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Excise taxes and pricing activities of e-liquid products sold in online vape shops

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ABSTRACT

Background Although e-cigarette excise taxes have great potential to prevent the initiation and escalation of e-cigarette use, little information is available on pricing activities of online vape shops, and how well taxation is implemented during web-based sales remains unclear.

Objectives We examine e-liquid pricing activities in popular online vape shops that sell nationwide in the USA and present how those stores charge excise taxes based on shipping addresses in states and local jurisdictions that have e-cigarette taxation in place.

Methods We collect e-liquid sales prices from five online vape shops using web data extraction, standardise prices for e-liquid products, and present e-liquid price distribution in the whole sample and in each store, as well as variations of excise taxes across states/local jurisdictions and between stores. The price data were scraped from the store websites from February to May in 2021.

Results We collected data on 14 477 e-liquid products from five stores. The average price of e-liquids is $0.25/mL, and the median price is $0.20/mL in our sample. E-liquid products sold online are very affordable and the average prices are lower compared with price estimates using other sources (eg, self-reports, sales data). In addition, online stores charge state excise taxes inconsistently and fail to comply with county-level or city-level excise taxes.

Conclusion E-liquid products sold online are priced low, and stricter enforcement of e-cigarette excise tax is needed in online purchasing channels.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Twenty-three per cent of current adult e-cigarette users and 14%–16% of youth and young adult e-cigarette users in the USA reported purchasing their products from online stores.

WHAT THIS STUDY ADDS

⇒ A snapshot of prices and taxes of e-liquid products sold in online stores.
⇒ The average price of over 14 000 e-liquid products sold in five online stores was $0.25/mL, and the average volume size per bottle was 68 mL.
⇒ The evidence suggests that online e-liquid products are sold at a relatively low price, and that tax compliance is inconsistent and low.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE AND/OR POLICY

⇒ The choice of e-cigarette tax bases such as existing state-level taxes based on wholesale prices may leave room for retailers and wholesalers to manipulate tax levels.
⇒ Policy innovations and compliance checks may be needed to regulate products sold online.
⇒ Future studies will benefit from rapid surveillance of the characteristics and sales of e-cigarette products sold online.

INTRODUCTION

Use of electronic nicotine delivery systems (ENDS) products, often called electronic cigarettes (e-cigarettes), increased significantly among adolescents and young adults (AYAs) during the past decade.[1 2] Increasing prices through taxation is considered one of the most effective policy tools to curb cigarette consumption and therefore has been increasingly adopted by states and localities to regulate e-cigarette use.[3–8] As of May 2021, 28 states, the District of Columbia (DC) and 9 local jurisdictions in the USA have imposed excise taxes on e-cigarettes.[9–11]

In light of this policy change, a growing number of studies have estimated the impact of e-cigarette taxes on a series of behavioural outcomes, including cigarette smoking and e-cigarette use. However, these studies exclusively use Nielsen Retail Scanner sales data gathered from brick-and-mortar stores.[3 12–15] Despite being an important source for e-cigarette prices and sales, Nielsen Retail Scanner data do not capture products sold online or in vape shops, which together accounted for about one-half of e-cigarette sales in the USA during 2019.[16]

Moreover, online stores and vape shops carry a variety of brands that are not captured in Nielsen Retail Scanner data, many of which are open-system e-liquid products.[17–19] These products are generally less expensive than cartridge-based systems and disposables. Therefore, by not including price data from online stores and vape shops, existing studies may overestimate e-cigarette price levels and bias the estimates of their impacts on behaviours, such as the price elasticity of e-cigarette demand.[20 21]

Compared with local vape shops, online stores pose unique challenges to e-cigarette taxation because it is unclear how these stores apply state and local e-cigarette excise taxes during online transactions. Further, online vaping stores are among the most common outlets for e-cigarette purchases,[22–24] supplying 23% of current adult e-cigarette users and 14%–16% of AYA e-cigarette users.[25–28] In particular, due to the complexity of e-cigarette tax structures (eg, specific excise taxes based on volume or unit, and/or ad valorem excise taxes based on

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wholesale or retail prices),[9–11] online stores may have difficulty complying with regulations.

In March of 2021, the Preventing All Cigarette Trafficking (PACT) Act was amended by the Congress to include new regulations on vaping products.[29] The amendment extends the PACT Act's age verification delivery requirements to e-cigarettes, bans mailing vaping products via the US Postal Service, and requires online sellers of vaping products to comply with state-level and local-level e-cigarette excise taxes.[29 30] However, how well online sales outlets comply with this regulation is unclear.

Web data extraction presents a unique opportunity to complement e-cigarette price data collected from brick-and-mortar stores. There are numerous brands of e-cigarettes sold online and in vape shops that are not captured in Nielsen Retail Scanner data.[17–19] Although researchers can evaluate the price distribution of e-cigarettes using self-reported survey data, the price estimates are susceptible to measurement errors for a variety of reasons.[20] First, unlike conventional cigarettes that are sold in packs of 20 sticks, e-cigarettes come in a variety of pack sizes and volumes. It is challenging for respondents to accurately report the pack or volume size for the products they purchased. Second, there are many different models of e-cigarettes such as disposables, rechargeables, pods, cartridges, etc. It is challenging for users of multiple e-cigarette models to accurately report the prices of each model they own. These data reporting challenges also arise when evaluating the association between marijuana prices and demand, because the market has a similarly large number of product forms/models and brands.[31 32] In a study that assesses the data quality of marijuana prices, the authors suggest using web data extraction instead of self-reported prices to accurately estimate the price distribution.[32]

To address this data limitation, evaluate the price difference by purchase sources, and understand how online stores comply with state and local e-cigarette excise taxes, this study collects price data of e-liquid products sold online and documents how online vape shops charge e-liquid excise taxes, using web scraping. To the best of our knowledge, our study is the first to present price distribution, price variability and tax collection of e-liquid products sold in online vape shops. As the number of states with e-cigarette excise taxes in place has rapidly increased since 2018, and as tax bases and rates vary across states, findings from our study provide insights on effective taxation practices for regulating e-cigarettes. Our study also presents timely evidence on e-liquid tax compliance with the PACT Act by popular online vape shops that sell nationwide in the USA.

METHODS

We collected data on e-liquid sales prices and excise taxes from five popular online vape shops using web data extraction, and standardised prices to dollar per millilitre to present the price distribution of e-liquid products. We further documented how these stores charge excise taxes to e-liquid consumers during online transactions.

Online vape shops

We use stores 1–5 to describe the online vape shops in our sample, for the purpose of masking store identities. The selection process of online stores is detailed in the online supplemental appendix. We scraped data from store 1 on 17 February 2021; we scraped data from stores 2 and 4 on 7 April 2021; we obtained data from store 5 on 4 May 2021; and we extracted data from store 3 on 20 May 2021. For information about store names and links to websites, see online supplemental table A1.

Excise tax rates and bases on vaping products

The data sources for excise tax rates and bases on e-cigarettes in 28 states and DC were the Centers for Disease Control and Prevention and the Public Health Law Center.[9 10] We obtained information on e-cigarette taxation in nine local jurisdictions in the USA from *Taxation of Emerging Tobacco Products*.[28] As of May 2021, there were 38 jurisdictions in the USA that had an e-cigarette excise tax in place, and most of them imposed excise taxes on e-liquid products either based on product volume (mL) or product value (either wholesale or retail price). Specifically, Chicago imposed excise tax on e-liquid products at a rate of $1.50 per product unit, plus $1.20/mL of liquid; Omaha in Nebraska included e-liquid products in the city's 3% tobacco tax; Delaware, Kansas, Louisiana, New Jersey, North Carolina, Ohio, Utah, Virginia, Washington, West Virginia, Wisconsin and Cook County in Illinois imposed excise taxes on e-liquid products based on volume (mL); California, Connecticut, Georgia, Illinois, Maine, Massachusetts, Minnesota, New Hampshire, Nevada, Oregon, Vermont, Wyoming, five boroughs in Alaska (Juneau, Northwest Arctic, Petersburg, Anchorage and Matanuska-Susitna), and Montgomery County in Maryland imposed excise taxes on e-liquid products based on a fixed percentage of wholesale price; Colorado, Kentucky, New Mexico, New York, Pennsylvania, Utah and Washington, DC imposed excise taxes on e-liquid products based on a fixed percentage of retail price.

Using addresses in each of the 28 states and DC, as well as the nine local jurisdictions, we then collected e-liquid excise taxes charged by the five online stores in our sample, both manually and through web scraping. Specifically, we collected excise tax data manually for store 1 between 10 May and 12 May 2021, store 2 on 26 May 2021, store 3 on 29 June, store 4 on 12 August 2021, and store 5 on 19 July 2021. A research specialist in our team first went to the website of an online vape shop in our sample, then selected a specific e-liquid product, and then entered addresses by hand on the checkout page of each store website and documented the excise tax charged on that product based on each shipping address, as shown on the store website. All research personnel involved in data collection of e-liquid excise taxes were above 21 years old, and thus were able to enter each store website in our sample by clicking on the 'yes' button for age verification that appeared on the home page.

While collecting tax data, research staff entered pseudo personal information (including names, email addresses and phone numbers) on the checkout webpage, along with pseudo shipping addresses from each ENDS-taxing jurisdiction. We used shipping addresses of universities for each of 28 states and Chicago, and middle/high school addresses for DC and the remaining eight local jurisdictions (including Juneau Borough, Northwest Arctic Borough, Petersburg Borough, Anchorage Borough and Matanuska-Susitna Borough in Alaska; Cook County in Illinois; Montgomery County in Maryland; and Omaha in Nebraska).

Excise tax information appeared on the checkout webpage once the required information was entered, and the research specialists took screenshots of the tax information. We further verified the tax information using curated automatic extraction aided by machine extraction, which essentially followed similar steps to those in the manual collection. This double-coding procedure ensures accuracy and consistency.

We chose similar e-liquid products to compare taxes across stores and across different states and local jurisdictions. Nonetheless, there were some variations in product volume and/or

price across stores due to product availability and price variability. Specifically, we chose the following products for five stores: Tobacco Gold No. 1 (120 mL, 6 mg) by Twist E-Liquids at $21.95 for store 1, White No. 1 (120 mL, 6 mg) by Twist E-Liquids at $21.99 for store 2, Tobacco Gold No. 1 (120 mL, 6 mg) by Twist E-Liquids at $16.99 for store 3, Strawberry Watermelon Bubblegum (100 mL, 6 mg) by Candy King E-Liquid at $13.99 for store 4, and Pink No. 1 E-Juice (120 mL, 3 mg) by Twist E-Liquids at $18.99 for store 5. The product we chose for store 1 and for store 3 was the same, but its price varied between the two websites.

Standardised price measure

Using data on product price and volume for e-liquids sold in five online vape shops, we standardised e-liquid price in the following way:

$$\text{Standardised price} = \frac{\text{actual price of the product}}{\text{total volume of the product}}$$

.Thus, the unit of standardised price is $/mL. We distinguished actual price from original price for products with discounts or on sale, and used actual price to calculate standardised price. For products that have multiple bottles in a sales pack, we distinguished between total volume per pack and volume per bottle, and used total volume per pack as the denominator of our standardised price measure. Total volume of each multi-bottle product equals volume per bottle times its pack sizes (ie, number of bottles in the product). Price data used in our analyses are shared here: https://www.ce-shang.com/vape-shop-product-information-collection.html.

RESULTS

In table 1, we present summary statistics of product price per pack (in $), volume per pack (in mL), and standardised price (in $/mL) for the whole sample (panel A) and by stores (panels B–F). We scraped in total 14 477 e-liquid products from the five stores, among which 9685 (66.90%) were in stock at the time of scraping. After dropping 77 products with missing price or volume information, we calculated standardised prices for 14 400 e-liquid products.

Table 1 Summary statistics

	n	Mean	SD	Minimum	Maximum
Panel A: whole sample					
Product price ($)	14 400	15.81	9.19	0.49	131.89
Volume (mL)	14 400	83.03	67.85	1.40	1000.00
Standardised price ($/mL)	14 400	0.25	0.14	0.02	3.33
Panel B: store 1					
Product price ($)	1649	17.62	7.01	3.49	89.95
Volume (mL)	1649	66.97	33.83	1.40	300.00
Standardised price ($/mL)	1649	0.33	0.23	0.05	3.33
Panel C: store 2					
Product price ($)	2803	15.06	2.13	7.99	23.99
Volume (mL)	2803	62.62	29.02	30.00	120.00
Standardised price ($/mL)	2803	0.29	0.13	0.11	0.67
Panel D: store 3					
Product price ($)	4568	12.84	2.87	2.49	27.99
Volume (mL)	4568	75.47	31.72	10.00	200.00
Standardised price ($/mL)	4568	0.21	0.11	0.05	0.60
Panel E: store 4					
Product price ($)	3512	20.29	16.05	0.49	131.89
Volume (mL)	3512	116.05	114.25	15.00	1000.00
Standardised price ($/mL)	3512	0.23	0.12	0.02	0.53
Panel F: store 5					
Product price ($)	1868	14.17	5.54	5.99	74.99
Volume (mL)	1868	84.26	56.34	15.00	500.00
Standardised price ($/mL)	1868	0.22	0.12	0.05	0.57

Product price and volume are per sales pack and may contain one or more e-liquid bottles.

Figure 1 Price distribution by store (box plots).

As shown in table 1, the number of e-liquid products sold in each store ranged from 1649 to 4568. Panel A summarises the average results across the five stores. The e-liquid price per pack had a range of $0.49–$131.89, with an average price of $15.81. The e-liquid volume per pack varied from 1.4 mL to 1000 mL, with an average of 83.03 mL. The standardised price ranged from $0.02 to $3.33, with an average of $0.25/mL.

Table 1 panels B–F show summary statistics for each of the five stores. Store 4 (panel E) offers e-liquid product(s) at the lowest price in our sample ($0.02/mL), whereas store 1 (panel B) offers the most expensive e-liquid product(s) at $3.33/mL. All five stores offer very cheap e-liquid options as demonstrated by the minimum and maximum prices in each store. We observe that four out of five stores had their lowest prices at or below $0.05/mL and that the same number of stores had their highest price below $1/mL.

We present the distribution of standardised price of e-liquid products by store in box plots, as shown in figure 1. The median of standardised price in each store varies from $0.17/mL to $0.27/mL. Among the five stores, store 1 has the greatest price variability. All five stores have right-skewed distributions of standardised prices, which means median price is lower than average price in each store. Most of the e-liquid products in our data are priced under $0.3/mL. Out of the 14 400 e-liquid products in our sample, 10 609 (73.67%) of them are cheaper than $0.3/mL. There are some differences in median price across stores, but the differences are relatively small. Outside values are excluded when plotting figure 1, but they are nonetheless included in the analyses.

In table 2, we show 5%, 10%, 25%, 50%, 75%, 90% and 95% percentiles of standardised prices for the whole sample and for each store. The distribution in general suggests that prices are skewed to the low end—the difference between the 5 percentile and the 25 percentile standardised prices was merely about $0.03–$0.05 per mL. In contrast, the difference between the 75 percentile and 95 percentile standardised prices ranges between $0.07 and $0.2. As shown in figure 1 and tables 1 and 2, e-liquids are very affordable, with plenty of price minimisation opportunities.

Table 2 Price distribution and variability, whole sample and by store

Panel A: percentiles							
	5%	10%	25%	50%	75%	90%	95%
Whole sample	0.10	0.12	0.14	0.20	0.37	0.43	0.50
Store 1	0.13	0.16	0.18	0.27	0.47	0.60	0.67
Store 2	0.15	0.16	0.18	0.25	0.43	0.50	0.50
Store 3	0.08	0.11	0.13	0.17	0.23	0.43	0.43
Store 4	0.10	0.12	0.13	0.18	0.33	0.43	0.43
Store 5	0.10	0.12	0.14	0.17	0.33	0.40	0.43
Panel B: IQR to mean ratios							
		IQR			IQR to mean ratio		
Whole sample		0.23			0.92		
Store 1		0.28			0.85		
Store 2		0.25			0.85		
Store 3		0.10			0.48		
Store 4		0.20			0.89		
Store 5		0.19			0.87		

Percentiles and IQR to mean ratios of standardised price ($/mL) are presented in this table.

In addition to percentiles, table 2 also presents price variability in the whole sample and in each store, using IQR to mean ratio. Store 3 has the lowest IQR to mean ratio (0.48) and thus the lowest price variability among the five stores, whereas store 4 has the greatest IQR to mean ratio (0.89) or price variability. The IQR to mean ratio across the five stores was 0.92, suggesting that the between-store price variation was greater than the within-store price variation.

We present the distribution of standardised prices for the whole sample and for each store using kernel density estimation, as shown in figure 2. Based on figure 2 (1)–(6), there are outliers in the sample, and they are mostly from store 1. We excluded e-liquid products with standardised prices greater than $0.6/mL, and plotted kernel density estimates again for the whole sample and for store 1, in figure 2 (7)–(8). As shown in figure 2 (3)–(8), the price distribution is rather similar across stores. Among the 14 400 e-liquid products in our sample, 132 of them are priced higher than $0.6/mL, and 128 of those are in store 1.

In table 3, we present the results of e-liquid excise tax compliance along with the effective dates of e-cigarette taxation in each state/local jurisdiction. Due to product availability, we chose a similar—but not the same—e-liquid product for store 2 relative to store 1 to check the e-liquid excise tax for each address. Specifically, we chose White No. 1 by the same brand (Twist E-Liquid) with the same volume and nicotine concentration and a very close price ($21.99).

The results demonstrate the many challenges to imposing excise taxes on e-liquids that are sold online. First, the rate of e-liquid excise tax compliance is low, and only three out of five stores charge e-liquid excise taxes at checkout. Second, among stores that impose excise taxes on e-liquids, the accuracy of excise tax amounts is low. For example, store 1 only charges excise taxes correctly in 11 out of 28 states. Third, it is particularly challenging for stores to appropriately charge excise taxes on e-liquid products shipped to ENDS-taxing local jurisdictions. None of the stores impose county or city excise taxes on e-liquids, except for store 2 on e-liquids shipped to Montgomery County in Maryland. Fourth, ad valorem excise taxes based on wholesale prices could vary drastically by stores. For example, for sales of similarly priced e-liquid products to states including Illinois, Vermont, Nevada, New Hampshire, Maine, Massachusetts and Wyoming, store 1 charges excise taxes twice as high as the excise taxes charged by store 2. In summary, online stores do not impose e-liquid excise taxes accurately or consistently in the market.

In addition, although standardising prices does not require information on volume size per bottle or before-discount prices, this information could be valuble for policymakers who are interested in regulating e-liquid bottle sizes or price promotions. Therefore, we present the frequency table of e-liquid volume per bottle in online supplemental table A1. On average, the volume size per bottle was 67.86 mL and the most frequent sizes were 30 mL (24.75%), 60 mL (38.33%), 100 mL (26.97%) and 120 mL (7.42%) per bottle. We further present distribution plots of e-liquid volume per bottle by store in online supplemental figures A1 and A2, and the before-discount price per pack in online supplemental figures A3 and A4.

DISCUSSION AND CONCLUSION

The increase in e-cigarette popularity, especially among youth and young adults, has raised public health concerns and prompted many states and localities in the USA to impose excise taxes on e-cigarettes. As a result, it is important to obtain accurate measures of e-cigarette prices in order to estimate the consequences of e-cigarette taxation policies. However, a comprehensive dataset that captures the full spectrum of e-cigarette prices is lacking.[17–19]

Specifically, Nielsen Retail Scanner data—a major data source for e-cigarette prices—are primarily collected from brick-and-mortar stores, which does not capture e-cigarette products sold in specialty vape shops or online stores. Alternatively, e-cigarette price data measured using survey questionnaires contain self-report errors and are likely biased due to consumers' price minimisation behaviours.[20] Furthermore, it is particularly challenging to measure e-liquid prices used in open systems, because many brands are not captured either by survey or by Nielsen data.

To address this data limitation, we scrape e-liquid product information including prices and volume sizes from online vape stores. Our study finds that the average price of e-liquid products sold online is $0.25/mL, with an IQR of 0.23. This price level is lower compared with e-liquid prices reported from other sources. For example, Cheng *et al* examined the 2016

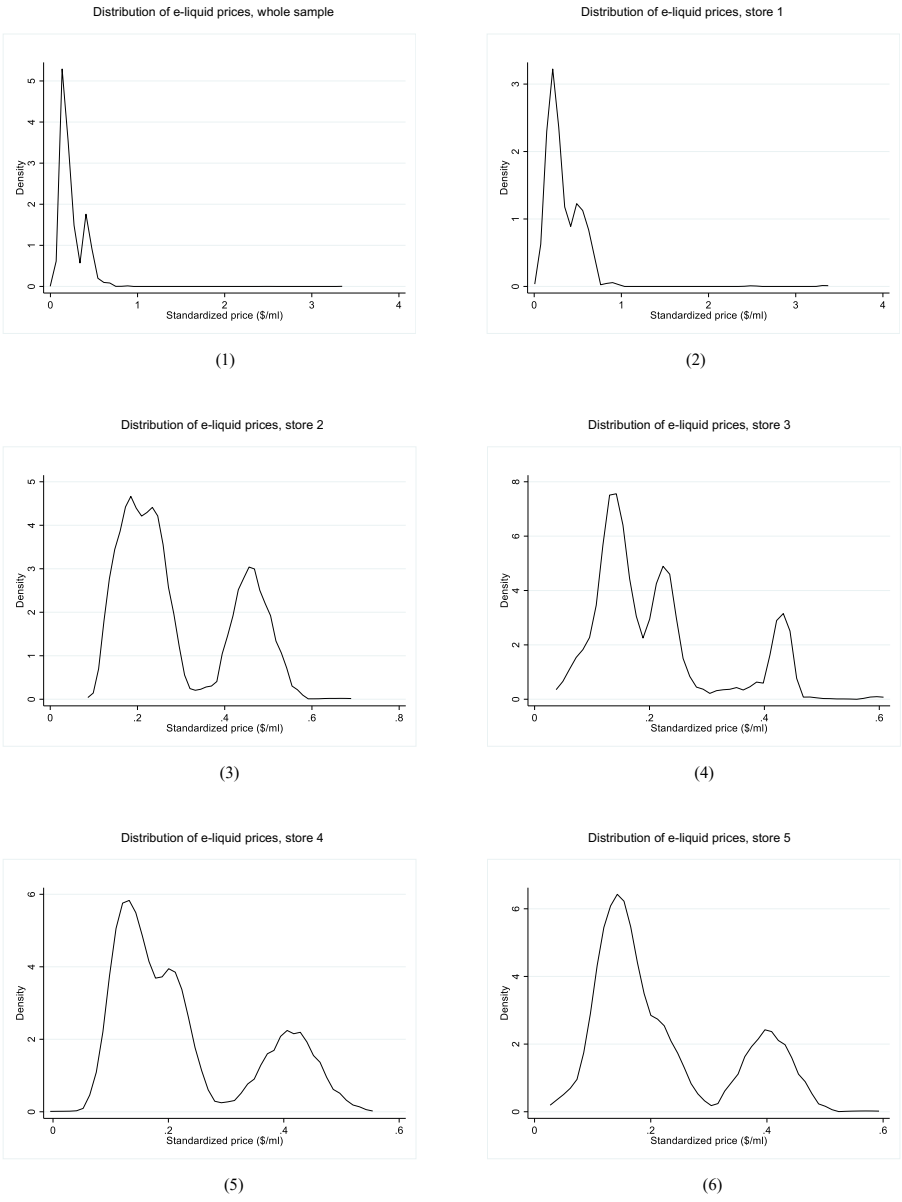

Figure 2 Price distribution by store (kernel density estimates).

International Tobacco Control Project US data and estimated the self-reported prices to be $0.91/mL.[20] Another study by Wang *et al* used the Nielsen Retail Scanner data in 2016 and estimated the price of one bottle of e-liquid to be $6.83 per bottle (roughly $1/mL if the average volume size per bottle is 68 mL).[21] Although these price estimates are from previous years, they are more than three times larger compared with the average price we observe in online stores, suggesting that online stores may supply consumers with low-priced products. This finding highlights the importance of collecting and understanding price data from sources other than brick-and-mortar stores, further suggesting that studies can benefit from using price information beyond the Nielsen Retail Scanner data to avoid potential biases in price measures.

Our data collection further aids the survey questionnaire design and analyses. Specifically, price estimation using self-reported answers to survey questionnaires often contains measurement errors. One common approach is to trim data points within lowest and highest 1–5 percentiles.[20] Our results suggest that low prices such as $0.02/mL (minimum price in our data) and high prices such as $3.33/mL (maximum price in our data) are plausible and therefore should not be trimmed. We also find that volume sizes such as 30 mL, 60 mL, 100 mL and 120 mL are the most common, so those values could replace the open-ended question that has been used to elicit volume sizes in surveys.

We also present a snapshot of excise taxes charged by each store for specific e-liquid products based on different shipping addresses. As of May 2021, 28 states, DC, and 9 local jurisdictions have had e-cigarette excise taxes in place, and the tax base, as well as tax rate, greatly vary across jurisdictions. We show that for shipping addresses in those states and local jurisdictions that have e-cigarette taxation policies, excise taxes charged by online vape shops lack accuracy and consistency for the same or similar e-liquid products. E-cigarette tax structures that differ across states and local jurisdictions make it somewhat difficult for online store owners to calculate and charge e-liquid excise tax correctly and stay compliant with taxation laws. As requirements in the PACT Act amendment went into effect in March 2021, we check the tax compliance of online vape shops during May–August 2021, and find that two out of five stores (stores 4 and 5)

Table 3 Effective dates of taxation and e-liquid excise taxes charged by stores

Jurisdiction	E-cigarette excise tax effective date	Excise tax on 120 mL e-liquid (that is nicotine-containing) sold at retail price of $21.95, based on taxation policies as of May 2021	E-liquid excise taxes charged by stores				
			Store 1 Tobacco Gold No. 1 by Twist E-Liquid 120 mL 6 mg $21.95	Store 2 White No. 1 by Twist E-Liquid 120 mL 6 mg $21.99	Store 3 Tobacco Gold No. 1 by Twist E-Liquid 120 mL 6 mg $16.99	Store 4 Strawberry Watermelon Bubblegum by Candy King E-Liquid 100 mL 6 mg $13.99	Store 5 Pink No. 1 E-Juice by Twist E-Liquid 120 mL 3 mg $18.99
28 states, and DC							
Minnesota	1 Aug 2010	95% of wholesale price	$9.60	$10.45	$11.00	$0	$0
North Carolina	1 June 2015	**$6.00**	**$6.00**	$6.00	$0	$0	$0
Louisiana	1 July 2015	**$6.00**	**$6.00**	$6.00	N/A*	$0	$0
West Virginia	1 July 2016	**$9.00**	**$9.00**	$9.00	$0	$0	$0
Pennsylvania	13 July 2016	**$8.78**	**$8.78**	$4.40	$11.40	$0	$0
California	1 Apr 2017	56.93% of wholesale price	$5.75	$0.00	$0	$0	$0
Kansas	1 July 2017	**$6.00**	**$6.00**	$6.00	N/A*	$0	$0
Delaware	1 Jan 2018	**$6.00**	**$6.00**	$6.00	N/A*	$0	$0
New Jersey	30 Sep 2018	**$2.20**	**$2.20***	$2.20	$0	$0	N/A*
Illinois	1 July 2019	15% of wholesale price	$3.29	$1.65	$0	$0	$0
New Mexico	1 July 2019	$2.74	$1.26	$1.38	N/A*	$0	$0
Utah	1 July 2019	$12.29	N/A*	$6.16	N/A*	$0	N/A*
Vermont	1 July 2019	92% of wholesale price	$20.19*	$10.12	N/A*	$0	N/A*
Wisconsin	5 July 2019	$6.00	$0	$0	$0	$0	$0
Connecticut	1 Oct 2019	10% of wholesale price	$2.20	$1.10	$0	$0	$0
Washington	1 Oct 2019	$32.40	$10.80	$10.80	$0	$0	$0
Ohio	17 Oct 2019	**$12.00**	**$12.00**	$12.00	$18.00	$0	$0
New York	1 Dec 2019	**$4.39**	**$4.39***	$4.40	$0	$0	N/A*
Nevada	1 Jan 2020	30% of wholesale price	$6.59	$3.30	N/A*	$0	$0
New Hampshire	1 Jan 2020	8% of wholesale price	$1.76	$0.88	N/A*	$0	$0
Maine	2 Jan 2020	43% of wholesale price	$9.44*	$4.73	N/A*	$0	N/A*
Massachusetts	1 June 2020	75% of wholesale price	$16.46*	$8.25	N/A*	$0	N/A*
Virginia	1 July 2020	**$7.92**	**$7.92**	$7.92	$1.20†	$0	$0
Wyoming	1 July 2020	15% of wholesale price	$3.29	$1.65	N/A*	$0	$0
Kentucky	1 Aug 2020	**$3.29**	**$3.29**	$1.65	$0	$0	$0
Colorado	1 Jan 2021	$6.59	$3.03	$3.30	$0	$0	$0
Georgia	1 Jan 2021	7% of wholesale price	$0	$0.77	N/A*	$0	N/A*
Oregon	1 Jan 2021	65% of wholesale price	$6.57	$7.15	$0	$0	$0
DC	1 Oct 2015	91% of wholesale price	$9.19	$10.12	N/A*	$0	$0
9 local jurisdictions							
Juneau Borough, Alaska	1 Apr 2015	45% of wholesale price	$0	$0	$0	$0	$0
Northwest Arctic Borough, Alaska	N/A	45% of wholesale price	$0	$0	$0	$0	$0
Petersburg Borough, Alaska	N/A	45% of wholesale price	$0	$0	$0	$0	$0
Anchorage Borough, Alaska	1 Jan 2021	55% of wholesale price	$0	$0	$0	$0	$0
Matanuska-Susitna Borough, Alaska	N/A	55% of wholesale price	$0	$0	$0	$0	$0
Chicago, Illinois	1 Jan 2016	$145.50	$0	$0	$0	$0	N/A*
Cook County, Illinois	1 May 2016	$24.00	$0	$0	$0	$0	$0
Montgomery County, Maryland	19 Aug 2015	30% of wholesale price	$0	$2.64	$0	$0	$0
Omaha, Nebraska	2019	3% tobacco tax	$0	$0	$0	$0	$0

Bold values indicate values in the 3rd column equal to those in the 4th column.
*E-liquid product was shown as not allowed to ship in the corresponding state/local jurisdiction on store webpage.
†For Virginia address, store 3 charged $7.20 for shipping cost and excise tax, and state e-liquid excise tax was not explicitly stated; given that shipping cost (when charged on this website) was $6 for other contiguous states in the USA, we inferred that store 3 charged vapour tax of $1.20 for Virginia address.
DC, District of Columbia.

in our sample did not impose any excise taxes on e-liquid products, one store (store 3) imposed taxes on shipping to a limited number of states and two stores (stores 1 and 2) imposed taxes on e-liquids shipped to the majority of taxing states. However, even among stores that charged taxes on e-liquids shipped to taxing states, the amount of taxes was not calculated consistently. Furthermore, all stores failed to charge county-level or city-level e-cigarette taxes, except store 2 on e-liquids shipped to Montgomery, Maryland. Overall compliance with the PACT Act among online stores that we sampled is low.

There are challenges in calculating e-cigarette taxes based on wholesale prices. Most traditional tobacco products, including cigarettes, are distributed through a three-tier system—that is, manufacturers or importers, distributors or wholesalers, and retailers. On the other hand, e-cigarette products are often not distributed in the same three-tier system. The e-cigarette market has a much larger number of small manufacturers, and those manufacturers may sell vaping products directly to customers via online stores and vape shops, or they might sell to retailers without going through wholesale distributors.[28]

Based on our observation, when online stores are required to apply taxes based on wholesale prices,[9 10 28] they tend to use different wholesale price bases for the same product in different states. For example, when store 1 calculates taxes for sales to Minnesota (95% of wholesale prices) and Oregon (65% of wholesale prices), they use a wholesale price base that is about half of the listed price (roughly $10), suggesting a wholesale-to-retail markup rate of 100%. However, for sales to states such as Illinois (15% of wholesale prices) and Connecticut (10% of wholesale prices), they directly use the listed prices (roughly $20) as the base to calculate taxes. In addition, although the taxes based on volume are more consistently applied than taxes based on wholesale prices, the amount of taxes charged by stores could still deviate from the excise tax rate. For example, we found that stores charged taxes at a much lower rate for shipments to the state of Washington. Although we cannot generalise this practice to all online stores, this evidence suggests inconsistency in tax calculation and that there is room for pricing strategies for online sales. States and localities will need to consider setting consistent standards and adopting implementation strategies to collect the full amount of taxes from products sold online.

Our study has several limitations. First, we checked tax compliance based on a single e-liquid product for each store in our sample, which is not comprehensive. We are currently developing new tools to scrape excise tax data for all e-liquid products in each online store and will reassess tax compliance in future analyses. Second, we used a convenience sampling strategy and chose online stores based on simple Google and Reddit search results, which may be subject to curation based on viewer locations, browsing histories and Google advertising. Nonetheless, we did not intend to collect representative samples of online stores.

Furthermore, to address the data quality issues, we cross-verified stores from Google and Reddit searches, and one store (store 2) appeared in both searches, suggesting a consensus on store popularity. In addition, the number of e-liquid products sold in each store was quite large, and the five stores together cover 241 unique brands, which provides some assurance that our sampling covered a significant proportion of products. We also find that the e-liquid price distribution was similar across the five stores, further indicating that the price data we scraped reflect the common pricing strategies in the online market.

Lastly, we scraped e-liquid prices from each online store on a rather arbitrary date and did not track e-liquid pricing activities over time. However, with continuing effort, in future studies we will be able to track prices, check consistency over time, plot the time trend of e-liquid pricing, and assess how taxes are passed to prices as the rates and structures change.

Despite the limitations, our study is the first in-depth investigation of the pricing and taxing strategies of e-liquid products sold online. The evidence suggests that online e-liquid products are sold at a relatively low price, and that tax compliance is inconsistent and low. The choice of e-cigarette tax bases such as existing state-level taxes based on wholesale prices may leave room for retailers and wholesalers to manipulate tax levels. Policy innovations and compliance checks may be needed to regulate products sold online. In addition, future studies will benefit from rapid surveillance of the characteristics and sales of e-cigarette products sold online.

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Contributors Conceptualisation—CS and SM. Methodology—JC, SJ, ML, BL, CS and SM. Software—SJ, ML, CS and SM. Validation—CS. Formal analysis—SM. Investigation—SM and CS. Resources—CS and JC. Data curation—SJ and SM. Writing (original draft preparation)—SM. Writing (review and editing)—CS, JC, BL, SJ and ML. Visualisation—SM and CS. Supervision—CS and JC. Project administration—SM and SJ. Funding acquisition—CS and JC. All authors have read and agreed to the published version of the manuscript. CS is responsible for the overall content as the guarantor.

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