and (3) changes in e-cigarette use would be negatively associated with changes in cigarette smoking.

METHODS

Participants and procedures

We conducted a pre–post online survey of a cohort of adults in Indonesia. We created Facebook and Instagram ads to recruit Indonesian participants before the e-liquid tax (Finance Ministerial Regulation No. 146/010/2017) went into effect on 1 October 2018. The Facebook and Instagram target audience selections were set for Indonesian adults with an interest in e-cigarettes. After the law took effect, we recontacted participants using a series of WhatsApp messages and emails. Two researchers with doctoral degrees in public health and extensive research experience oversaw recruitment. Our pretest (wave 1) survey was conducted on 16–21 September 2018 and the post-test (wave 2) survey was conducted on 8 November through 3 December 2018. The survey was written in English, translated into Bahasa Indonesia (the national language of Indonesia) by professional translators and verified by native speakers. We pretested the survey with several native Bahasa speakers before collecting data to ensure that questions were understood correctly.

We used Qualtrics (an online survey platform) to programme the surveys and collect data. People who clicked on the Facebook and Instagram ads were directed to take the open survey to see if they were eligible for participation. Before completing the surveys, all eligible participants read a consent form and agreed

to participate in the study. Participants were informed that the study was voluntary and they could withdraw at any point. The survey used adaptive questioning (items were conditionally displayed based on responses to other items) to reduce the number and complexity of the questions. The survey also used randomisation of response options for some questions to prevent bias. The surveys contained around 80 questions each, with no more than 5 questions displayed on a single page. Because we used adaptive questioning, each participant saw a different number of pages in the survey. Participants were able to change responses to some previous questions with a ‘back’ button. We used a feature in Qualtrics to prevent multiple submissions. If participants did not answer certain questions, a message appeared requesting them to complete that question before continuing. Participants received a 50 000 Indonesian rupiah (IDR) phone credit (~US\$3.50) for taking each survey. So that we could link the two surveys together and send participants their gift cards, we collected participants’ phone numbers and electronic contact information. Only research team members had access to participants’ data and identifiable information was deleted after incentives were sent to participants.

Because we were interested in how the e-liquid tax could affect e-cigarette and cigarette use, we focused our study on people with experience with both products. Specifically, at wave 1, we included participants who were aged 18 years or older, currently used e-cigarettes, and either: (1) currently or occasionally smoked cigarettes or (2) quit smoking cigarettes within the past year. Before asking about e-cigarette use, we told participants: ‘The next few questions are about e-cigarettes, also called vapes. E-cigarettes are battery-powered and produce vapour instead of smoke. There are many different types of e-cigarettes.’ We also included a photo of eight different types of commonly used e-cigarette devices as examples. To assess e-cigarette use status at wave 1, we asked participants who reported ever using e-cigarettes: ‘How often do you currently use an e-cigarette?’^{18 19} Response options included: 1=daily, 2=less than daily but at least once a week, 3=less than weekly but at least once a month, 4=less than monthly, but occasionally, 0=not at all. Participants who chose response option 0 or 4 were not eligible for participating in our study.

To assess cigarette use status at wave 1, we asked participants: ‘How often, if at all, do you currently smoke cigarettes?’ (modified from Thompson *et al*²⁰). Response options were the same as the e-cigarette response options above with one additional category: ‘not at all; I’ve quit smoking completely’. Participants who chose this response option were then asked: ‘How long ago did you quit smoking’, with response options ranging from ‘less than 1 week ago’ to ‘more than 5 years ago’.²⁰ Participants who quit more than a year ago were excluded from participating. Participants who did not currently smoke cigarettes at all were also excluded from participating.

There were 1322 participants who were eligible and completed the wave 1 survey and of these participants, 1039 completed the wave 2 survey (79% follow-up rate).

Measures

Price of last purchased e-liquid

We asked participants about their last e-liquid purchase size and price at wave 1 and wave 2. To assess size, we asked participants: 'The last time you purchased e-cigarette liquid, what size was the bottle?' Response options ranged from 15 mL to 100 mL and included an 'other' option where participants could fill in the appropriate amount. To assess price, we asked participants: 'The last time you purchased a bottle of e-cigarette liquid, how much did you pay for it? (you can round).' We standardised the price of e-liquid per 60 mL since that was the most frequently purchased size.

Stockpiling and price minimisation techniques

We asked participants at wave 1 and wave 2: 'In the past month, have you bought more, less or about the same amount of e-liquid as usual?' Response options were: 'less e-liquid than usual', 'about the same amount of e-liquid as usual' and 'more e-liquid than usual'. We also asked participants about nine price minimisation techniques at wave 1 and wave 2 with the question: 'In the past 2 weeks, have you done any of the following things to try and save money on e-cigarette liquid?' An example price minimisation technique was 'bought a cheaper brand of e-liquid'. Response options were yes or no.

Recall of tax stamp

We assessed participant recall of seeing a tax stamp on their recent purchase by asking participants at wave 1 and wave 2: 'The last time you purchased e-cigarette liquid, was there a tax stamp on it?' and showed participants a picture of the tax stamp. Responses were coded as yes or no. Responses of 'don't know' were coded as missing. We asked this item at wave 1, even though the survey was conducted before the implementation of the tax regulation. Because the tax regulation was actually planned to be launched in July but delayed to October, some retailers had products with tax stamps prior to October.

E-cigarette and cigarette use

We had four primary outcomes that were measured at wave 1 and wave 2: (1) e-cigarette use status, (2) e-cigarette use frequency, (3) cigarette use status and (4) cigarette use quantity. To assess e-cigarette use status, we used the measure described above for eligibility and collapsed e-cigarette users into three categories: (1) daily e-cigarette users, (2) non-daily e-cigarette users and (3) former e-cigarette users (wave 2 only). To assess e-cigarette use frequency, we asked participants: 'During the past 7 days, including today, on how many days did you use an e-cigarette?' with responses restricted to numbers between 0 and 7 (modified from reference 21). If participants reported having quit e-cigarettes at wave 2, then they were coded as 0 for this variable.

To assess cigarette use status, we used the measures described above for eligibility and collapsed smokers into three categories: (1) daily smokers, (2) non-daily smokers and (3) former smokers. To assess cigarette use quantity, we asked non-daily smokers: 'On average, about how many cigarettes do you currently smoke each week?' with responses restricted between 0 and 150.²² For daily smokers, we asked: 'On average, about how many cigarettes do you currently smoke each day?' with responses restricted between 0 and 150.²² We then multiplied the cigarettes that daily smokers used by 7 to create a composite measure of cigarettes per week. Participants who reported having quit smoking at wave 1 or wave 2 were assigned a 0 for this variable.

Demographics and socioeconomic variables

We asked participants at wave 1 their sex, level of education attained (ranging from less than primary school to postgraduate degree), their income per month and urbanicity. To assess urbanicity, we asked: 'Do you live in an urban, suburban or rural area?'

Data analysis

We used participants' names, phone numbers and IP addresses to ensure there were no duplicates in the data. Any duplicate entries were deleted before analysis. We analysed data from all participants who were eligible for and completed both surveys, regardless of whether there were missing data. We first observed if there was change over time in the variables described above. To assess change in continuous variables, we used paired t-tests. To assess change in dichotomous variables, we used McNemar's test. To assess change in ordinal variables, we used a Wilcoxon signed-rank test, which is appropriate for paired ordinal data.

We then observed if change in e-cigarette use status was associated with change in cigarette use status using a multinomial model. In the multinomial model, we modelled our outcome as change in cigarette use, which had three levels: increased cigarette use (eg, moving from a non-daily cigarette user at wave 1 to daily cigarette user at wave 2), no change in cigarette use (referent group) and decreased cigarette use (eg, moving from a daily to a non-daily cigarette user). We calculated an adjusted model (controlling for demographics and socioeconomic variables) with the main correlate being change in e-cigarette use, which also had three levels: increased e-cigarette use from wave 1 to wave 2, no change in e-cigarette use (referent group) and decreased e-cigarette use. Finally, we observed if change in e-cigarette use frequency was associated with change in cigarette use quantity using a multivariable linear regression. For the linear regression, we calculated an adjusted model (controlling for demographics and socioeconomic variables) with the main correlate being change in e-cigarette use frequency.

Table 1 Demographics, as measured at wave 1

| Variable | N (%) |
|---------------------------------------|-------------|
| Age* | |
| 18–24 | 679 (65.4) |
| 25+ | 360 (34.7) |
| Sex | |
| Male | 1001 (96.4) |
| Female | 37 (3.6) |
| Education attained | |
| Less than high school | 21 (2.0) |
| High school | 608 (58.5) |
| College/university | 396 (38.1) |
| Graduate degree | 14 (1.4) |
| Income, per month | |
| IDR 0–1.5 million (<US\$103) | 334 (32.3) |
| IDR 1.5–3.5 million (US\$103–US\$240) | 400 (38.7) |
| IDR 3.5–7 million (US\$240–US\$480) | 2239 (3.1) |
| More than IDR 7 million (>US\$480) | 62 (6.0) |
| Urban status | |
| Urban | 666 (64.1) |
| Suburban | 275 (26.5) |
| Rural | 98 (9.4) |

*Age ranged from 18 to 55 years.
IDR, Indonesian rupiah.

Results from our multinomial model include adjusted odds ratios (aORs). Results from the linear regression model include beta coefficients (β) and

SEs. We conducted analyses in SAS V.9.4 (SAS Institute, 2011), set $\alpha=0.05$ and used two-tailed statistical tests.

Patient and public involvement

No patient involved.

RESULTS

At wave 1, our sample (n=1039) was primarily comprised of men (96.4%), which aligns with the high prevalence of cigarette smoking among males in Indonesia. In addition, most participants were young adults between the ages of 18 and 25 years (65.4%), had a high school (58.5%) or university degree (38.1%), lived in an urban area (64.1%), and earned 1.5–3.5 million IDR (about US\$103–240) per month (38.7%) or less than 1.5 million IDR per month (32.3%) (table 1). Participants represented 32 out of the 34 provinces in Indonesia.

Price of last purchased e-liquid and recall of tax stamps

The price of e-liquid significantly increased from wave 1 when it cost 138 000 IDR on average (about US\$9.50) per 60 mL to wave 2 when it cost 144 000 IDR on average (about US\$10.00) per 60 mL based on self-reported data (table 2). We also found that 49.4% of the sample reported paying more for their most recent purchase of e-liquid at wave 2 than wave 1 (online supplemental table A).

Significantly more participants also reported seeing a tax stamp on their most recent purchase at wave 2 (73.8%) than wave 1 (22.5%) ($p<0.001$). For participants who recalled seeing a tax stamp at wave 2 but not wave 1,

Table 2 Cigarette and e-cigarette use status, frequency, and quantity at wave 1 and wave 2

| Variables | Wave 1 N (%) | Wave 2 N (%) | P value |
|--|------------------------|-----------------------|------------------|
| E-liquid price per 60 mL, mean (SD) | IDR: 137 839 (112 833) | IDR: 144 224 (94 417) | 0.02 |
| Recall seeing tax stamp on most recent purchase | | | |
| No | 786 (77.5) | 267 (26.2) | <0.001 |
| Yes | 228 (22.5) | 752 (73.8) | |
| E-cigarette use status | | | |
| None* | — | 38 (3.7) | <0.001 |
| Non-daily | 250 (24.1) | 339 (32.7) | |
| Daily | 789 (75.9) | 660 (63.6) | |
| Number of past 7 days used e-cigarettes, mean (SD) | 5.7 (1.9) | 5.2 (2.3) | <0.001 |
| Cigarette use status | | | |
| None—completely quit smoking | 213 (20.5) | 249 (24.1) | <0.001 |
| Non-daily | 532 (51.2) | 537 (51.9) | |
| Daily | 294 (28.3) | 248 (24.0) | |
| Cigarettes per week (all smokers), mean (SD) | 34.2 (54.7) | 25.6 (38.1) | <0.001 |

Boldface denotes statistical significance $p<0.05$.
*Participants who did not use e-cigarettes daily or non-daily at wave 1 were not eligible for participation.
IDR, Indonesian rupiah.

participants reported paying 7.7% more for their e-liquid at wave 2 (145 000 IDR) compared with wave 1 (134 000 IDR) (data not shown in table).

Stockpiling and price minimisation techniques

More participants reported stockpiling before the e-liquid tax than after (online supplemental table B). Specifically, at wave 1, 7.1% of participants reported buying more e-liquid than usual in the past month (ie, stockpiling); whereas at wave 2, only 4.4% of participants reported buying more e-liquid than usual in the past month ($p<0.001$). In addition, two price minimisation techniques increased from wave 1 to wave 2. More participants reported using less e-liquid following the e-liquid tax (44.0% at wave 2 vs 39.1% at wave 1, $p=0.003$) and sharing e-liquid less with others (50.1% at wave 2 vs 46.1% at wave 1, $p=0.02$).

Hypothesis 1

E-cigarette use significantly declined between wave 1 and wave 2. Specifically, more participants were daily e-cigarette users at wave 1 compared with wave 2 (75.9% vs 63.6%) and fewer participants were non-daily e-cigarette users at wave 1 than wave 2 (24.1% vs 32.7%) ($p<0.001$). In addition, participants used e-cigarettes 5.7 days of the past week (SD: 1.9), on average, at wave 1 which was significantly higher than wave 2, when participants used e-cigarettes 5.2 days of the past week (SD: 2.3) at wave 2 ($p<0.001$).

Hypothesis 2

Contrary to our hypothesis, cigarette use significantly declined between wave 1 and wave 2 on average. Specifically, more participants were daily cigarette smokers at wave 1 compared with wave 2 (28.3% vs 24.0%) ($p<0.001$). In addition, participants smoked an average of 34.2 cigarettes per week (SD: 54.7) at wave 1, which was significantly higher than wave 2, when participants smoked 25.6 cigarettes per week (SD: 38.1). When we stratified results by cigarette smoking status at wave 1, we found that cigarettes per week declined for everyone except recent quitters at wave 1, for whom cigarettes per week increased by 8.2 cigarettes per week by wave 2 (SD: 27.2, $p<0.001$).

Hypothesis 3

In multivariable models, participants who reported decreasing their e-cigarette use from wave 1 to wave 2—relative to reporting no change—had higher odds of reporting increasing their cigarette use from wave 1 to wave 2 (aOR: 2.99; 95% CI: 1.95 to 4.59) (table 3). In addition, as participants reported decreasing how frequently they used e-cigarettes, they reported increasing the number of cigarettes they used per week ($\beta=-2.41$, $p=0.007$).

Further, in a sensitivity analysis, we found (1) that controlling for weekly amount of money spent on cigarettes did not change associations found between change in e-cigarette use and change in cigarette use (online supplemental table C) and (2) no relationship between

price paid for most recent e-liquid purchase and vaping/smoking behaviours (online supplemental table D).

DISCUSSION

In this study, we found that following the implementation of an e-liquid tax in Indonesia, e-cigarette use reportedly declined in our sample and participants who reported decreasing their e-cigarette use were more likely to report increasing their cigarette use. In addition, we found that while participants reported that they paid a higher price for e-liquids following the tax, this increase was far below the planned 57% tax. Finally, contrary to our hypothesis, on average, cigarette use declined.

As expected, we found that e-cigarette use reportedly declined following the e-liquid tax in Indonesia, both in the number of days participants used e-cigarettes in the past week and in the proportion of daily e-cigarette users. A large body of research shows that taxes are one of the most effective strategies to decrease tobacco product use,²³ including e-cigarette use.^{9–11 13 24} For instance, results from the USA and European Union show that increasing the price of e-cigarettes is associated with declining e-cigarette sales and that e-cigarette demand may be even more price responsive than the demand for regular cigarettes.^{9 24} Our results extend these conclusions by showing that e-cigarette taxes can potentially decrease use of e-cigarettes in a middle-income country.

Importantly, we observed that the Indonesian e-liquid tax, written as a 57% tax on the retail price in the legislation, was not implemented as such. Instead, e-liquids had tax-tiered levels of stamps that ranged from 10 000 IDR (US\$0.70) for a low-priced 15 mL bottle to 276 000 IDR (US\$19.24) for a 100 mL high-priced bottle (online supplemental table E). The tax appeared to only result in a 5%–8% increase in the price of e-liquid among consumers, according to consumers' self-report. There are at least three potential reasons why we observed such a large difference between the intended tax increase and the price increase reported by participants. First, we discussed our findings with four tax officials (two at a public vaping event in fall of 2018 prior to the law implementation and two in private meetings), and learnt that the tax was applied at the manufacturer level; therefore, there were loopholes so that manufacturers and distributors could avoid a higher tax. As enacted, the tax was closer to 40%, substantially lower than the intended 57%. Second, and more importantly, it appears manufacturers, distributors and retailers have been able to absorb most of the tax. While research from the USA shows that excise tobacco taxes are often overshifted to consumers (ie, prices increase more than the tax would indicate),²⁵ research in middle-income countries like South Africa and Indonesia has found taxes being absorbed rather than passed on.^{26 27} Third, before the date the tax was to be implemented, we were able to find some bottles of e-liquid with a tax stamp already applied, which aligns with our finding that 22.5% of the sample reported

**Table 3** Correlates of change in cigarette use status and number of cigarettes used per week

| Variable | Change in cigarette use status | | Change in cigarettes per week |
|---------------------------------------|--|--|-------------------------------|
| | Increased use (vs no change) aOR (95% CI) | Decreased use (vs no change) aOR (95% CI) | β (SE), p value |
| Age | | | |
| 18–24 | 1.05 (0.66 to 1.67) | 1.04 (0.70 to 1.55) | 5.60 (4.07), p=0.17 |
| 25+ | Ref | Ref | Ref |
| Sex | | | |
| Male | Ref | Ref | Ref |
| Female | 0.92 (0.33 to 2.54) | 1.32 (0.58 to 3.04) | 4.10 (8.97), p=0.65 |
| Education attained | | | |
| Secondary school or less | 1.71 (0.45 to 6.41) | 1.07 (0.33 to 3.46) | –15.52 (12.31), p=0.21 |
| High school | Ref | Ref | Ref |
| College/university | 0.91 (0.59 to 1.42) | 1.29 (0.89 to 1.87) | –3.10 (3.82), p=0.42 |
| Graduate degree | 2.52 (0.61 to 10.50) | 1.50 (0.37 to 6.03) | 16.45 (14.82), p=0.27 |
| Income, per month | | | |
| IDR 0–1.5 million (<US\$103) | Ref | Ref | Ref |
| IDR 1.5–3.5 million (US\$103–US\$240) | 1.74 (1.05 to 2.88) | 0.71 (0.47 to 1.07) | 7.01 (4.11), p=0.09 |
| IDR 3.5–7 million (US\$240–US\$480) | 2.16 (1.19 to 3.92) | 1.16 (0.72 to 1.87) | 6.81 (5.08), p=0.18 |
| More than IDR 7 million (>US\$480) | 0.74 (0.23 to 2.35) | 0.94 (0.45 to 1.96) | 7.68 (7.99), p=0.34 |
| Urban status | | | |
| Urban | Ref | Ref | Ref |
| Suburban | 0.81 (0.51 to 1.28) | 0.77 (0.52 to 1.15) | 0.66 (3.89), p=0.86 |
| Rural | 0.72 (0.32 to 1.62) | 1.67 (0.99 to 2.81) | 4.76 (5.99), p=0.43 |
| E-cigarette use status | | | |
| Increased use | 0.97 (0.28 to 3.39) | 1.64 (0.70 to 3.83) | – |
| Stayed the same | Ref | Ref | – |
| Decreased use | 3.00 (1.95 to 4.60) | 0.82 (0.51 to 1.31) | – |
| E-cigarette use frequency | – | – | –2.39 (0.89), p=0.007 |

Boldface denotes statistical significance p<0.05.
aOR, adjusted OR; IDR, Indonesian rupiah.

seeing a tax stamp at wave 1. This is likely because the tax regulation was actually planned to be launched in July but delayed to October, so some manufacturers had products with tax stamps prior to October.

In our study, even with the small tax increase, we found effects on e-cigarette and cigarette use. However, it is important to note that a price increase of 5%–8% would typically not have had much of an effect on consumption.²⁸ Therefore, it is possible that other factors beyond the price increase might have influenced e-cigarette and cigarette use—particularly since we found no association between the price participants reported paying for their most recent e-liquid purchase and their vaping/smoking behaviours. For instance, it is possible that access to e-cigarettes, marketing of e-cigarettes, supply of e-cigarettes or hearing news about the e-cigarette tax could have influenced participants' e-cigarette use. It is also possible that

as e-cigarettes became more commonplace in Indonesia and the design of e-cigarettes improved to deliver nicotine more efficiently, people may have used less e-liquid. Future research, especially in low-income and middle-income countries, should examine how e-cigarette taxes affect the retail sales price of e-cigarettes and the extent to which they are passed through to consumers, and how this supports or hinders public health goals.

We also found evidence that e-cigarettes and cigarettes may act as substitutes for one another since participants in our study who reported decreasing their e-cigarette use were more likely to have reported increasing their cigarette use. These findings align with prior research on e-cigarette and cigarette cross-substitution.^{9–14} For instance, research from both the European Union and USA shows that higher cigarette prices and taxes are associated with increased use and demand for e-cigarettes^{9 10} and vice

versa.^{10–13} Our study adds to this growing body of research by providing data on the effects of an e-cigarette tax in a middle-income country. Our findings also highlight the effect of differential taxation for tobacco products, especially e-cigarettes and cigarettes. Taxes are a powerful tool that policymakers can use to reduce use of tobacco products, and could be specifically leveraged to disincentivise use of the most harmful products (combustibles). Or, at the least, to reduce unintended consequences harmful to public health, a prudent approach would be to raise taxes on combustible products at the same time as any increased taxes on non-combustible products.

Finally, contrary to our hypothesis, we found that cigarette use declined from wave 1 to wave 2 on average in our sample. That both e-cigarette and cigarette use declined at follow-up could indicate that these products are complements for another (ie, decreased demand for one is associated with decreased demand for the other). However, we also found that individuals who reported decreasing their e-cigarette use were more likely to have reported increasing their cigarette use (ie, substitution). More rigorous evaluations in low-income and middle-income countries—including those with a control group and longer follow-up periods—are needed to establish whether e-cigarettes and cigarettes are substitutes or complements. Moreover, evaluations of whether e-cigarettes are complements or substitutes may need to consider subgroup analyses, given that we found increased cigarette smoking among middle-income participants and participants who had quit smoking at wave 1. Thus, for some participants, such as lower income participants, e-cigarettes and cigarettes may serve as complements to one another and the e-liquid tax could have decreased consumption of both products, whereas for other participants, such as middle-income participants, e-cigarettes and cigarettes may have served as substitutes for one another, and the e-liquid tax could have decreased consumption of e-cigarettes but increased consumption of cigarettes. Similarly, for recent quitters, it is possible that the e-liquid tax potentially led them back to smoking, as has been shown to occur elsewhere.¹⁴

Limitations

Importantly, participants could have changed their e-cigarette or cigarette use over the course of the study for reasons unrelated to the tax. Since we did not have a control group/country, we could not be certain the effects we observed are due strictly to the tax. Relatedly, we only assessed tobacco use behaviours over a period of 2–3 months between wave 1 and wave 2; it is possible that the novelty of the tax triggered short-term changes in tobacco use that might not be sustained over a longer time period.

Although we tried to recruit participants from across Indonesia, our study is not necessarily representative of all Indonesians. While the income levels of our sample were approximately in line with the national average of 2.9 million rupiah per month²⁹ and most participants

were from urban areas which is also in line with the national average,³⁰ our sample skewed younger and toward a higher than average education level, perhaps due to our recruitment via social media. It is challenging to acquire a representative sample from Indonesia, which is the largest archipelago in the world, but we did manage to recruit participants from 32 of Indonesia's 34 provinces. Relatedly, there were relatively few women in our sample, which may mean that results are not generalisable to women, and we did not include youth or people who were not established e-cigarette/cigarette users. In addition, our survey item asking about recall of the tax stamp at wave 1 may have triggered participants to look for a tax stamp at wave 2 and rounding may have affected the prices participants reported paying for their e-liquid. Finally, we had some participants who were lost to follow-up. In a loss to follow-up analysis, we found that the only characteristic on which participants differed was income, in that people with a higher income were more likely to complete the wave 2 survey and people with a lower income were more likely to be lost to follow-up (online supplemental table F).

CONCLUSIONS

Following the implementation of an e-liquid tax in Indonesia, prices of e-liquid increased, e-cigarette use and cigarette use declined, and people who reported decreasing their e-cigarette use reported increasing their cigarette use. These findings suggest that cigarettes and e-cigarettes may be substitutes for one another and that care should be taken when proposing tobacco taxes so as to not unintentionally increase the use of cigarettes.

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Contributors SK drafted the initial manuscript, cleaned and analysed the data, and revised the manuscript. MJB, DA, AG and ENO conceptualised the study. MJB supervised the study and acquired funding. SK, DA, ENO, LR, AG and MJB designed and revised the survey instrument. DA and ENO helped collect the data. KSK reviewed the study analysis. All authors interpreted the data, revised the manuscript for important intellectual content and approved the final manuscript. MJB is the guarantor for the study.

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Patient consent for publication Not required.

Ethics approval This study involves human participants and was approved by the University of North Carolina at Chapel Hill Institutional Review Board in 2018 (18-2153). Participants gave informed consent to participate in the study before taking part.

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Data availability statement Data are available upon reasonable request. Data are available upon request by emailing MJB (jbyron@unc.edu).

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