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# Tax incidence of electronic nicotine delivery systems (ENDS) in the USA

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## ABSTRACT

**Background** A growing number of states or jurisdictions in the USA have imposed excise taxes on electronic nicotine delivery systems (ENDS). However, there is no consensus on how best to tax ENDS.

**Objectives** We specifically compare the tax incidence or burden for ENDS and cigarettes and analyse how ENDS tax incidence is associated with the choices of tax bases and rates.

**Methods** We calculate ENDS excise tax incidence as the percentage of retail prices for each state or jurisdiction. Next, we use ordinary least squares to evaluate how tax incidence is associated with the choices of tax bases (eg, a specific tax base vs a value or ad valorem tax base) and rates and how these associations are moderated by product types.

**Results** ENDS and cigarette tax incidence is similar at the state level. Nonetheless, when federal cigarette taxes are considered, the cigarette tax incidence is higher than the tax incidence on closed-system ENDS. The proportion of states that impose value taxes is higher for open systems (65.4%) than for closed systems (46.2%). A value tax base is associated with a 7 percentage point lower tax incidence compared with a specific tax base. Product type further moderates the association between tax base and incidence.

**Conclusion** Tax incidence can be used to measure the strength of ENDS tax policies and how they are compared with cigarette taxes. Policymakers who aim to prevent youth from using ENDS may consider a value tax base to raise the tax incidence of closed systems—the product type preferred by young people.

## INTRODUCTION

Increasing excise taxes on cigarettes is one of the most effective tobacco control interventions for reducing smoking and its adverse public health consequences.<sup>1–4</sup> As electronic nicotine delivery systems (ENDS) rapidly gained popularity in recent years, particularly among young people, many states in the USA have adopted excise taxes on ENDS to curb their use<sup>5–13</sup> or raise revenue.<sup>14</sup> By the end of year 2020, 25 states, Washington, DC (hereafter referred as DC), and several local jurisdictions had ENDS excise taxes in place, up from nine states in 2018 (figure 1).<sup>14–19</sup> Recent evidence suggests that these taxes sufficiently raise ENDS prices, further reducing ENDS use among youth (6%–20% reduction when taxes increase by 10%), young adults (OR=0.64) and adults (OR=0.89).<sup>9 20–22</sup>

The imposition of ENDS excise taxes has stirred a debate on how best to design and implement ENDS tax policies to benefit the public health. The unknown long-term health effects of

ENDS compared with combustible tobacco; the complexity and diversity of ENDS product features such as nicotine levels, sizes and components; and the different impacts of different possible ENDS tax structures (ie, different tax bases and rates) create challenges for policymakers who want to raise revenue and/or promote the public health as effectively as possible.<sup>23 24</sup>

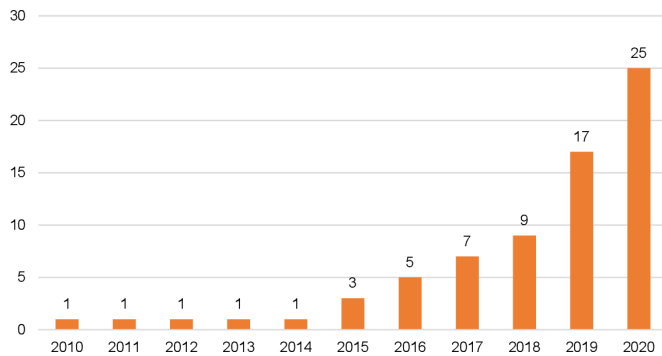
The first challenge is to measure and determine tax rates for ENDS that come in a variety of product design (eg, open vs closed system), pack size, price range and nicotine levels, including how to set ENDS tax rates relative to combustible tobacco tax rates. Currently, both states of California and Minnesota claim to set their ENDS tax rates as 'equivalent' to state cigarette tax rates; specifically, California taxes ENDS products at the rate of 59.27% of wholesale price, while the ENDS tax rate in Minnesota is 95% of wholesale price.<sup>15</sup> However, it is not clear how they determine that such tax rates are equivalent to cigarette tax rates which are based on units rather than wholesale prices.

From a technical perspective, converting taxes or prices to equivalent or comparable units is necessary to make comparisons among products that are complex in design and significantly different from each other. There are two primary approaches to conduct the conversion: (1) to establish absolute equivalent units (eg, an X amount of JUUL pods is equivalent to a pack of 20 cigarettes)<sup>25</sup>; and (2) to establish relative equivalent units, such as tax incidence or burden measured by the percentage of taxes among retail prices. The first approach for conversion requires a consensus on whether the conversion needs to be based on nicotine content or typical use behaviours or equivalent harms, which does not exist yet. In contrast, the second approach of conversion by establishing relative equivalent units in the form of tax incidence (ie, % of taxes among retail prices) is more straightforward and has been widely used by the WHO Framework Convention on Tobacco Control to recommend and measure cigarette tax policy strength across the globe.<sup>26 27</sup> This measure has the advantage of comparing taxes across countries where price ranges and product types drastically differ (eg, roll-your-own vs manufactured cigarettes), thereby holds the greatest potential to measure how ENDS taxes vary by types and differ from cigarette taxes in a transparent way. In a recent tool developed by the Campaign for Tobacco-Free Kids, tax incidence or burden is used to compare tax levels between cigarettes and heated tobacco products (<https://www.tobaccofreekids.org/what-we-do/global/taxation-price/tax-burden-htp>), further demonstrating its function as an anchor to compare tax levels between heterogeneous products.



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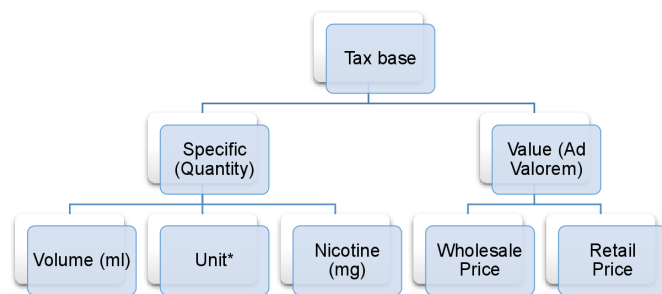
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**Figure 1** Number of US states with electronic nicotine delivery systems (ENDS) excise tax, by the end of year 2020.

The second challenge is to choose the most constructive excise tax base for ENDS. ENDS taxes can take the form of either value (ie, ad valorem) taxes, similar to a value-added tax,<sup>14 15</sup> or specific taxes (ie, at a constant rate per unit of quantity) on ENDS products based on characteristics, such as taxes by liquid volumes, or milligrams of nicotine (figure 2). Currently, most of the US states that apply specific excise taxes on ENDS products are based on volume or a fixed amount per millilitre (mL) of liquid nicotine irrespective of nicotine strength. For instance, Louisiana charges a volume-based tax on ENDS products at \$0.05/mL of consumable nicotine liquid solution or other material containing nicotine. Instead of specific states, many states choose to impose ENDS value (ad valorem) taxes, that is, based on the market value (wholesale or retail prices) of the products. Value excise taxes often take the form of a fixed percentage of the product wholesale or retail price. For example, the State of New York imposes value excise taxes on ENDS products at 20% of ENDS retail price. Other states with value excise taxes often base their taxes on ENDS wholesale prices.

Further, the choices of tax bases will alter the relative prices of different ENDS products that have different features and, consequently, have different impacts on consumer product choices.<sup>4 28–31</sup> This extensive product diversity among ENDS is quite different from cigarettes and other long-standing tobacco products, which are much more homogeneous within each product category, allowing for much simpler and straightforward taxation and related evaluations of tax impacts.<sup>31</sup> For example, the cigarette literature already shows that, compared with a specific tax base, a value tax base is associated with a lower tax incidence, greater price variability and increased cigarette consumption.<sup>4 30–32</sup> Nonetheless, a value tax base has the advantage of keeping up with inflation, and functions more effectively than a specific tax base in raising prices in countries where inflation and economic growth are high (eg, low and middle-income countries). There are gaps in the understanding of the choices of ENDS tax bases such as whether value taxes are associated with a



**Figure 2** The categorisation of existing and proposed e-cigarette tax bases. \*Product unit, such as per closed-system cartridge.

lower tax incidence and more consumption, similar to the conclusion for cigarette value taxes; and how product heterogeneity moderates the association between tax bases, tax incidence and other downstream outcomes. Empirical evidence is needed to inform the design of ENDS tax bases.

In this study, we present a snapshot of states' ENDS tax structure choices in 26 jurisdictions in the USA during 2020. We calculate tax incidence on ENDS and compare it with cigarette tax incidence, which is a necessary first step to gauge the relative levels of taxes in an empirical way. We further analyse how different ENDS tax bases and rates are associated with tax incidences and how these associations are moderated by product type such as open versus closed-system ENDS. These findings will inform policymakers who are considering the imposition of ENDS taxes or contemplating ENDS tax structure reforms.

## METHODS

### Data sources for cigarette tax incidence

Cigarette tax incidence (tax as a percentage of retail price) in the year 2020 (as of 1 January 2020) comes from the table 14 in the 'Taxation of Emerging Tobacco Products' report by Tobacconomics,<sup>15</sup> which was estimated using trend analysis and November 2018 cigarette prices by states reported in the 'Tax Burden on Tobacco'.<sup>33</sup> Both cigarette price and tax data were collected and estimated at the state level.

### Data sources for ENDS tax incidence

State-level ENDS tax rates and bases in the year 2020 (as of 1 January 2021) come from the Public Health Law Center and Centers for Disease Control and Prevention.<sup>18 19</sup> These data were compiled and coded by legal researchers. National-level ENDS prices of typical products—a 30 mL e-liquid bottle, a 0.7 mL JUUL pod and a 1 mL Blu disposable in 2019—come from online searches of product websites and the e-cigarette intelligence database. These prices reflect national averages and do not vary by states or jurisdictions.

### Outcome measures: tax incidence

The primary outcome measure of this study is ENDS tax incidence, calculated as excise taxes as a percentage of retail prices. To calculate the tax incidence for ENDS products, we first impute state-level tax per mL for typical products: a 30 mL e-liquid bottle, a 0.7 mL JUUL pod and a 1 mL Blu disposable using national-level prices and state-level ENDS tax rates. For states or jurisdictions using value taxes based on wholesale or retail prices, we calculate tax per mL for them in the following way: tax per mL = value tax rate × price per mL.

Since many states impose taxes as a percentage of wholesale prices, we first need to convert retail prices to wholesale prices. Here, we make three different assumptions based on existing wholesale to retail price ratios for cigarettes and production/distribution practices of ENDS retailers: wholesale prices are equal to retail prices (eg, when sellers produce their own e-liquid); retail prices are 115% of wholesale prices; and retail prices are 130% of wholesale prices. The latter two ratios are based on cigarette wholesale to retail price ratios, which reflect the possible ranges for ENDS when they are distributed and sold using the existing channels for cigarettes.<sup>15</sup> Given that many large ENDS producers such as JUUL or Blu are either owned or partially owned by traditional cigarette companies, we expect these ratios to reflect ENDS wholesale to retail price mark-ups. Next, we use the following three equations to calculate three alternative measures of ENDS taxes per mL.

Assuming wholesale prices=retail prices, then:

$$\text{tax per mL} = \text{value tax rate based on wholesale prices} \times \text{retail prices per mL}$$

(1) Assuming retail prices =  $1.15 \times$  wholesale prices, then:

$$\text{tax per mL} = \text{value tax rate based on wholesale prices} \times \frac{\text{retail prices per mL}}{1.15}$$

(2) Assuming retail prices =  $1.3 \times$  wholesale prices, then:

$$\text{tax per mL} = \text{value tax rate based on wholesale prices} \times \frac{\text{retail prices per mL}}{1.3}$$

Because many states implement different tax rates and bases by whether a product is an open or closed system and the price difference between the two product types, we calculate the tax incidence at the state level for both systems. Specifically, we estimate the price of closed systems using the average price of Blu disposables and JUUL pods, standardised into price per mL. We then calculate the tax incidence by dividing tax per mL with price per mL. We calculate the tax incidence for open systems by dividing tax per mL with price per mL for e-liquid bottles.

### Explanatory measures: tax bases and rates

The independent variables are tax structure measures including tax rates and bases. Tax bases are measured using a dummy variable that indicates a value tax base, with a specific tax base as the omitted category. We follow the existing literature and calculate tax rates using the formula that a 1 percentage point of value tax based on wholesale price translates to  $\$0.044/\text{mL}$ .<sup>5</sup> Specifically, we transform value taxes in the following way:

$$\text{tax per mL} = \text{value tax rate in percentage points} \times 0.044$$

The details of this transformation are detailed in Pesko *et al.*<sup>5</sup> They used DC's value or ad valorem tax rate and tax revenues in 2017 as benchmark to develop this formula to estimate tax measures that are less subject to endogeneity in a value or ad valorem tax system. In short, this procedure addresses the following two issues: (1) economists would like to calculate average taxes that are independent of individual product prices; and (2) by construct, value taxes on individual products are never independent of prices. Therefore, a transformation is required to construct an independent tax variable in a value-based system that averages over the product spectrum.

### ANALYSES

We use ordinary least squares regressions to analyse the associations between ENDS tax structures (bases and rates) and tax incidence. Specifically, we regress ENDS tax incidence on tax rates ( $\$$  tax/mL), tax base (a dummy variable for value—quantity as the omitted category), product type (a dummy variable for closed systems—open systems as the omitted category) and the interaction term between tax bases and product types. We cluster SEs at the state/jurisdiction level to adjust for correlations within observations from the same states/jurisdictions. The regression model can be expressed using the following formula:

$$\text{Tax Incidence}_s = b_0 + b_1.\text{Tax.Rates}_s + b_2.\text{Tax.Bases}_s + b_3.\text{Product.Types}_s + b_4.\text{Product.Types}_s \times \text{Tax.Bases}_s + e_s$$

In the above equation,  $s$  denotes state and we use data on ENDS taxation in 2020. Here, we test the following three hypotheses. First, higher tax rates per mL (value tax rates are converted to dollar tax rates) are associated with a higher tax incidence ( $b_1 > 0$ ). Second, compared with a value base, a quantity base is associated with a higher tax incidence ( $b_2 < 0$ ). Third, compared with an open system, a closed system on average bears a lower tax incidence ( $b_3 < 0$ ) in a restrictive model where the interaction of product type and tax bases is left out ( $b_4$  not estimated). This is because we hypothesise that product type will moderate the association between tax bases and tax incidence. Specifically, tax incidence would be the same across product types under a value-based system where taxes are levied as a percentage of prices; however, given the small volume size of closed

**Table 1** ENDS excise tax bases and rates in the USA, by the end of year 2020

Tax characteristics	Descriptions
Impose ENDS excise taxes	26 out of 50 states and DC
Different tax bases or rates for closed versus open systems	6 out of 25 states and DC
Tax bases for closed systems	14 states/DC use quantity (2 use unit +12 use volume) versus 12 use value (1 use retail price +11 use wholesale price)
Tax bases for open systems	9 use quantity (all use volume) versus 17 use value (1 use retail price, 1 use retail or wholesale price and 15 use wholesale price)

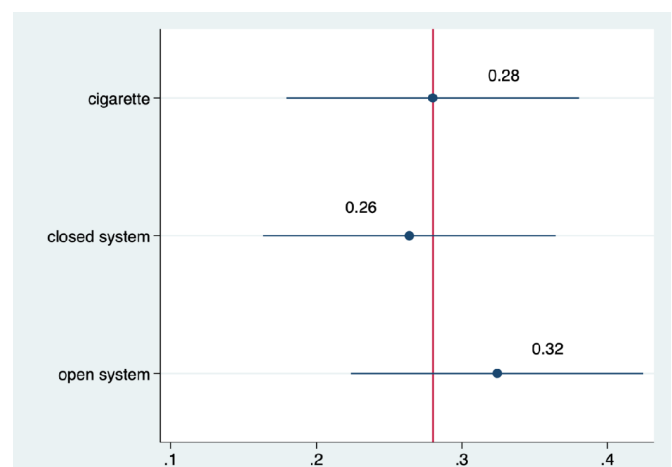
DC, Washington, DC; ENDS, electronic nicotine delivery systems.

systems, they bear a lower tax incidence than open systems using e-liquid under a specific volume-based tax system.

### RESULTS

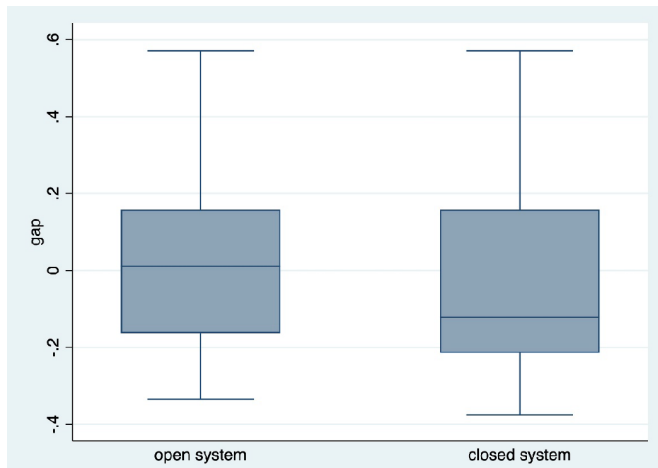
Table 1 shows the choices of ENDS tax bases and whether different tax rates are applied to different ENDS product types in US states in 2020. Among the 26 jurisdictions (25 states and DC) that have imposed ENDS taxes, six states have imposed different tax bases or rates for closed versus open systems. For closed systems, 13 states and DC use specific taxes based on quantities; specifically, two of them choose product unit (such as per closed-system cartridge) as tax base, and the rest of 12 jurisdictions choose the tax base of e-liquid volume; the remaining 12 states use value taxes, with one choosing retail price as the base and 11 choosing wholesale price as the base. For open systems, 9 states use specific taxes on liquid volume, and the other 17 states use value taxes, with 1 using retail price as the base, 1 using retail or wholesale price and 15 using wholesale price.

In figure 3, we show the results of comparing state-level average tax incidence among cigarettes, closed-system ENDS and open-system ENDS in the 26 states or jurisdictions with ENDS taxes. The mean state-level tax incidence in 2020 is 28% for cigarettes, 26% for closed-system ENDS and 32% for open-system ENDS. The standard errors for these mean estimates are relatively large, suggesting that tax incidence differs by states. Nonetheless, the average tax incidence between state-level ENDS (both closed and open systems) and cigarettes is small and not statistically significant. We further calculate the gap in state-level tax incidence between ENDS and cigarettes (tax incidence of ENDS minus the tax incidence of cigarettes), and then



**Figure 3** Tax incidence on cigarettes (n=26), closed-system electronic nicotine delivery systems (ENDS) (n=26) and open-system ENDS (n=26).





**Figure 4** Tax incidence gap between ENDS and cigarettes (ENDS tax incidence minus cigarette tax incidence), by system.

plot the distribution using boxplot in figure 4. Similarly, while there is heterogeneity in tax incidence gap, the average gap is small and not significantly different to zero. In other words, when we examine state-level tax incidence for tobacco or nicotine products, ENDS tax incidence can be higher, about the same or lower compared with cigarette tax incidence. However, likely due to the difference between states and the lack of common strategies, the average state-level tax incidence gap between ENDS and cigarettes across 26 states and DC is small and non-significant. It is worth noting that in these analyses we did not factor in the federal cigarette taxes. If we include federal cigarette taxes, the tax incidence on cigarettes amounts to 42% and significantly higher than the tax incidence for closed-system ENDS. The tax incidence difference between cigarettes and open-system ENDS remains non-significant from 0.

Table 2 presents the summary statistics of ENDS tax structures (rates and bases) by closed versus open systems. Fewer than half of the ENDS-taxing states or jurisdictions use value tax bases for closed systems, but roughly two-thirds using value-based taxes for open systems. In all the direct-taxing states or jurisdictions, the ENDS taxes per mL are similar between systems—averaging

\$1.21/mL on closed systems and \$1.19/mL on open systems. Looking at all the ENDS-taxing states, the tax incidence range is between 20% and 26% for closed systems and between 26% and 32% for open systems. Although open systems rely more on value taxes and bear about 6% more tax incidence than closed systems, these differences are not statistically significant.

Table 3 presents the associations between tax structures (bases and rates) and incidences for ENDS products. We consider ENDS taxation on open systems as well as closed systems in each of the 26

jurisdictions, so in total there are 52 observations in each column. The findings suggest that tax rates and bases are independently associated with tax incidences. Higher tax rates (a \$1/mL increase in ENDS taxes) are associated with a 17–23 percentage point higher tax incidence, depending on the assumptions of wholesale to retail price mark-up ratio. Compared with a specific system with quantity bases, a value-based system is associated with a 7 percentage point lower tax incidence, after controlling for tax rates (columns 1, 3 and 5). When comparing product types, closed systems in the ENDS-taxing states are associated with an 8 percentage point lower tax incidence than open systems (columns 1, 3 and 5). When the regressions control for the interaction term between product type and tax bases (columns 2, 4, and 6), the results show that closed systems are associated with an 18 percentage point higher tax incidence with value taxes than with specific taxes.

## DISCUSSION AND CONCLUSION

In this study, we use tax incidence (ie, the percentage of excise tax in retail price) to compare state-level taxes across diverse tobacco and nicotine products. We find that, while the average state-level tax incidence (28%–32%) is similar between cigarettes and ENDS, individual states could have ENDS tax incidence that is higher, about the same and lower compared with state-level cigarette tax incidence. This suggests that states have not reached consensus on how to set ENDS tax rates relative to cigarette tax rates. Further, if we add the US federal cigarette excise taxes on top of state cigarette excise taxes, the tax incidence on cigarettes is higher than the incidence on closed-system ENDS. Given that both cigarette and ENDS taxes are over-shifted to prices, this implies that the current tax systems may have favoured closed-system ENDS such as JUUL relative to cigarettes by imposing a relatively lower tax incidence on closed-system ENDS. The ongoing debate over ENDS taxes has been primarily focused on the dilemma that while ENDS taxes may prevent ENDS initiation among young populations and reduce overall nicotine consumption and addiction, these ENDS taxes could hurt adult smokers who would not otherwise quit smoking by switching completely to ENDS use. The overall costs and benefits of imposing ENDS taxes will need to be continuously reassessed as more evidence on the relative harms between ENDS and combustible tobacco comes to light. However, in reality, a majority of controlled substances such as recreational marijuana and alcoholic beverages are subject to state-level or federal-level excise taxes in the USA; it is unclear whether ENDS' potential benefits to a subpopulation are sufficient to exempt the products that are by nature addictive from being taxed. Furthermore, as this study shows, with cigarettes being taxed at both the state and federal levels in the USA, the combined federal and cigarette tax incidence on cigarettes remains to be higher than the incidence on closed-system ENDS, leaving an economic incentive for smokers to switch to ENDS.

**Table 2** Summary statistics of ENDS excise taxes and tax incidence by tax base

Variables	Closed system (n=26) Mean (SD) or frequency (%)	Open system (n=26) Mean (SD) or frequency (%)	Difference between closed and open systems
Value	46.2%	65.4%	P=0.17
\$ taxes/mL	1.21 (0.28)	1.19 (0.28)	P=0.96
Tax incidence Wholesale=retail price	0.26 (0.06)	0.32 (0.06)	P=0.48
Tax incidence Wholesale*115%=retail price	0.23 (0.06)	0.29 (0.05)	P=0.43
Tax incidence Wholesale*130%=retail price	0.2 (0.05)	0.26 (0.04)	P=0.39

ENDS, electronic nicotine delivery systems.

**Table 3** The associations between ENDS tax structures (rates and bases) and tax incidence (n=52)

Variables	Tax incidence Wholesale=retail price		Tax incidence Wholesale*115%=retail price		Tax incidence Wholesale*130%=retail price	
	(1)	(2)	(3)	(4)	(5)	(6)
Tax rates	0.23*	0.22*	0.2*	0.19*	0.18*	0.17*
\$ taxes	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
Tax base						
Quantity	–	–	–	–	–	–
Value	–0.07*	–0.15*	–0.07*	–0.15*	–0.07*	–0.15*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Type						
Open	–	–	–	–	–	–
Closed	–0.08*	–0.18*	–0.08*	–0.17*	–0.07*	–0.17*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
Value*closed system	–	0.18*	–	0.17*	–	0.17*
		(0.02)		(0.02)		(0.02)
R <sup>2</sup>	0.97	0.99	0.96	0.99	0.95	0.99

We report SEs clustered at the state/jurisdiction level in parentheses.  
\*Indicates statistical significance at 1% level.  
ENDS, electronic nicotine delivery systems.

This study further shows that the choices of ENDS tax bases matter. Closed-system ENDS bear a much higher tax incidence when they are taxed by values compared with when they are taxed by volume. Yet, fewer than half of all ENDS-taxing states use value taxes on closed-system ENDS. As a result, the tax incidence on closed systems is lower compared with the tax incidence on open systems or cigarettes. For policymakers whose primary goal is to prevent youth addiction to ENDS, they may want to advocate for a value tax base to tax ENDS closed systems such as JUUL, which are the most popular among young populations.<sup>34</sup> We also find that specific taxes based on the volume of ENDS liquid are associated with higher tax incidence (eg, higher taxes on low-priced products), compared with value taxes. This finding is consistent with the cigarette literature where evidence shows that specific taxes per pack are more effective than value taxes in raising cigarette prices, reducing price variability, reducing opportunities for tax avoidance and reducing consumption among adult smokers.<sup>4 30–32</sup> This is also likely the case for ENDS. However, compared with specific taxes based on volume, taxes based on values are easier to implement for heterogeneous products like ENDS and are associated with higher tax incidence on closed-system ENDS. As the varieties of ENDS products grow, value taxes may be a useful tool to address the challenges from product heterogeneity. In addition, if the tax policy goal is to maintain economic incentives for adult smokers to switch to ENDS, efficiency in raising prices using a specific volume base may be secondary to ENDS policy design. With these considerations, value or ad valorem taxes may be more appropriate than a specific volume tax base to tax closed-system ENDS. Nonetheless, policymakers may need to keep an open mind and track market development in order to form ENDS tax policies. For example, if the situation changes in the future such that JUUL or standard ENDS products dominate the market to the extent that product heterogeneity diminishes, specific taxes based on unit or volume could become a better option to tax ENDS.

Finally, similar to other studies, we find higher ENDS tax rates are significantly associated with higher tax incidence.<sup>20 35–37</sup> Prior research had shown that ENDS taxes are overshifted to the prices of products sold in retail outlets, which subsequently reduces sales.<sup>5 6 10 11</sup> In particular, Cotti *et al*<sup>20</sup> find a tax-to-price pass-through rate of 1.44 and an own-price elasticity of –1.3 for e-cigarettes. Therefore, ENDS taxes are effective in reducing ENDS consumption in general.

However, the critical question remains whether these taxes can be designed in a way to deter initiation by otherwise non-using youth or adults while maintaining economic incentives for adult smokers who would not otherwise quit to switch to using only ENDS, instead of continuing to smoke.

This study has several limitations. First, many states levy ENDS taxes based on wholesale prices. However, we do not have data on wholesale prices in the market or how taxes are levied at the stage of wholesale. Therefore, tax incidences are calculated under the assumption that taxes are fully passed to prices at the wholesale level, and hypothetical wholesale-to-retail mark-up rates are used to generate tax incidence outcome variables. Future data collection is needed to accurately measure tax incidence. Second, we primarily compare specific (volume) and value taxes without making further distinctions on detailed bases such as wholesale versus retail price bases or unit versus volume tax bases. Future research is needed to ascertain how to choose among these bases. Third, although nicotine-based taxes could be an option, none of the states have imposed such taxes. Without policies implemented in the real world, experimental studies are needed to answer how such taxes perform in comparison with existing bases on volume or values. Fourth, our study assesses the associations between tax structures (including rates and bases) and tax incidence using cross-sectional data, and the findings should be not interpreted as causal. Although longitudinal data would strengthen the analyses, there has not been any changes in tax bases given the novelty of ENDS products and taxes (see figure 1). Further, even though ENDS taxes (the actual dollars paid as taxes) have been changing over time due to price changes (many states use value or ad valorem taxes), the tax rate changes were limited. Therefore, for our specification, there is not much additional variation to gain by using existing longitudinal data. Future changes in state tax bases and rates will allow observational studies to infer causal impact. Alternatively, future studies could use discrete choice experiments or similar eliciting methods to generate hypothetical variations in tax structures to estimate their impacts on behaviours. Fifth, tax administration challenges such as how to prevent loopholes that affect tax collections (eg, selling nicotine juice and nicotine separately to bypass taxes) merit future investigation using qualitative studies, which however is beyond the scope of the current study. Finally, as the market evolves and more evidence is available on the public health

impact of ENDS, tax structures including rates and bases would need adjustments accordingly.

### What this paper adds

- ⇒ Tax incidences (ie, excise taxes as a percentage of retail prices) on electronic nicotine delivery systems (ENDS) vary significantly by states and could be higher. The combined federal and state cigarette tax incidence is higher than the average state tax incidence on closed-system ENDS.
- ⇒ Higher ENDS tax rates are significantly associated with higher tax incidences.
- ⇒ In the existing ENDS-taxing jurisdictions, closed-system ENDS bear a higher tax incidence under a value base than a specific (volume) tax base.
- ⇒ At comparable rates, specific taxes based on volume are associated with higher tax incidence, relative to value taxes.
- ⇒ Policymakers may need to assess the trade-offs when choosing between value versus volume (specific) taxes because specific taxes have advantages in raising tax incidence whereas value taxes keep up with inflation and easy to administer to ENDS, which have a wide range of features.

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**Contributors** CS and ENL conceptualised the study. CS and SM wrote the first draft. ENL provided the comments. CS is responsible for the overall content as the guarantor.

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**Patient consent for publication** Not required.

**Ethics approval** This study was approved by the OSU Institutional Review Board (IRB).

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available in a public, open access repository. Data are available from the Public Health Law Center website.

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