Spatial Spillover Effects of State-Level Policies Banning ENDS Products

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Research Objective

- After an outbreak of e-cigarette or vaping product use-associated lung injuries (EVALI) that was later identified as strongly linked to use of illicit tetrahydrocannabinol (THC)-containing products, several states passed short-term bans on the sale of Electronic Nicotine Delivery Systems (ENDS) products.
- Unlike combustible cigarettes, regulation in the U.S. of ENDS has only been introduced in recent years and varies by state and locality. Thus, little direct policy research has been done on the impact of such changes in regulation.
- Evidence of the consequences of ENDS regulation is crucial to inform policy making in the context of tobacco harm reduction. Our study seeks to systematically estimate the impact of these emergent ENDS restrictions, with a focus on the cross-border spillover effect.
- We utilize a fixed-effect panel regression model with a difference-in-differences approach embedded to evaluate both spillover and direct effects of state-level ENDS bans enforced in Massachusetts, Washington, Rhode Island, and Montana on tobacco product sales. This method enables us to provide a comprehensive picture of the consequences, both intended and unintended, of ENDS restrictions in the states with bans and their neighboring areas.

Study Design

Data Sources:

- ENDS Ban Policies[1]:
  - Massachusetts: the temporary ban on all ENDS products was in place from Sept 24th, 2019 - Dec 11th, 2019, and the ban on flavored (non-tobacco) ENDS products became effective on Dec 12th, 2019.
  - Washington, Rhode Island and Montana: four-month ban on flavored (non-tobacco) ENDS products on Oct 10th, Oct 4th, and Dec 18th, 2019, respectively.
- Outcome: store- and county- level monthly value sales of total ENDS, tobacco-flavored ENDS, menthol/mint-flavored ENDS, and cigarettes aggregated from the weekly Nielsen Retail Scanner Data (NRSD) from March 2016 to February 2020.
- Control variables: state-level e-cigarette and cigarette tax; state-level quarterly real Gross Domestic Product (GDP) by different industries; county-level weather-related monthly measures including precipitation, maximum temperature, minimum temperature, and average temperature; county-level monthly employed population, labor force, and unemployment rate.

[1]The effective dates are from Public Health Law Center (2020) States and Tribes Stepping in to Protect Communities from the Dangers of E-cigarettes: Actions and Options. https://www.publichealthlawcenter.org/resources/states-and-tribes-stepping-protect-communities-dangers-e-cigarettes-actions-and-options

[2]Kenkel, Donald S., Sida Peng, Michael F. Pesko, and Hua Wang. 2020. "Mostly Harmless Regulation? Electronic Cigarettes, Public Policy, and Consumer Welfare." Health Economics 29 (11): 1364–77. https://doi.org/10.1002/hec.4136.

[3]Buckell, John, Joachim Marti, and Jody L Sindelar. 2018. "Should Flavors Be Banned in Combustible and Electronic Cigarettes? Evidence on Adult Smokers and Recent Quitters from a Discrete Choice Experiment." Tobacco Control, May. https://doi.org/10.1136/tobaccocontrol-2017-054165.

Methods:

- We use the difference-in-difference panel regression models to examine direct and spatial spillover effects on ENDS and cigarette sales, after controlling for macroeconomic variables and seasonal and location-specific variation with fixed effects.
- The county level analyses include 257 counties and use the county population in 2015 as the sample weight. The empirical specification is:

$$y_{ct} = \alpha_c + \beta_1 D1_{ct} + \beta_2 D2_{ct} + \beta_3 N1_{ct} + \beta_4 N2_{ct} + \gamma X_{ct} + \varepsilon_{ct}$$

where

- y_{ct} can be average per-store monthly sales of all ENDS products, menthol/mint-flavored ENDS, tobacco-flavored ENDS, or cigarettes in county c in month t;
- α_c is the county fixed effect;
- $D1_{ct}$ or $D2_{ct}$ are the direct ENDS ban indicators for county c in month t subject to a state-level full ban or a flavor ENDS ban. $N1_{ct}$ or $N2_{ct}$ become 1 if county c is not subject to any state-level bans in month t but adjacent to another state that is subject to a full ENDS ban or a flavor ENDS ban in month t. Details of indicator assignment are summarized in **Table 1**.
- X_{ct} is a vector of control variables for each county.
- ε_{ct} is the error term.

Table 1 Summary of the counties neighboring states with bans

States with bans (D)	Neighboring states	Neighboring counties(N)
Massachusetts Full Ban (Sept 2019 to Dec 2019) Flavor Ban (Jan 2020 to Feb 2020)	Connecticut New Hampshire Vermont Rhode Island (only Sept 2019)	Hartford, Litchfield, Tolland, Windham Hillsborough, Cheshire, Rockingham Bennington, Windham Bristol, Newport, Providence
Rhode Island Flavor Ban (Oct 2019 to Feb 2020)	Connecticut	New London, Windham
Washington Flavor Ban (Oct 2019 to Feb 2020)	Oregon Idaho	Multnomah, Sherman, Umatilla Kootenai
Montana Flavor Ban (Dec 2019 to Feb 2020)	North Dakota South Dakota Wyoming	Bowman, Golden Valley, McKenzie, Williams Butte Campbell, Crook, Sheridan

Results

Key Findings:

- According to estimates reported in column (1) of **Table 2**, both full and partial (non-tobacco flavors) ENDS bans have large, statistically significant, negative direct impact on monthly ENDS sales. The full ban drastically reduces all ENDS sales, while the flavor ban decreases monthly per-store ENDS sales by 47.1 percent of the pre-ban regional average ($4,970, p<0.01).
- The estimated coefficients imply that the state-level flavor ban increases per-store ENDS sales in adjacent counties by 14.7 percent ($1,548, p<0.05). The full ban has an even larger spatial spillover effect, with ENDS sales increasing by 52.7 percent ($5,563, p<0.05).
- Since the specified flavor bans only affect the sale of all non-tobacco flavors, the flavor ban reduces all menthol/mint-flavored ENDS sales, as shown in column (2) of **Table 2**, but has a significant, positive direct impact on tobacco-flavored ENDS sales as shown in column (3). These results suggest that at least some ENDS consumers shift to tobacco-flavored products when other flavors become unavailable under the ban.
- The monthly combustible cigarette sales increase by 8.0 percent ($6,241) under a full ban, based on column (4). This result implies under the full ban, ENDS consumers may substitute with combustible cigarettes.

Table 2 Direct and spatial spillover effects of ENDS ban on ENDS and cigarettes sales, county level

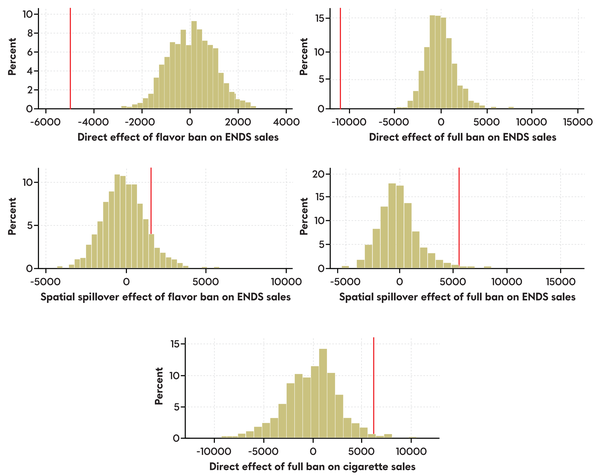
	Monthly sales value per store			
Monthly average (07/2018 – 06/2019)	(1) ENDS 10551.28	(2) ENDS Menthol/Mint 5926.09	(3) ENDS tobacco 1818.901	(4) cigarettes 77836.72
1(Direct ENDS flavor ban)	-4970.0*** (1362.8)	-6453.8*** (646.4)	2153.7* (1247.6)	-162.1 (2711.0)
1(Direct ENDS full ban)	-10996.8*** (1008.7)	-7509.3*** (577.3)	-3346.0*** (647.0)	6241.3* (3238.2)
1(Neighbor of counties with ENDS flavor ban)	1548.0** (753.6)	719.7 (742.7)	836.0 (524.5)	-2873.0 (4997.7)
1(Neighbor of counties with ENDS full ban)	5562.5** (2656.8)	5462.1*** (2075.9)	338.6 (718.0)	3195.2 (3042.4)
Observations	11774	11774	11774	11774
County Number	257	257	257	257
Adjusted:R^2	0.858	0.839	0.827	0.976
County FE	Yes	Yes	Yes	Yes
State by calendar month FE	Yes	Yes	Yes	Yes
Region by month of sample FE	Yes	Yes	Yes	Yes
State quarterly GDPs	Yes	Yes	Yes	Yes
Other control variables	Yes	Yes	Yes	Yes

Note: Robust standard errors (in parentheses) are clustered at the county level. Asterisks ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Robustness Checks

- Findings are robust to multiple specifications and robustness tests, and lead test shows parallel pre-trends.
- The random permutation test of 1,000 repeats prove the direct and spatial spillover effects estimated from our main analyses are unlikely to be driven by unobserved endogenous factors. The vertical red lines of **Figure 1** represent the estimates from our main results.
- The top two graphs display the distributions of estimated coefficients for direct effects of flavor and full bans on ENDS sale; not a single observation from 1,000 repetitions approaches the magnitude of our estimates in the change of ENDS sales in the counties with bans.
- The middle two graphs present the distributions of estimated coefficients for spatial spillover effects of flavor and full bans on ENDS sales. Only 2.1% of the permutations result in estimates larger than our estimates of spatial spillover effect of the full ENDS ban, and 12.1% of the permutations result in estimates larger than our estimates of spatial spillover effect of the flavor ENDS ban. The chance that both of these two estimates from the permutation repeats achieve at least the same magnitudes of our main estimates simultaneously is only 0.8%.
- The bottom panel of **Figure 1** shows that it's unlikely that the estimation of any random assignment is larger than the direct effect of full ban on cigarette sales.

Figure 1 Results of the permutation test at the county level



Conclusion

- This study addresses the evidence gap in policy research on ENDS bans and provides a comprehensive picture of both direct and spillover effects of ENDS restrictions in states instituting bans on these products and their neighboring areas. The data strongly indicates the existence of cross-border purchasing behavior after states ban the ENDS products.
- Beside spatial spillover effects, our results also suggest that consumers switch to other ENDS products or to combustible cigarettes when their preferred ENDS product becomes unavailable, which is consistent with findings from the existing literature[2,3].

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Conflict of interest disclosure: Tengjiao Chen and Lanxin Jiang are full-time employees of JUUL Labs, Inc. Shivaani Prakash was a full-time employee of JUUL Labs, Inc., during the time that this work was conducted.

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