Estimating the Effects of an Excise Tax on Electronic Cigarettes Consumption with a Difference-in-Difference Analysis

Xueting Deng*

Ph.D. Student, Department of Agricultural Economics, University of Kentucky, 333 Charles E. Barnhart Building, Lexington, KY 40546, USA. Phone: (859) 218-5202; e-mail: xueting.deng@uky.edu. *Corresponding author.

Yuqing Zheng, Ph.D.

Assistant Professor, Department of Agricultural Economics, University of Kentucky, 317 Charles E. Barnhart Building, Lexington, KY 40546, USA. Phone: (859) 257-8842; fax: (859) 257-7290; e-mail: yuqing.zheng@uky.edu.

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Regulating sales of electronic cigarettes through taxation has been applied in more and more states across many U.S. jurisdictions. We assess the effectiveness of a volume excise tax policy on volume sales using a panel data of retail purchases. The excise tax is imposed in North Carolina on June 1, 2015 at 5 cents per milliliter fluid. With a difference-in-difference analysis identification strategy, we measure the tax effects of the treated stores in North Carolina against untreated stores in Pennsylvania and the untreated period. Our results show that the tax increases the price of the treated area, however the tax effect on the sales of electronic cigarettes are not statistically significant.

Key words: Excise tax, difference-in-differences, electronic cigarettes.

JEL codes: C23, D12, H20, H23, Q53.

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The sales of electronic cigarettes (e-cigarettes) have increased dramatically in recent years and will continue to rise and even exceed the traditional tobacco cigarettes in 2021 (Abcede, 2017, Craver, 2013). In contrast, the volume of traditional cigarettes sales in the United States has declined in 2016, according to Euromonitor International (2017). Partly this is due to e-cigarettes are less regulated than traditional cigarettes, and even no tax regulation exists in most states. However, states and localities in states recently pass laws of e-cigarettes excise taxes to regulate sales due to their risks on health, especially on youth nicotine addiction. An excise tax is an indirect tax of a product paid by the manufacturer or retailer before passing along to the consumer in the price.

E-cigarettes excise tax in the US is relatively new and implemented in smaller areas than cigarettes. Both federal and state laws execute cigarettes excise tax, in addition to sales taxes and other local taxes. In terms of e-cigarettes, till now there is no federal excise tax while some states implement excise tax on e-cigarettes. On the state level, nine jurisdictions pass laws to apply e-cigarettes excise taxes including California, Delaware, Kansas, Louisiana, Minnesota, North Carolina, Pennsylvania, West Virginia and the District of Columbia as of September 2017. Methods on which these jurisdictions base to tax e-cigarettes vary from taxing percentage of purchase price to taxing milliliters of consumable product. Some of the other 41 states, such as Alaska, Illinois, and Maryland, use local laws to regulate e-cigarettes even if the state does not.

Understanding the effects of excise tax on consumption will provide essential evidence for governments to regulate sales and protect public health. The tax revenues generated from e-cigarettes excise tax can have similar benefits as cigarettes tax such as fund health research, anti-smoking campaigns, and even preschool education (Fiore, et al., 2004, Marr and Huang, 2014).

Myriad studies have investigated tobacco tax on its influence on tobacco sales and recommend tax increase as an effective strategy to control tobacco consumption. One strand of studies shows that cigarette taxes negatively impact cigarette sales. Amato, et al. (2015) provides evidence that a $1.75 increase of cigarette tax in Minnesota reduces the number of packs purchased by 12.1% in the post-tax period in 2013. Another strand of studies investigates effects of cigarettes excise taxes on the use of other tobacco products. Ohsfeldt, et al. (1997) show that increasing cigarette excise tax is associated with an increased probability of using smokeless tobacco products. In addition, Huang, et al. (2014) focus on the price of e-cigarettes, their results indicate that e-cigarettes are very sensitive to price change; the own price elasticities for disposable e-cigarettes are around -1.2 while that for reusable e-cigarettes are about -1.9., and disposable e-cigarettes are substitutes for reusable e-cigarettes.

In terms of research on e-cigarettes excise tax, to our knowledge only one article evaluates excise tax on its own consumption so far. However, Amato and Boyle (2016) find the results are mixed due to applying data with simultaneous tax increases for both cigarettes and e-cigarettes. In the post-tax periods, their results show that a short period spike arises in e-cigarettes consumption purchased from convenience stores prior to a consumption decline;

a decrease of cigarettes consumption co-occurs with an e-cigarettes consumption increase. However, evaluating the trends of consumption qualitatively, they do not show whether the consumption change and how much of this change are due to e-cigarettes tax. Consequently, a gap in the literature exists in analyzing the consumption magnitude quantitatively. What's more, the implementation of the new e-cigarettes tax policy of Minnesota in 2016 is entangled with a tax increase on cigarettes; existing research does not address these two tax effects separately. The mixed results of their research may attribute to the substitution of combustible cigarettes for e-cigarettes when the relative price of cigarettes are higher as shown in previous research (Grace, et al., 2014).Thus, it challenges to quantitatively estimate the e-cigarettes tax effects on consumption of e-cigarettes without evaluating the two tax policies separately.

Estimating the e-cigarettes tax effect on its consumption quantitatively and independently from a tax change of cigarettes needs a quantitative estimating method and data with no concurrence of the two tax changes. Thus, this study aims to apply proper data and methods to quantitatively evaluate the magnitudes of consumption effects from an e-cigarettes tax change. Evidence from our research can facilitate policymakers' decisions on additional e-cigarette tax to address concerns of public health and the state economy.

Utilizing a panel dataset of consumer purchases of e-cigarettes from 2014 to 2016, we investigate the effects of a tax policy change on sales of e-cigarettes, on which North Carolina imposed an excise tax on June 1, 2015. We compare sales in the treated stores in North Carolina with sales of the control stores in Pennsylvania. Stores in North Carolina are similar to those in Pennsylvania. The consumption trends in the pre-treatment period are

similar. This allows us to use a difference-in-difference approach to estimate the consumption change in the treated state due to this tax change. Our results of difference-in-difference estimations show that when taxed, the average sales quantity of e-cigarettes in North Carolina does not have a statistically significant difference from the untaxed control state. This might be due to the tax effect is too small to detect or because of heterogeneity responses from different income groups or to different product types.

This article proceeds as follows. First, we describe the data and compare North Carolina and Pennsylvania with graphs and tables. Then, the empirical strategy describes the difference-in-difference estimator. The results section present results from all the empirical estimations. The last section concludes.

Data

The main source of our data is the Nielsen retail scanner database. It provides store-level weekly prices and the number of units purchased for each product (UPC) level regarding e-cigarettes. E-cigarettes sales include total e-cigarette devices, cartridges, and liquid for a variety of outlets such as convenience stores, drug stores, and mass merchandisers. The panel begins on January 1, 2014 and ends on September 30, 2016. The tax imposition date for North Carolina is June 1, 2015. This generates 17 months before the tax and 16 months post the tax. We do not include data from October 1, 2016 to December 30, 2016 because Pennsylvania imposed an excise tax on e-cigarettes at 40 percent of retail price. An observation from the scanner data is the number of units sold for a UPC in a week at a particular store. The regressions we conducted include store-UPC fixed effects, week of

the year fixed effects, year-month fixed effects, brand fixed effects, and size fixed effects. In addition, these scanner data are matched with the median household income of each county where each store is located.

In our analysis, the treated state is North Carolina (NC). Its control state is Pennsylvania (PA). Our data contains 1,671 stores from NC and a total of 1,371 stores from PA. On the dimension of time, our data includes 2,942 stores post the tax and 2,907 stores before the tax imposition. The total number of UPC-store-weeks observations in our analysis is 785,931 including 374,196 observations from NC and 411,735 observations from PA. According to the HB 1050 of 2014 bill from NC, all UPCs of e-cigarettes with fluid are subject to the tax. The total number of UPCs in the data is 350. This yields 294 taxed UPCs post the tax and 264 untaxed UPCs before June 1, 2015.

Before conducting estimations, we generate total weekly volume sales for each UPC and average weekly price for the smallest size of each UPC. In our dataset, the smallest size is count (CT). This volume quantity and price are used in all our following estimations. To compare NC and PA, table 1 presents summary statistics for log of quantity, log of price, number of stores, and number of UPC products sold. These statistics are for the treated and control states examined in two time periods: pre-period and tax period.

Comparing with PA, table 1 show that the average purchase quantity of e-cigarettes is relatively lower and the average price is higher in NC for both pre-tax period and the tax policy period. It also indicates that average quantity increases in the tax period for both the control and the treated state. In contrast, price, as the main determinant of quantity purchased, reduces in the tax period for both states. However, the tax change in NC generates a higher

tax-inclusive price in NC. This attenuates the price reduction amount in NC. Accordingly, PA reduces price more than NC in the tax policy period. If time and state are not controlled, an estimation of the treatment effect is the difference in the quantity change between treated and control state in response to the NC tax change.

The quantity, price, and income are in log format. Differencing quantity in each column of table 1 across periods provides percentage change in quantity with regard to the tax changes. Take derivative of quantity with respect to price or income yields the own price elasticity and the income elasticity. Interestingly, we observe a zero quantity difference in means between treated and control state with the tax imposition. However, the average price difference is 0.011. Taken together, the tax leads to a higher price in the treated state, but the higher price does not reduce the consumption of e-cigarettes. In addition to these means comparisons, table 1 shows a need to use a difference-in-difference approach to discover the tax effect on the treatment state, since there are changes in the price and quantities of e-cigarettes in the control state. Accordingly, we will apply a formal difference-in-difference strategy.

Comparison of the Treated State and the Control State

A comparison of the treated state and the control state shows whether the observable factors influencing the demand for e-cigarettes are similar in the pre-tax period between the treated and control state. When the match becomes less exact, we use the data to control for (1) differences of stores and products in the treated state and control state as well as (2) differences in wee, month, or year. These controls are applied as (1) product-store fixed

effects controlling for observed and unobserved time-invariant differences influencing demand at the product-store level, and (2) as week and month-year fixed effects that are common to all products. In addition, brand fixed effects and size fixed effects are also included.

Table 2 presents summary statistics for the treated state and control sate for e-cigarettes before June 1, 2015. From the statistics, NC has statistically lower consumption quantity and lower median household income, comparing with the control state. However, the sample quantity consumed is qualitatively similar, suggesting that the treated and control state shares a broadly similar patterns in the pre-tax period.

To generate the pre-tax period trends in the quantity sold and price, we use data at the most aggregate level: all UPCs across all stores in a state-month. The quantity represents the total volume sales across all taxed UPCs in each month. The price is a volume-weighted average price, created by using each UPC's volume sold in each store-month as the weight, following the method of Rojas and Wang (2017). This volume weighted price is a more precise estimate of the effective average price paid by consumers. It also accounts for the skewness in the popularity of e-cigarettes products by assigning different weights to products of different popularity. Finally, it also captures the price "arbitrage" behavior by consumers through piling during promotion and seeking stores of lower price. This way accounts for the compromising effect of consumers' behavior of price "arbitrage" on the tax effective.

Figure 1 displays aggregate quantity results while figure 2 shows average price results against month. The vertical bar indicates the time at which the tax is beginning to be imposed. The left side of the vertical bar is the pre-tax period while the right side shows the

tax policy period. To ease graphical comparisons between the control state and treated state, we normalize both the quantity variable and the price variable using January 2014 levels for each state. In this way, volume and price are equal to one on January 2014 for both NC and PA. This normalization is important because PA is a much larger state having a larger population and higher volume sales of e-cigarettes. The store fixed effects will control for all these time-invariant factors influencing the demand for e-cigarettes in the following regressions.

Above all, both figure 1 and figure 2 show that the trends in NC and PA are similar during the pre-tax period. The tax effect on price looks evident since the price in NC increases after the tax policy. However, the tax imposition seems to lead to an increase of e-cigarettes sales in NC. Additionally, both NC and PA are on the east border of the U.S. After conducting graph comparisons of volume and price with other neighboring states including South Carolina, Virginia, Georgia, Kentucky, and Tennessee, we find that PA is the most similar state to NC.

Empirical Strategy

We utilize a difference-in-differences approach to investigate the effect of a treatment, an excise tax change of e-cigarettes, on the quantity of e-cigarettes sold. This approach compares the performance of treatment group pre- and during-treatment with the performance of the control group pre- and during-treatment. North Carolina is the treated state and Pennsylvania is selected as the control state. On June 1, 2015, NC began to tax e-cigarettes at 5 cents per fluid milliliter but PA did not apply an excise tax on e-cigarettes. The pre-treatment period is

from January 1, 2014 to May 31, 2015; the tax period is from June 1, 2015 to September 30, 2016.

In the following regressions, each product is identified by its bar code (UPC). The outcome variable of interest is the log of weekly purchases of e-cigarettes at the UPC by store level. Thus, Q_{isw} is the quantity of product i purchased in store s in week w. Stores in NC are treatment stores while stores in PA are control stores. The dummy variable T_{is} equals one for stores in the treated state NC. Time dummy variable, r_{iw}, identifies two time periods: weeks before the tax imposition where r_{iw} is zero and weeks during the tax period during which r_{iw} equals one. These two periods are called as "pre-tax" and "tax policy".

To evaluate the sensitivity of the treatment effect to different underlying assumptions, we conduct several estimations with different difference-in-differences specifications. The preferred specification contains product-store fixed effects, time fixed effects, price, and income. The least restrict specification only includes data on e-cigarettes without including any fixed effects. It does not control for potential covariates which could lead to a biased estimate of the treatment effect. These covariates include consumers' different demand for different products, preferences to different stores, and etc. To reduce the probability of getting biased estimates, we include interactions of store with products, the weekly price, and the median county household income. In our preferred specification, we also add week fixed effects to control for weekly changes that are common across all stores, as well as year-by-month fixed effects.

This specification is shown as the following:

(1) $\ln Q_{isw} = \alpha_{y\text{-}m} + \alpha_w + \alpha_{is} + \beta_0 + \beta_1 r_{iw} + \beta_2 T_{is} t_{iw} + \beta_3 \ln P_{isw} + \beta_4 \ln Inc_{isw} + \varepsilon_{isw}$,

where the coefficient on r_{iw} is time period effects that are identical across the treated and control stores, the coefficient of $T_{is}t_{iw}$ represents the effect of the tax treatment. Year-by-month fixed effects are signified by $\alpha_{y\text{-}m}$, α_w represents week of the year fixed effects, and α_{is} shows product-store fixed effects. The error term is ε_{isw}.

Results

In this section, we first show the average change in the quantity of e-cigarettes purchased after the tax imposition from the difference-in-differences approach. Then, we compare the quantity changes across different product types responding to the tax, applying the triple-difference identification strategy.

Average Effects of the Excise Tax Policy

Results for the specifications of the difference-in-differences approach are displayed in table 3. The dependent variable is log of weekly quantity sold for all regressions. Column (1) presents the results from the least restrictive specification. It contains a time period dummy ("Post") indicates the imposition of the tax, a dummy ("NC") denotes stores in the treated state NC, as well as the interaction of time dummy and the treatment store dummy ("Post_NC"). The "Post_NC" term estimates average treatment effect of the policy change. Column (2) is similar to column (1), but it adds time fixed effects represented by week dummies and year-by-month dummies. Compared with column (2), column (3) adds product-by-store fixed effects. Built upon column (3), column (4) adds log price of the smallest size for each e-cigarettes product. This price is more informative than the unit price from the raw

data. Lastly, column (5) adds log median county household income to the specification of column (4). Standard errors for all specifications are robust to heterogeneity and are clustered at the Nielsen designated market area (DMA) level.

Adding fixed effects changes the regression coefficients. Controls for price also slightly changes the tax effect estimates. However, all the estimates for tax effect are not statistically significant. Column (1) in table 3 shows that on average consumers purchased 2% more quantity of e-cigarettes products after the pre-tax period. Consumers in the treated state NC purchased about 20% less than consumers in PA. This period effect and state effect are not estimated in other specifications of table 3. The period effect is subsumed in the time fixed effects in columns (3), (4), and (5). The state effect is also contained in the product by store fixed effects in columns (4) and (5). Comparing across these columns, the tax effect estimates from "Post_NC" stays statistically insignificant.

Starting from a pure difference-in-differences estimate without any fixed effects in column (1) with an OLS specification, table 3 shows that the quantity does not change after the tax imposition based on the coefficient of "Post_NC". The tax imposition keeps statistically insignificant for all the specifications, when we control for fixed effects at the year-by-month dummies and week dummies in column (2), fixed effects at the product-store level and the time fixed effects in column (3), price in column (4), and income in column (5). The main finding from table 3 is that we do not find statistically significant sales quantity changes in NC after the tax policy change.

To examine the tax policy effect on price, we conduct similar regressions. The

dependent variable in table 4 is log price of the smallest count unit. The first specification does not include any fixed effects. The second specification is similar to column (3) in table 3. From the first column, NC charges a 5.9% higher average price than PA. Comparing with the pre-tax period, both the treated and control states reduce price about 8.3% during the tax policy period. Both columns show that the tax change effects on the price is positive and statistically significant, according to the coefficients of "Post_NC". This is consistent with the preliminary evidence from table 1.

Conclusion

This article uses a product-store level scanner data sold from various stores across NC and PA from January 1, 2014 to September 30, 2016 to estimate the purchase quantity change of e-cigarettes after the imposition of an excise tax in NC. Our estimates do not find statistically significant changes in purchases due to the tax. This implies that the demand for e-cigarettes is inelastic. Therefore, a larger quantity of tax can be levied on e-cigarettes. Furthermore, the price of e-cigarettes in the tax period drops a larger amount than the 5 cents tax increase on per milliliter fluid. This could be a reason that consumers do not have statistically significant responses to the tax.

In the future, investigations on different consumer groups or on different product types may provide more evidence on the tax effect. Another future research direction is to compare tax reactions of another taxed state to further test the effectiveness of the tax. Moreover, when consumers do not change the quantity of e-cigarettes purchases, the health

effect from the consumption side may be compromised. However, the tax collected from this policy can still be applied to education programs to indirectly reduce smoking since the tax is inelastic.

Table 1. Means of Treated and Control States for E-cigarettes

Period	Variable	Control State (PA)	Treated State (NC)
Pre-tax	Log(Q)	1.134	0.931
		(0.979)	(0.919)
	Log(P)	1.642	1.701
		(0.713)	(0.771)
	Log(Income)	10.967	10.796
		(0.251)	(0.199)
	Number of Stores	1,314	1,593
	Number of UPC IDs	239	223
Tax policy	Log(Q)	1.155	0.952
		(0.945)	(0.877)
	Log(P)	1.559	1.629
		(0.648)	(0.723)
	Log(Income)	10.927	10.855
		(0.251)	(0.208)
	Number of Stores	1,327	1,615
	Number of UPC IDs	275	237

Source: Authors' calculations from Nielsen scanner data. Note: standard deviations show in parentheses. The pre-tax period is January 1, 2014 through May 31, 2015. The tax period is June 1, 2015 through September 30, 2016.

Table 2. Treated and Control States in the Pre-tax Period for E-cigarettes

Variables	Control State (PA)	Treated State (NC)	P-value of Difference
Log(Q)	1.134	0.931	0.000
	(0.002)	(0.002)	
Log(P)	1.642	1.701	0.000
	(0.002)	(0.002)	
Log(Income)	10.927	10.796	0.000
	(0.0005)	(0.0005)	

Source: Authors' calculations from Nielsen scanner data. Note: standard deviations show in parentheses. Median household income in dollars is from the 2017 Census Bureau data.

Table 3. Difference-in-differences Regressions for Log of Quantity of E-cigarettes

Variables	(1)	(2)	(3)	(4)	(5)
Post_NC	-0.001	0.002	0.026	0.023	0.023
	(0.011)	(0.010)	(0.015)	(0.015)	(0.015)
Post	0.021***				
	(0.007)				
NC	-0.203***	-0.207***			
	(0.032)	(0.033)			
Log(P)				-0.078***	-0.078***
				(0.004)	(0.003)
Log(Inc)					-0.064
					(0.072)
Time FE	No	Yes	Yes	Yes	Yes
Product_store FE	No	No	Yes	Yes	Yes
R-squared	0.012	0.634	0.755	0.756	0.757
Observations	785,931	785,929	758,551	758,551	758,551
Number of upc_store			81,942	81,942	81,942
Number of DMA	21	21	21	21	21

Note: Standard errors are in parentheses, clustered at the DMA level. Asterisks ***, **, and * are significant levels at 1%, 5%, and 10% respectively. Time fixed effects include week dummies and year by month dummies. FE stands for fixed effects. Singleton observations are dropped in regressions. DMA is designated market area assigned by Nielsen.

Table 4. Difference-in-differences Regressions for Log of Price of E-cigarettes

Variables	Log(P)	Log(P)
Post_NC	0.011***	0.084***
	(0.003)	(0.001)
Post	-0.083***	
	(0.002)	
NC	0.059***	
	(0.002)	
Time FE	No	Yes
Product_store FE	No	Yes
R-squared	0.012	0.599
Observations	785,931	785,931
Number of upc_store		81,942

Note: Standard errors are in parentheses. Asterisks ***, **, and * are significant levels at 1%, 5%, and 10% respectively. Time fixed effects include week dummies and year by month dummies. FE stands for fixed effects.

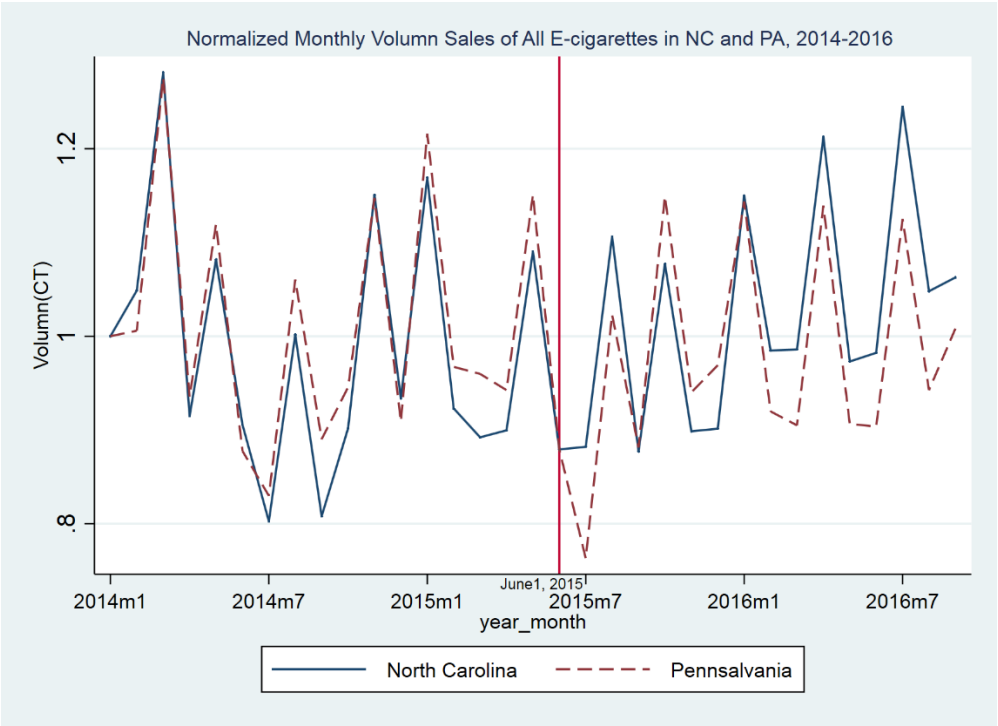

Figure 1. Total Quantity of E-cigarettes Sold by Month and State

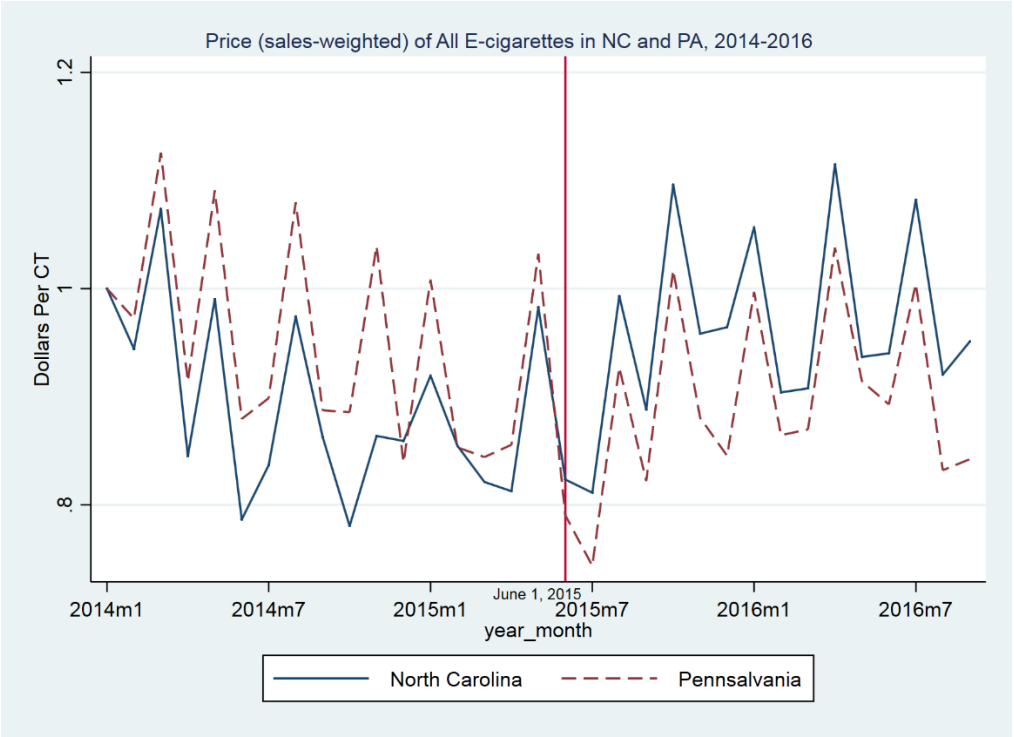

Figure 2. Average Monthly Price of E-cigarettes by Month and State

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