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The impact of price and tobacco control policies on the demand for electronic nicotine delivery systems

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ABSTRACT

Background While much is known about the demand for conventional cigarettes, little is known about the determinants of demand for electronic nicotine delivery systems (ENDS or e-cigarettes). The goal of this study is to estimate the own and cross-price elasticity of demand for e-cigarettes and to examine the impact of cigarette prices and smoke-free policies on e-cigarette sales.

Methods Quarterly e-cigarette prices and sales and conventional cigarette prices from 2009 to 2012 were constructed from commercial retail store scanner data from 52 US markets, for food, drug and mass stores, and from 25 markets, for convenience stores. Fixed-effects models were used to estimate the own and cross-price elasticity of demand for e-cigarettes and associations between e-cigarette sales and cigarette prices and smoke-free policies.

Results Estimated own price elasticities for disposable e-cigarettes centred around −1.2, while those for reusable e-cigarettes were approximately −1.9. Disposable e-cigarette sales were higher in markets where reusable e-cigarette prices were higher and where less of the population was covered by a comprehensive smoke-free policy. There were no consistent and statistically significant relationships between cigarette prices and e-cigarette sales.

Conclusions E-cigarette sales are very responsive to own price changes. Disposable e-cigarettes appear to be substitutes for reusable e-cigarettes. Policies increasing e-cigarette retail prices, such as limiting rebates, discounts and coupons and imposing a tax on e-cigarettes, could potentially lead to significant reductions in e-cigarette sales. Differential tax policies based on product type could lead to substitution between different types of e-cigarettes.

BACKGROUND

Electronic nicotine delivery systems (ENDS), commonly known as electronic cigarettes or e-cigarettes, encompass a variety of products that provide nicotine and/or other additives to the user. The vast majority of ENDS products fall into three broad categories: cigarette-like e-cigarettes; medium-size pen-style e-cigarettes, popularly known as 'e-hookahs', 'hookah pens', or 'vape pipes';[1] and large tank-size e-cigarettes known as 'advanced personal vaporisers (APVs)' or 'Mods'. Depending on the refillability of the liquid solution (e-liquids) and rechargeability of its power source, ENDS can also be grouped into two major categories: disposable and reusable/refillable/rechargeable e-cigarettes. A disposable e-cigarette is no longer useable once its battery is drained or e-liquid is exhausted. Depending on the brand and nicotine concentration, a disposable e-cigarette can be equivalent to one to two packs of conventional cigarettes. Reusable e-cigarettes are assembled using rechargeable or replaceable batteries and refillable cartridges, and can be used many times.

Awareness and use of e-cigarettes have increased sharply in recent years. Two recent studies reported that awareness of e-cigarettes among US adults increased from 40% in 2010 to 58% in 2011, while ever use grew from 3.3% to 6.2%. Similarly, ever use of e-cigarettes among US youth more than doubled from 3.3% in 2011 to 6.8% in 2012.[2 3] The rapid increase in e-cigarette use, particularly among youth, has generated concerns in the public health field given the absence of regulations on product standards and the limited scientific evidence on the health impact of e-cigarette use and secondhand vaping.[4] Some argue that lack of measures restricting youth access, aggressive marketing, low price and widespread availability of flavoured e-cigarettes may have contributed to the rapid growth of e-cigarette use among youth and young adults.[5] Many are also concerned that e-cigarette use among youth may serve as a gateway to other tobacco products and substance use, leading to life-long nicotine addiction.

Given these concerns, various policies have been proposed to address the rapid growth of e-cigarette use among youth, including setting minimum purchase age, limiting youth access, licensing e-cigarette sales, restricting e-cigarette marketing and sale of flavoured e-cigarettes, limiting samples and taxing e-cigarettes. The impact of taxes and limits on price-reducing marketing will depend on how demand for e-cigarettes responds to price changes, that is, the price elasticity of demand for e-cigarettes. To date, no published studies have estimated the price elasticity of e-cigarette demand. In addition, very little is known about the substitutability between different types of e-cigarettes and how tax-induced price changes may affect the demand for different types of e-cigarettes.

This paper fills this gap by estimating the own and cross-price elasticity of demand for disposable and reusable e-cigarettes using sales and price data obtained from a commercial store scanner database. In addition, it also addresses an important and understudied topic: the relationship between e-cigarette sales and existing tobacco control policies, focusing on conventional cigarette prices and smoke-free policies that, until recently, have primarily covered conventional cigarettes. A better understanding of the relationship between e-cigarette sales and cigarette prices and smoke-free policies can help inform the discussion and adoption of appropriate polices that reduce the use of both e-cigarettes and conventional cigarettes among youth.

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METHODS

Data

The data used in this study come from the store scanner data compiled by the Nielsen Company and consist of quarterly prices and sales of e-cigarettes for 52 US Nielsen markets from 2009 through 2012. A Nielsen market consists of groups of counties centred on a major city. In many cases, counties in the same Nielsen market belong to different states, as a Nielsen market can cross state borders and cover areas in two or multiple states. Nielsen markets are similar to metropolitan statistical areas (MSAs), but the delineation of Nielsen markets and MSAs is different. The Nielsen store scanner data contain detailed information on e-cigarette retail prices and sales, and are gathered directly from Nielsen's participating retailers, which include food, drug and mass (FDM) stores in 52 US markets and convenience stores in a subset (25) of markets. These data allow us to identify the product type (reusable vs disposable), as well as dollar sales amount and sales volume of a given type of e-cigarette product in a Nielsen market. Nielsen participating retailers include mass stores (such as K-Mart and Target), drug stores (such as CVS, Walgreens and RiteAid), grocery stores (such as Kroger, Food Lion, Publix, Safeway, Albertsons and Winn Dixie) and convenience stores, including those at gas stations (such as 7 Eleven, Shell, Circle K, BP and Exxon). While sales data were provided separately for convenience stores, sales in FDM stores were combined by Nielsen. The population residing in those 52 Nielsen markets represents approximately 80% of the total US population.

Measures

Per capita e-cigarette sales volume: For each market and quarter, separately for FDM and convenience stores, Nielsen provided us sales units for all e-cigarette products sold by its participating retailers. The sales volume for a given e-cigarette product in a given market/quarter/store type was calculated by multiplying the total sales units for that product in that market/quarter/store type with the number of e-cigarettes contained in one single sales unit (one sales unit may contain more than one e-cigarettes, eg, each sales unit of Njoy King 3 Pack contains three e-cigarettes). The total sales volume was derived by summing the sales volume for all e-cigarette products, separately for disposable and reusable e-cigarettes. We analyse reusable and disposable e-cigarettes separately because of the considerable differences in product characteristics and prices. The dependent variable in our analysis—per capita sales volume—was constructed by dividing the total sales volume in a market/quarter/store type by the total population in that market/quarter. In our data, sales for reusable e-cigarettes became available starting from 2010, and disposable e-cigarette sales from late 2009. Both products were not sold in all 52 markets in all quarters; as a result, analyses of reusable e-cigarette sales have fewer observations than those for disposable e-cigarettes (474 vs 569).

Inflation-adjusted e-cigarette prices: The average e-cigarette price per piece in a given market/quarter/store type was calculated by dividing total dollar sales by sales volume in that market/quarter/store type. The e-cigarette price variable used in our analyses was adjusted for inflation using the Consumer Price Index (indexed to 1 for the last quarter of 2012) obtained from the Bureau of Labor Statistics.

Inflation-adjusted cigarette prices: The average inflation-adjusted cigarette price per stick in a market/quarter/store type was constructed using the same methodology for constructing e-cigarette prices, described in the previous paragraph.

Smoke-free policies: Market-level quarterly smoke-free policy measures were created using data from the American Nonsmokers' Rights Foundation US Tobacco Control Laws Database, which take into account both state and local smoke-free policies. The smoke-free policies were constructed from county-level measures using the weights of the percent of a county's population in a given market. Three continuous variables with the value ranging from 0 to 1 were constructed to capture the percent of total population within a Nielsen market covered by a 100% smoking ban (a complete ban without any exemptions) at the end of each quarter for three venue types: bars, restaurants and private workplaces. A final variable reflecting the average of these three variables was used in our analyses in order to capture the extent of smoke-free policies in each Nielsen market for each quarter.

Inflation-adjusted cigarette taxes: The cigarette tax in a market/quarter used in our analyses was constructed as the county population weighted cigarette taxes that were effective at the end of each quarter in the counties that comprise each market. In cases where there were no local taxes, county cigarette taxes were the same as state cigarette taxes. In some cases, where there were local taxes (either city or county taxes on top of state taxes), the county tax was constructed as the subcounty division population weighted cigarette taxes. The tax measure was adjusted for inflation following the same approach used for prices.

Socioeconomic and demographic measures: Market-level demographic and socioeconomic characteristics were compiled from the Census Bureau based on county-level characteristics constructed from the American Community Survey (ACS) 5-year estimates files (2006–2010 and 2007–2011), which includes measures of gender, age, race/ethnicity, employment, education and income distribution (a complete list of these variables can be found in online supplementary appendix tables 1 and 2). For each county, we extrapolated and projected quarterly data from 2009 to 2012 based on ACS. Market-level measures were then constructed as the county population weighted averages.

Empirical models

Market-store fixed-effects models were used to estimate the own price elasticity of demand for e-cigarettes. The baseline fixed effects models were specified as follows:

$$\begin{aligned}&\mathrm{Ln(Ecig\ Sales\ Volume)}_{\mathrm{market/quarter/storetype}}\\&=\mathrm{Intercept}+\beta_1\mathrm{Ln(Ecig\ Price)}_{\mathrm{market/quarter/storetype}}\\&+\beta_2\mathrm{Year}+\beta_3\mathrm{Quarter}+\beta_4(\mathrm{Market-Store\ Dummies})\\&+\mathrm{error}\end{aligned}\qquad(1)$$

The dependent variable in equation 1 is the natural log of per capita e-cigarette sales volume in a market/quarter/store type. The key independent variable is the inflation-adjusted e-cigarette price per piece, also in log form. The estimated β_1 represents the own price elasticity of demand for e-cigarettes. Year is a vector of dichotomous variables that captures time-varying influences on e-cigarette sales that are common to all markets. Quarter is a vector of three dichotomous variables (the first quarter was omitted as the reference category) that captures seasonality in e-cigarette sales. Market-store dummies are dichotomous variables for each market and store type that capture the influence of market-store-level characteristics that are constant over time within a market and store type but that vary across markets/stores. Equation 1 was estimated separately for disposable and reusable e-cigarettes.

Table 1 Descriptive statistics

Variables	Reusable e-cigarettes				Disposable e-cigarettes			
	Mean	SD	Min	Max	Mean	SD	Min	Max
E-cigarette sales volume per capita (in log)	−8.74	1.91	−16.03	−5.52	−7.96	2.32	−15.31	−3.77
E-cigarette sales volume per capita	0.00051	0.00069	0	0.00402	0.002	0.0032	0	0.0231
E-cigarette price (in log)	3.26	0.33	2.42	4.41	2.29	0.22	0.78	3.35
E-cigarette price ($ per piece)	27.86	11.42	11.3	82.18	10.12	2.83	2.18	28.37
Cigarette price (in log)	−1.34	0.18	−1.72	−0.83	−1.32	0.2	−1.73	−0.75
Cigarette price ($ per piece)	0.27	0.052	0.18	0.44	0.27	0.061	0.18	0.47
Smoke-free policy	0.62	0.32	0.011	1	0.65	0.32	0.011	1
Cigarette tax (in log)	4.68	0.61	3.43	5.93	4.73	0.65	3.43	6.08
Cigarette tax (in cents)	128	76	30	376	137	89	30	435
Store dummy (1=food, drug and mass stores; 0=convenience store)	0.45	0.5	0	1	0.53	0.5	0	1
E-cig sales dollars (FDM store)	24 830	45 761	22	260 068	39 847	100 897	11	642 833
E-cig sales volume (FDM store)	724	1141	1	6167	4164	10 376	1	65 823
E-cig sales dollars (Conv store)	108 524	93 920	68	537 412	198 918	297 806	10	3 033 058
E-cig sales volume (Conv store)	4688	4129	1	26 236	22 220	33 522	1	335 096
Market population	5 991 489	4 070 396	1 105 923	20 628 688	5 547 356	3 838 943	1 090 263	20 628 688
N	474				569			

Not shown in the table: year dummy (2009–2012), quarter dummy (1–4) and market dummy (market #1–market #52).
FDM, food, drug and mass.

To estimate cross-price elasticity between disposable and reusable e-cigarettes, the following models were used:

$$\begin{aligned}&\mathrm{Ln(Disposable\ Ecig\ Sales\ Volume)}_{\mathrm{market/quarter/store\ type}}\\&=\mathrm{Intercept}+\beta_1\mathrm{Ln(Disposable\ Ecig\ Price)}_{\mathrm{market/quarter/store\ type}}\\&+\beta_2\mathrm{Ln(ReusableEcigPrice)}_{\mathrm{market/quarter/store\ type}}\\&+\beta_3\mathrm{Year}+\beta_4\mathrm{Quarter}+\beta_5(\mathrm{Market-Store\ Dummies})\\&+\mathrm{error}\end{aligned}\tag{2}$$

$$\begin{aligned}&\mathrm{Ln(Reusable\ Ecig\ Sales\ Volume)}_{\mathrm{market/quarter/storetype}}\\&=\mathrm{Intercept}+\beta_1\mathrm{Ln(Reusable\ Ecig\ Price)}_{\mathrm{market/quarter/store\ type}}\\&+\beta_2\mathrm{Ln(Disposable\ Ecig\ Price)}_{\mathrm{market/quarter/store\ type}}\\&+\beta_3\mathrm{Year}+\beta_4\mathrm{Quarter}+\beta_5(\mathrm{Market-Store\ Dummies})\\&+\mathrm{error}\end{aligned}\tag{3}$$

The estimated β_2 from equations 2 and 3 reflect cross-price elasticity of demand, which would reveal how changes in disposable e-cigarette price influence sales of reusable e-cigarettes and vice versa.

To investigate the associations between e-cigarette sales and cigarette tax/price and smoke-free policies, inflation-adjusted cigarette tax/price (in log form) and smoke-free policies were added to equations 1, 2 and 3.

Sensitivity analyses were also conducted by adding market-level demographic and socioeconomic characteristics to the above-specified market-store fixed-effects models (results in online supplementary appendix table 3).

To examine whether price elasticities differ by store types, we conducted analyses separately for FDM and convenience stores. In those analyses, market-store fixed effects in equations 1–3 were replaced by market fixed effects.

RESULTS

Summary statistics for key variables are presented in table 1. Average quarterly sales volume for disposable e-cigarettes in a Nielsen market was approximately 11 100 pieces (0.002*5.55 million), almost four times higher than that of reusable e-cigarettes (3000 pieces, 0.00051*5.99 million) between 2010 and 2012. Average inflation-adjusted retail price for reusable e-cigarettes was significantly higher than that of disposable e-cigarettes ($27.9 per piece vs $10.1 per piece). Average inflation-adjusted retail price for cigarettes in a Nielsen market was $5.40 per pack ($0.27*20). Market-level average inflation-adjusted cigarette tax was $1.28 per pack in the reusable e-cigarette sample and $1.37 per pack in the disposable e-cigarette sample. Average smoke-free index was 0.62 in the reusable e-cigarette sample and 0.65 in the disposable e-cigarette sample, indicating on average approximately 62% (65%) of the total population within a market were covered by 100% smoke-free bans at bars, restaurants and/or private workplaces. There were significant differences in the sales between FDM and convenience stores. For both disposable and reusable e-cigarettes, sales were at least five times higher in convenience stores than in FDM stores.

Table 2 summarises the main findings from our analysis, with the first five columns presenting estimates for disposable e-cigarettes and the last five columns showing estimates for reusable e-cigarettes. For each e-cigarette type, it starts with a baseline market-store fixed-effects model, followed by incorporating smoke-free policies, cigarette tax, and cigarette price, sequentially, into the baseline model. Cross-price elasticity estimates are presented at the very end (columns 5 and 10). The estimated price elasticities of demand for disposable e-cigarettes cluster around −1.2, indicating a 10% increase in disposable e-cigarette price would reduce its sales by 12%. The estimated price elasticities for reusable e-cigarettes centre around −1.9, implying a 10% increase in reusable e-cigarette price would reduce its sales by about 19%.

Cross-price elasticity analyses show that an increase in reusable e-cigarette price would increase sales of disposable e-cigarettes (cross-price elasticity 0.5, indicating 10% increase

Table 2 Analysis of disposable and reusable e-cigarettes (market-store fixed-effects models)

	Disposable e-cigarettes					Reusable e-cigarettes				
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Own price elasticity	−1.096**	−1.171**	−1.162**	−1.175**	−2.135**	−1.858***	−1.851***	−1.829***	−1.871***	−2.019***
	(0.535)	(0.473)	(0.471)	(0.475)	(0.833)	(0.485)	(0.493)	(0.491)	(0.482)	(0.457)
SFA index		−2.963**	−2.925**	−3.002***	2.002		3.311	3.927	3.039	3.291
		(1.214)	(1.289)	(1.134)	(5.952)		(5.731)	(5.402)	(5.735)	(6.076)
Ln tax cigarette			−0.302					−2.501*		
			(2.184)					(1.456)		
Ln price cigarette				0.562	0.967				3.274	0.648
				(3.556)	(3.310)				(3.998)	(3.201)
Cross prod. price elasticity					0.535*					1.217
					(0.301)					(0.822)
Year=2009	−0.388	−1.968**	−2.012**	−1.952**						
	(1.033)	(0.932)	(0.945)	(0.959)						
Year=2010	−3.898***	−3.987***	−4.002***	−4.009***	−4.098***	−2.387***	−2.315***	−2.418***	−2.427***	−2.629***
	(0.348)	(0.345)	(0.361)	(0.376)	(0.478)	(0.327)	(0.318)	(0.338)	(0.341)	(0.542)
Year=2011	−1.589***	−1.613***	1.622***	−1.618***	−1.629***	−0.850***	−0.818***	−0.878***	−0.845***	−0.886***
	(0.202)	(0.201)	(0.201)	(0.212)	(0.205)	(0.254)	(0.247)	(0.254)	(0.256)	(0.266)
Quarter=2	−0.118	−0.0925	−0.0928	−0.0848	0.145	0.0309	0.0287	0.0309	0.0718	0.0576
	(0.122)	(0.118)	(0.118)	(0.133)	(0.106)	(0.106)	(0.105)	(0.105)	(0.0886)	(0.0849)
Quarter=3	0.0223	0.0703	0.0705	0.0736	0.103	−0.0649	−0.0805	−0.0755	−0.0652	−0.0640
	(0.122)	(0.126)	(0.127)	(0.129)	(0.125)	(0.108)	(0.112)	(0.114)	(0.107)	(0.109)
Quarter=4	0.473***	0.516***	0.517***	0.520***	0.489***	0.476***	0.456***	0.458***	0.474***	0.473***
	(0.138)	(0.134)	(0.134)	(0.137)	(0.110)	(0.108)	(0.111)	(0.114)	(0.103)	(0.123)
Constant	−4.643***	−2.554**	−1.164	−1.776	−3.726	−2.332	−4.426	6.846	0.202	−5.684
	(1.190)	(1.004)	(10.13)	(4.837)	(5.455)	(1.549)	(4.178)	(8.457)	(6.530)	(6.196)
Observations	569	569	569	569	459	474	474	474	474	459
R^2	0.571	0.578	0.578	0.578	0.651	0.479	0.482	0.488	0.484	0.467

Year 2012 and 1st quarter are reference groups. Market-store-level dummies are not shown in the table. SEs are clustered at the market-store level. ***p<0.01, **p<0.05, *p<0.1.

Table 3 Analysis of disposable and reusable e-cigarettes broken down by FDM and convenience stores

	FDM store: market fixed-effects models					Convenience store: market fixed-effects models				
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Disposable e-cigarettes										
Ln price E-cig disposable	−1.103*	−1.242**	−1.247**	−1.252**	−0.518	−1.303	−1.374	1.027	−1.617	−3.819**
	(0.555)	(0.495)	(0.496)	(0.524)	(0.755)	(1.227)	(1.259)	(1.167)	(1.233)	(1.598)
SFA index		−3.679***	−3.824***	−3.385***	3.092		2.254	3.602	1.635	3.160
		(0.657)	(0.821)	(0.688)	(2.311)		(5.685)	(5.570)	(5.585)	(8.286)
Ln tax cigarette			2.149					−3.498**		
			(4.315)					(1.548)		
Ln price cigarette				−5.373	−8.320*				6.648	6.130
				(6.040)	(4.177)				(5.376)	(5.969)
Ln price e-cig reusable					0.478**					0.599
					(0.230)					(0.480)
Observations	304	304	304	304	211	265	265	265	265	248
R^2	0.363	0.391	0.395	0.396	0.425	0.695	0.696	0.703	0.700	0.709
Reusable e-cigarettes										
Ln Price e-cig reusable	−0.394	−0.347	−0.344	−0.322	−0.421	−3.300***	−3.350***	−3.315***	−3.361***	−3.330***
	(0.298)	(0.303)	(0.304)	(0.307)	(0.313)	(0.613)	(0.618)	(0.624)	(0.601)	(0.596)
SFA index		2.073	2.121	2.218	2.960		4.320	5.137	3.892	5.708
		(2.251)	(2.251)	(2.378)	(2.524)		(7.108)	(7.072)	(7.140)	(7.130)
Ln tax cigarette			1.923**					−2.338**		
			(0.723)					(0.961)		
Ln price cigarette				−2.660	−2.930				4.401	1.736
				(4.470)	(4.525)				(5.466)	(3.484)
Ln price e-cig disposable					0.697					−1.193
					(0.733)					(1.287)
Observations	214	214	214	214	211	260	260	260	260	248
R^2	0.545	0.546	0.548	0.547	0.549	0.609	0.614	0.620	0.617	0.617

Year, quarter and market-level dummies are not shown in the table. SEs are clustered at the market level. ***p<0.01, **p<0.05, *p<0.1.
FDM, food, drug and mass.

in reusable e-cigarette price would increase the sales of disposable e-cigarettes by about 5%). Similarly, an increase in disposable e-cigarette price is positively associated with the sales of reusable e-cigarettes (cross-price elasticity 1.2); however, it is not statistically significant.

Cigarette prices are positively associated with sales of e-cigarettes regardless of e-cigarette types, indicating, everything else constant, markets with high cigarette prices have higher e-cigarette sales. However, the association is not statistically significant. The estimated coefficients for the cigarette tax are negative and not statistically significant for disposable e-cigarettes. The differences in the results between cigarette price and cigarette tax are likely due to the differences in how closely these two variables reflect the actual prices that smokers paid for cigarettes. As explained in the previous section, the cigarette price variable used in our analyses reflects market-store-level average cigarette retail prices, constructed directly from Nielsen store scanner data, and is a good approximation of the prices smokers actually pay. The cigarette tax variable, on the other hand, reflects the county population weighted average cigarette tax within a market and is therefore not a direct measure of prices and does not capture cross-border shopping in markets that cross state lines and/or those with significant local taxes.

Smoke-free polices are negatively associated with disposable e-cigarette sales in the own price elasticity models, suggesting markets where a lower proportion of the population is covered by 100% smoking bans have higher disposable e-cigarette sales. In the cross-price elasticity model, the association between smoke-free policies and e-cigarette sales is positive but not statistically significant. The same is true for reusable e-cigarettes as well.

There are significant time and seasonality effects in e-cigarette sales. Annual sales of both disposable and reusable e-cigarette increased significantly from 2009 to 2012. Compared with the first three quarters, the fourth quarter of a year had the highest sales in our analyses.

Table 3 summarises the results from the analyses broken down by store types. For disposable e-cigarettes, the magnitude of own and cross-price elasticity estimates in FDM stores is similar to that in convenience stores; however, the latter is not statistically significant. The smoke-free policies are negatively associated with sales in own price elasticity models in FDM stores, but are positively, but not statistically significantly, associated with sales in cross-price elasticity models and in convenience stores. There are no consistent relationships between cigarette tax/price and e-cigarette sales, with the sign flipped between FDM and convenience stores, and the estimates statistically significant in some models but not in others.

For reusable e-cigarettes, the estimated own price elasticities are vastly different between two types of stores. In FDM stores, own price elasticities centre around −0.4 and are not statistically significant. In convenience stores, however, the magnitude of own price elasticities are much larger, around −3.3, and highly statistically significant. Smoke-free policies are positively associated with sales, but the relationship is not statistically significant. The inconsistent relationship between cigarette tax/price and e-cigarette sales observed for disposable e-cigarettes also exists for reusable e-cigarettes.

CONCLUSIONS AND DISCUSSION

While e-cigarette sales in retail stores in the US have grown rapidly, increasing from $190 million in 2010 to $700 million in 2012,[6] researchers have yet to unravel many key questions such as the health impact of e-cigarette use and exposure to secondhand vapour, initiation of e-cigarette use and subsequent regular cigarette use among youth, dual use of e-cigarettes and other tobacco products, and the efficacy of e-cigarettes as a cessation tool. Because of its novelty, lack of scientific evidence, absence of federal regulations and uncertainty of viable policy solutions, state and local governments have struggled to come up with appropriate policies to limit youth e-cigarette use and non-users' exposure to e-cigarette vapours.

This is the first paper to examine the potential impact of price-related and tax-related policies on e-cigarette use by assessing the own and cross-price elasticity of demand for e-cigarettes. We found that price is a key determinant of the sales of both disposable and reusable e-cigarettes. A 10% increase in price reduces sales of disposable e-cigarettes by approximately 12%, and by about 19% for reusable e-cigarettes, suggesting that policies altering e-cigarette retail prices, such as limiting rebates, discounts and coupons and imposing a tax, could potentially lead to significant reductions in e-cigarette use. Compared with the price elasticities for conventional cigarettes, which cluster around −0.2 to −0.6,[7] our price elasticity estimates for e-cigarettes are 2–3 times larger, indicating sales of e-cigarettes are very sensitive to changes in their prices. Two factors may explain this; first, many e-cigarette users may be experimenting and are thus more sensitive to price changes. Second, our price elasticity estimate captures only a subset of e-cigarette products—e-cigarettes sold in Nielsen participating retailers. It left out online e-cigarette sales and pen-style or tank-size e-cigarettes, which are mostly sold in vape shops. Because of the substitutability between store-sold e-cigarettes and e-cigarettes sold online and in vape shops, price elasticity for the former alone would be more elastic compared with the price elasticity for the whole e-cigarette category.

Our study also reveals there are considerable cross product price effects between different types of e-cigarettes. A 10% increase in reusable e-cigarette price would increase sales of disposable e-cigarettes by about 5%. A disposable e-cigarette price increase has a positive, but not statistically significant, impact on reusable e-cigarette sales. This implies that differential tax policies based on e-cigarette product type could lead to cross product substitution and switching, and have implications for the impact of specific versus ad valorem excise taxes, given their differential impact on price for products at different price levels.

In addition, we also uncovered some interesting relationships between cigarette prices/smoke-free policies and e-cigarette sales. Specifically, we found that disposable e-cigarette sales were higher in markets where less of the population was covered by 100% smoking bans at restaurants, bars and workplaces. This is consistent with the findings based on the observational studies that examine the availability of e-cigarettes in retail stores,[8] which may reflect the greater availability and selective/targeted marketing and promotion of e-cigarettes in areas where there are more smokers.[8] Reusable e-cigarette sales were higher in markets with more of the population covered by 100% smoking bans; however, the association was not statistically significant. There was no consistent and statistically significant relationship between cigarette price/tax and e-cigarette sales, which may partly reflect the complex dynamics between existing tobacco control policies and e-cigarette sales. On the one hand, higher cigarette prices and stronger smoke-free policies may provide incentives for smokers to experiment and use e-cigarettes; on the other hand, the e-cigarette industry may target markets where there are more smokers, that is, markets with relatively weak tobacco control policies. Detecting the causal impact of existing tobacco control policies on e-cigarettes is difficult given the short time period e-cigarettes appeared in

retail stores in the USA and the rapidly evolving e-cigarette industry/market.

We also detected seasonality in e-cigarette sales, with the fourth quarter sales significantly higher than those in other quarters. A recent study found that e-cigarette marketing expenditures were markedly higher in fourth quarters during our study period,[9] which might explain higher fourth quarter sales in our analysis.

Our study has several limitations. First, our data only capture e-cigarette sales in Nielsen participating retailers, so our price elasticity estimates reflect only a subset of total e-cigarette sales. APVs and a large portion of medium-sized pen-style e-cigarettes, which are mostly sold online or in vape shops, were not captured in our study. Second, the Nielsen data do not track online e-cigarette sales, so our analyses did not take into account the proportion of online e-cigarette sales, which may account for between 40% and 60% of total e-cigarette sales according to some financial analysts.[10] Third, because our data were aggregated at the market level, we were unable to estimate price elasticity separately for important subpopulations, such as youth, young adults, racial/ethnic minorities, those with low incomes and/or mental health problems. More research is needed to better understand how the relative prices of e-cigarettes and cigarettes affect the mono/dual use of these products, and transitions between them.

Despite these limitations, our study demonstrates that policies that alter e-cigarette prices would likely lead to significant changes in e-cigarette use. As a result, policies that increase e-cigarette prices are likely to reduce e-cigarette consumption among youth and adults. Whether such policies would improve overall public health is unclear, given the uncertainties about how e-cigarette affects initiation, cessation, dual/poly use, as well as its long-term health impact.

What the paper adds

- While much is known about the demand for conventional cigarettes, little is known about the determinants of demand for electronic nicotine delivery systems.
- This is the first paper to examine the potential impact of price-related and tax-related policies on e-cigarette by assessing the own and cross-price elasticity of demand for e-cigarettes. We found that sales of e-cigarettes are very sensitive to price changes. Policies increasing e-cigarette retail prices could lead to significant reductions in e-cigarette sales, and substitution between different types of e-cigarettes.

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