# Online Appendices

## Contents

## A Differences from Rich (2022)

Our paper is most similar in objectives to an unpublished paper by Rich (2022) which uses monthly wholesaler cigarette shipment data and a similar difference-in-differences specification to analyze outcomes after the 2020 Massachusetts menthol ban. After accounting for cross-border shopping, Rich (2022) finds a sizable increase in demand for menthols, non-menthols, and total cigarettes. Conversely, we find an increase in non-menthol consumption but a decrease in menthols.

Rich (2022) reports an increase of 72.57 packs sold per 1000 people in a "treated' region which consists of Massachusetts and its neighboring states (New York, New Hampshire, Rhode Island, Vermont, and Connecticut). In 2019, Massachusetts accounted for 24% of the cigarette sales of this "treated" region (USCB, 2021). If this increase in consumption is indeed caused by changes in demand by Massachusetts residents, then the average treatment effect on the treated (ATT) change in demand specifically among Massachusetts residents would be equal to the intent to treat treatment effect (ITT) in the larger area (Massachusetts and its neighbors) divided by the treatment propensity (share of Massachusetts sales):

$$\begin{aligned}\text{ATT in MA} &= \frac{\text{ITT in treated region}}{\text{MA share of treated region sales}} \\ &= \frac{72.57}{0.24} \\ &= 302.37\end{aligned}$$

According to these calculations, the ATT would be an increase of 302.37 packs per 1000 people in Massachusetts. The descriptive statistics in the supplementary material of Rich (2022) state that the baseline level of Massachusetts menthol sales is 484.95, which implies that the Massachusetts menthol ban increased total cigarette sales by about 62% in Massachusetts — this is a very large increase and stands at odds with our results. We do not have access to the data used by Rich (2022) and therefore we cannot replicate their analysis directly. However, below we discuss a number of potential reasons that could explain the divergence between our results and Rich's.

Our empirical approach differs from Rich (2022) on some important dimensions: the data, the model, the analysis, and the main conclusions and takeaways. We now describe these differences in detail.

### Data

We use retail sales data, which means that we can observe realized sales and retail prices. Meanwhile, Rich (2022) uses wholesale shipment data from distributors to retailers. Because cigarette packs are small and easily storable, retailers that over-order cigarettes may choose to just keep the excess inventory in their warehouse rather than sending it back to the manufacturer. Under the Rich (2022) approach, this would be mis-measured as high consumer demand. Therefore, relying on wholesale transactions may lead to incorrect conclusions regarding consumer demand.

### Model

Our difference-in-differences specification is broadly similar to the specification in Rich (2022). One important difference is in the construction of the treatment vs. control groups. In our analysis, we omit states neighboring Massachusetts from the control group — these states were positively treated by the Massachusetts menthol ban because they receive some demand spillover in the form of cross-border shopping. Conversely, the "complete model" in Rich (2022) includes neighboring states as part of the analysis. This leads to an overstatement of the treatment effect, because they are comparing Massachusetts (where sales went down due to the menthol ban) with neighboring states (where sales went up due to the menthol ban). We believe that looking at non-neighboring states provides a better control group for our difference-in-differences analysis.

A second difference between the two difference-in-differences specifications has to do with the fixed effects: our model uses fixed effects by state and week, but Rich (2022) uses fixed effects by state, month-of-year, and year. These fixed effects are less granular than ours, and they may not correctly pick up on time trends (e.g., a general decline in cigarette sales, or a slightly different seasonality pattern in one year vs. another).

A third related difference between the two difference-in-differences specifications is that the outcome variable in our model is log-sales, rather than per-capita unit sales as in Rich (2022). Using unit sales can yield to misleading results in situations where different observational units (in their case, different states) have very different levels of sales. For instance, a one-percent decrease in Massachusetts sales is substantially different in quantity terms than a one-percent decrease in Vermont sales. Our log-sales dependent variable means that we are comparing percentage changes across states, rather than comparing level changes across states. Using unit sales like Rich (2022) can also lead to an overstatement of the treatment effect.

**Analysis**

Rich (2022) estimates a series of difference-in-differences regressions but does not provide any additional empirical exploration of the data. In this research, we verify the difference-in-differences regressions with a synthetic control model that yields similar estimates. Furthermore, we build on this analysis by investigating other issues that can yield additional insights about consumer demand for cigarettes. For instance, we are able to examine how different stores are differentially affected by the ban depending on how close they are to a state border — this yields valuable insights regarding travel costs among consumers and how likely they are to travel to buy menthol cigarettes. We also show how prices vary across states, and how that affects Massachusetts residents' willingness to travel and engage in cross-border shopping for cigarettes. Finally, we build on the difference-in-difference results by estimating a structural model that enables us to evaluate how demand for menthols and demand for total cigarettes would be affected by alternative policies like a full nationwide menthol ban or a statewide menthol tax.

**Conclusions and takeaways**

After accounting for cross-border shopping behavior among people in Massachusetts, Rich (2022) finds that the menthol ban led to increases in menthol sales, non-menthol sales, and total cigarette sales. Our results for non-menthol sales are similar, but we find that menthol sales and total cigarette sales both went down because of the ban. The differences in results are likely attributable to some of the key modeling differences between our approach and Rich (2022), as described above.

As a result of these differences, this research and Rich (2022) come to very different conclusions regarding the efficacy of the 2020 Massachusetts menthol ban. We find that the ban was only partially successful at reducing menthol usage in Massachusetts because about half of the pre-ban menthol sales were simply diverted to nearby states. Meanwhile, Rich (2022) finds that the ban actually *harmed* the state's goal of reducing menthol sales, because more than 100% of the pre-ban menthol sales were diverted to nearby states.

More broadly, our additional analysis and our structural model allow us to provide broader counterfactual takeaways beyond what the difference-in-differences model can show. We show that a national menthol ban would be more effective than a state-specific Massachusetts menthol ban, and we also show that a menthol tax might be a better option than a menthol ban because it can yield substantially increased tax revenue while also reducing menthol consumption and overall cigarette consumption. Rich (2022) is unable to comment on these kinds of counterfactual policy changes.

## B Data cleaning and compilation

In this section we discuss details regarding data compilation and usage.

### Cigarette flavors in the NielsenIQ sales data

The NielsenIQ data includes a product-level table in which each observation is a unique UPC. For cigarettes, the UPC description includes information about the flavor (menthol/non-menthol), filter, and their length. For instance, one of the UPCs in our data has the description 'NWT 1 NON M F 85 BX P', which means that the UPC belongs to the Newport brand, is non-menthol, and is filtered. The number 85 means that the cigarettes are 85mm long, and finally 'BX P' states that the box is a single pack (P) rather than a carton (C). We classify products as menthol/non-menthol based on this text description string. In particular, a product is classified as menthol if the string includes an isolated 'M' without any leading 'NON', and non-menthol otherwise. For instance, another UPC in our data has the description 'MRBI 1 F BOLD COOL M 85 BX P' — this is a pack of 85mm filtered Marlboro bold cool menthol cigarettes, and it is correctly classified as a menthol product based on our classification rule.

We then validate that the majority of the stores in Massachusetts stopped carrying menthol cigarettes in the last quarter of 2020 after the ban was imposed. Our analyses showed that menthol UPCs were carried in fewer than 1% of the stores in Massachusetts after the ban was implemented, with the exception of four UPCs that continued to be sold widely afterwards. We looked up all four of these UPCs and studied the packaging. All four UPCs were non-menthol products, and we manually changed their label from menthol to non-menthol in our analyses. Figure A1 shows the packaging for these products.


Product a    Product b    Product c    Product d

Figure A1: The four non-menthol UPCs which were labeled as menthols in the data. All of these products were relabeled as non-menthol after investigating the packaging.

### Cigarette buying and consumption among Massachusetts residents

In section 4.3 we state that "in-state purchases account for 83.39% percent of cigarette consumption in Massachusetts." This estimate comes from a combination of multiple data sources as well as intermediary data analysis done by LaFaive, Nesbit, and Drenkard (2016) and Boesen, Nesbit, and LaFaive (2021).

In a state-by-state analysis of cigarette smuggling activity, Boesen, Nesbit, and LaFaive (2021) calculate that Massachusetts has a net "smuggling rate" of 19.92%; this means that Massachusetts residents consumed 19.92% more cigarettes vs. what was legally sold in Massachusetts. This calculation is based on two sources of data. First, to estimate cigarette consumption by Massachusetts residents, they use data from the CDC's Behavioral Risk Factor Surveillance System survey regarding smoking prevalence and smoking intensity in each state. Second, to measure how many packs of cigarettes were sold in Massachusetts, they use excise tax revenue information from the Massachusetts Department of Revenue; this information is subsequently collected and reported in annual CDC reports called *The Tax Burden on Tobacco*. These two pieces of data are incorporated into a statistical model that yields a net smuggling rate; details of this model are provided in LaFaive, Nesbit, and Drenkard (2016).

LaFaive, Nesbit, and Drenkard (2016) provide the following formula to understand the connection between sales, consumption, and smuggling for a given state $i$ and year $t$:

$$PCSales_{i,t} = Cons_{i,t} + NetSmug_{i,t}$$

where $PCSales$ is per-adult cigarette sales (i.e., observed sales data), $Cons$ is per-adult consumption (estimated from the CDC data and a statistical model), and $NetSmug$ is the net smuggling rate as defined above. In our setting, we know that $NetSmug$ is -19.92% of $PCSales$, according to Boesen, Nesbit, and LaFaive (2021).

In our setting, we observe Massachusetts cigarette purchases through the NielsenIQ data and we would like to estimate how much of Massachusetts' cigarette consumption in 2019 is accounted for in Massachusetts retail sales. Using the terminology of LaFaive, Nesbit, and Drenkard (2016), we would like to calculate the ratio of $PCSales$ to $Cons$. We calculate this ratio as follows:

$$\begin{aligned}
PCSales_{MA,2019} &= Cons_{MA,2019} + NetSmug_{MA,2019} \\
PCSales_{MA,2019} &= Cons_{MA,2019} - (0.1992 \times PCSales_{MA,2019}) \\
1.1992 \times PCSales_{MA,2019} &= Cons_{MA,2019} \\
\frac{PCSales_{MA,2019}}{Cons_{MA,2019}} &= \frac{1}{1.1992} \\
&= 0.8339
\end{aligned}$$

The ratio of $PCSales$ to $Cons$ is 0.8339, which means that 83.39% of Massachusetts cigarette consumption happens through legal sales in Massachusetts. This yields a measure of the extent to which Massachusetts residents engage in cross-border shopping vs. buying their cigarettes locally.

The model in section 4.3 imposes two additional constraints for Massachusetts residents after the menthol ban was enforced: one for the overall share of menthol purchases, and another one for the share of out-of-state non-menthol purchases. For the first constraint, we start by calculating the share of menthol purchases by Massachusetts residents *before* the ban. Our calculation above shows that prior to the ban, 1-0.8339 = 16.61% of cigarette purchases made by Massachusetts residents took place outside the state. For menthol cigarettes, our results in Table 4 show that 1-0.5447 = 45.53% of the remaining 83.39% continued after the ban. Therefore, the share of menthol cigarettes purchases in the post-ban period relative to its value in the pre-ban period is equal to:

$$\underbrace{16.61\%}_{\text{pre-ban out-of-state share}} + \underbrace{83.39\%}_{\text{pre-ban in-state share}} \cdot \underbrace{(1 - 54.47\%)}_{\text{post-ban change in menthol consumption}} = 54.57\%.$$

Similarly, the share of total cigarettes sales post-ban relative to the pre-ban period is:

$$\underbrace{16.61\%}_{\text{pre-ban out-of-state share}} + \underbrace{83.39\%}_{\text{pre-ban in-state share}} \cdot \underbrace{(1 - 4.05\%)}_{\text{post-ban change in cigarette consumption}} = 96.62\%.$$

Hence, the post-ban ratio of menthol cigarette purchases to overall cigarette purchases made by

Massachusetts residents ($\psi_1$) is equal to:

$$\psi_1 = \overbrace{\underbrace{27.9\%}_{\text{pre-ban menthol share}} \cdot 54.57\%}^{\text{change in menthol relative to all}} \cdot \frac{1}{96.62\%}$$
$$= 0.1576$$

The next constraint governs the share of non-menthol purchases made by Massachusetts residents inside the state. The share of non-menthol purchases inside Massachusetts in the pre-ban period is 83.39% of the sales and based on our estimates in Table 4, this value grew by 9.86% after the ban was enforced:

$$\underbrace{83.39\%}_{\text{pre-ban in-state share}} \cdot \underbrace{(1 + 9.86\%)}_{\text{post-ban change in non-menthol in-state sales}} = 91.61\%$$

The total value of non-menthol purchases grew by 17.05% relative to the non-menthol sales inside Massachusetts, which means that out-of-state purchases grew by 17.05% - 9.86% = 7.19%. The pre-ban out-of-state non-menthol purchases is equal to 16.61%; therefore, the post-ban out-of-state non-menthol purchases relative to pre-ban in-state non-menthol purchases are equal to:

$$\underbrace{16.61\%}_{\text{pre-ban out-of-state share}} + \underbrace{83.39\%}_{\text{pre-ban in-state share}} \cdot \underbrace{7.19\%}_{\text{post-ban increase in out-of-state purchases}} = 22.61\%$$

Finally, the ratio of in-state non-menthol purchases to out-of-state non-menthol purchases ($\psi_2$) is equal to:

$$\psi_2 = \frac{\text{post-ban in-state share of non-menthols}}{(\text{post-ban in-state share of non-menthols}) + (\text{relative increase in out-of-state purchases})}$$
$$= \frac{91.61\%}{91.61\% + 22.61\%}$$
$$= 0.802$$

**Re-weighting store-level observations in the NielsenIQ data**

Much of the analysis in our paper focuses on cross-border shopping, and we examine this behavior by looking at sales in an agglomerated area of Massachusetts plus areas that are located within 30 miles of Massachusetts (we refer to this as MA+30). One challenge with looking at the MA+30 area is that NielsenIQ's data collection is based on a sample of stores rather than a complete census of stores. If NielsenIQ collects data from a different percentage of stores in each state, then simply adding our sales observations together will yield misleading results regarding the overall patterns in the MA+30 area.

We address this issue by re-weighting our sales data observations. To calculate weekly sales in the MA+30 area, we re-weight the store-level sales data to account for differences in the portion of sales that are recorded in our data across different states. We do this re-weighting using ancillary data on tax revenues. Cigarettes are subject to excise taxes that are charged per pack sold, and the state tax authorities report their total cigarette tax revenues collected in each fiscal year (USCB, 2021). We use this information to find the total number of cigarette packs sold within each state, and we divide that by the observed volume sold in each state in our data. These ratios represent how many sales in each state are not directly observed in our NielsenIQ data, and they are used to re-weight our stores when aggregating to larger regions such as the MA+30 region.

## C Determining the effective spillover radius

In the body of the paper, we mentioned that the spillover effect of the Massachusetts menthol ban was limited to Massachusetts and stores within 30 miles of the Massachusetts border. In this section, we discuss how this 30 mile ring was determined. Our goal is to determine how far from the Massachusetts border it is possible to detect the impact of the ban. Since the ban was limited to menthol cigarettes, one would expect the magnitude of the spillover effect to be larger for menthol cigarettes relative to non-menthol ones. We consider the set of all stores outside Massachusetts that are located within the New England and New York area. We then partition these stores into six distance bands: 0-10 miles, 10-20 miles, 20-30 miles, 30-40 miles, 40-50 miles, and 50+ miles from the Massachusetts border. To visualize these different bands, we plot them in different shades in Figure A2. We take stores located farther than 50 miles away from the border as the baseline and we measure if the sales of menthol increased disproportionately relative to non-menthol cigarettes for stores in each of these distance bands. In particular, we consider the following difference-in-difference-in-differences model:

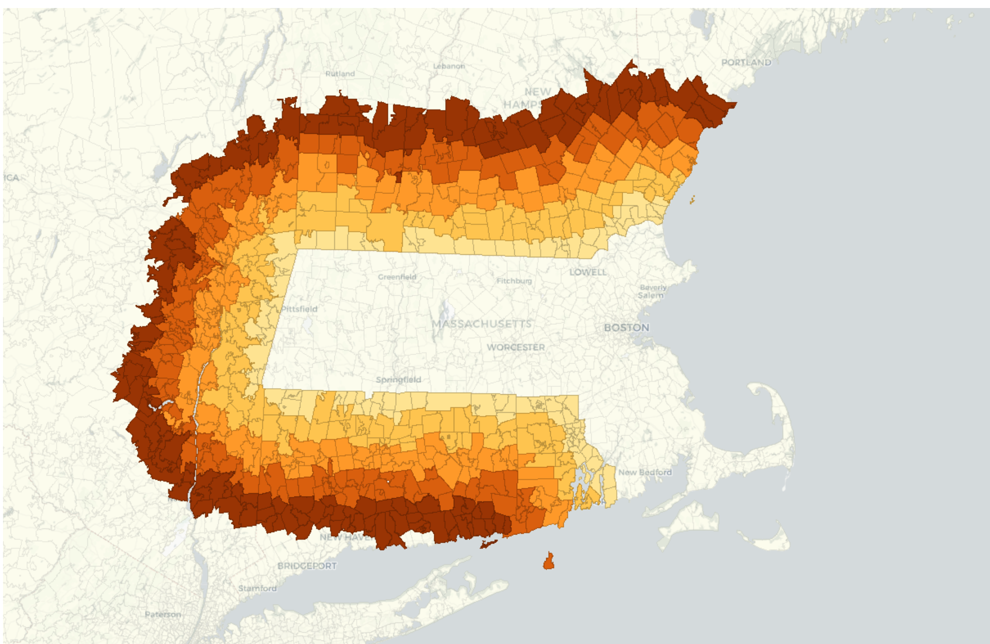



Figure A2: Massachusetts and the 10 to 50 miles (increments of 10) distance bands filled with different shades. Areas in the shaded bands correspond to zip codes in neighboring states.

$$\log(1 + Q_{ijt}) = \sum_{i=1}^{5} \alpha_i \cdot \mathbb{1}_{\{i \in \mathcal{D}_i\}} \cdot \mathbb{1}_{\{j=menthol\}} \cdot \mathbb{1}_{\{t>June\,2020\}} + \beta \log(P_{ijt}) + \eta_{it} + \eta_{ij} + \epsilon_{ijt}, \tag{A1}$$

where $i$, $j$, and $t$ index store, flavor (menthol/non-menthol), and week, respectively. $Q_{ijt}$, and $P_{ijt}$ are the number and price index of packs of flavor $j \in$ {menthol, non-menthol} at store $i$ during week $t$, respectively. $eta_{ij}$ and $\eta_{it}$ are store-flavor and store-week fixed effects. $\mathcal{D}_i$ is the set of stores located between $10 \cdot (i-1)$ to $10 \cdot i$ miles from the Massachusetts border. Whenever we use coarser fixed effects than store-flavor and store-week fixed effects the relevant interactions between the distance band dummies, flavor, and the time dummy $\mathbb{1}_{\{t>June\,2020\}}$ are included as controls in the regressions. We present the results of these analyses in Table A1. Moving from left to right in Table A1 we include more granular fixed effects. We do observe a treatment effect in the 10 mile area surrounding Massachusetts that shrinks as we move further out, and it becomes statistically indistinguishable from zero after the 30 mile mark.

Table A1: Investigating the spillover treatment intensity of Massachusetts menthol ban on cigarette sales in New England and New York as a function of distance from the Massachusetts border.

| | *Dependent variable:* | | |
|---|---|---|---|
| | log(Total packs + 1) | | |
| | (1) | (2) | (3) |
| less than 10 miles x Post ban x Menthol | 0.172*** | 0.177*** | 0.207*** |
| | (0.028) | (0.028) | (0.023) |
| 10 to 20 miles x Post ban x Menthol | 0.040** | 0.044** | 0.066*** |
| | (0.019) | (0.019) | (0.015) |
| 20 to 30 miles x Post ban x Menthol | 0.011 | 0.014 | 0.029** |
| | (0.015) | (0.015) | (0.013) |
| 30 to 40 miles x Post ban x Menthol | 0.011 | 0.017 | 0.001 |
| | (0.034) | (0.034) | (0.015) |
| 40 to 50 miles x Post ban x Menthol | −0.019 | −0.016 | −0.001 |
| | (0.026) | (0.026) | (0.025) |
| Week FE | | X | |
| Store-Week FE | | | X |
| Observations | 475,365 | 475,365 | 475,365 |
| $R^2$ | 0.939 | 0.941 | 0.988 |
| Adjusted $R^2$ | 0.938 | 0.941 | 0.976 |
| Residual Std. Error | 0.375 (df = 470186) | 0.367 (df = 470084) | 0.233 (df = 234741) |

*Note:* *p<0.1; **p<0.05; ***p<0.01
All regressions include store-flavor FEs and standard errors are clustered at store level.

## D Robustness: synthetic controls

In our analysis in section 4.1, we used a difference-in-differences estimator to evaluate the effect of the Massachusetts menthol ban on Massachusetts and the larger MA+30 area. One might be concerned that the parallel trends assumptions may fail to hold in this case. To relax this assumption, we now use a synthetic controls estimator (Abadie, Diamond, and Hainmueller, 2010) to evaluate the effect of the ban. Following our approach in section 4.1, we perform two sets of analyses: one for Massachusetts, and one for the larger MA+30 region. We rely on permutation tests for inference (Abadie, Diamond, and Hainmueller, 2010). In order to have enough permutations, we aggregate the data at the designated market area (DMA) and week level for regions outside New England and New York, and aggregate the sales for stores in Massachusetts or MA+30 (depending upon the analysis) to one treatment unit.

Ferman and Pinto (2021) and Cao and Dowd (2019) show that if the treatment assignment is confounded with unobservables, then the treatment estimates from synthetic control models could be biased even with a large number of pre-treatment periods. They propose a simple solution for alleviating this bias, which is to demean the outcomes using pre-treatment values. We follow this approach by taking the log sales for menthol and non-menthol cigarettes in each region and demeaning it by its 2019 value. This is akin to difference-in-differences with cross-sectional fixed effects. We then construct a synthetic control unit that matches the outcomes in each region (demeaned log menthol, demeaned non-menthol, and demeaned total cigarette sales) in the pre-treatment periods. The trajectory for the synthetic control and treatment for the Massachusetts and MA+30 regions are plotted in Figures A3-A4, and Table A2 summarizes these results. Our synthetic control estimates are consistent with the difference-in-differences analysis and statistically indistinguishable from those reported in Table 4.

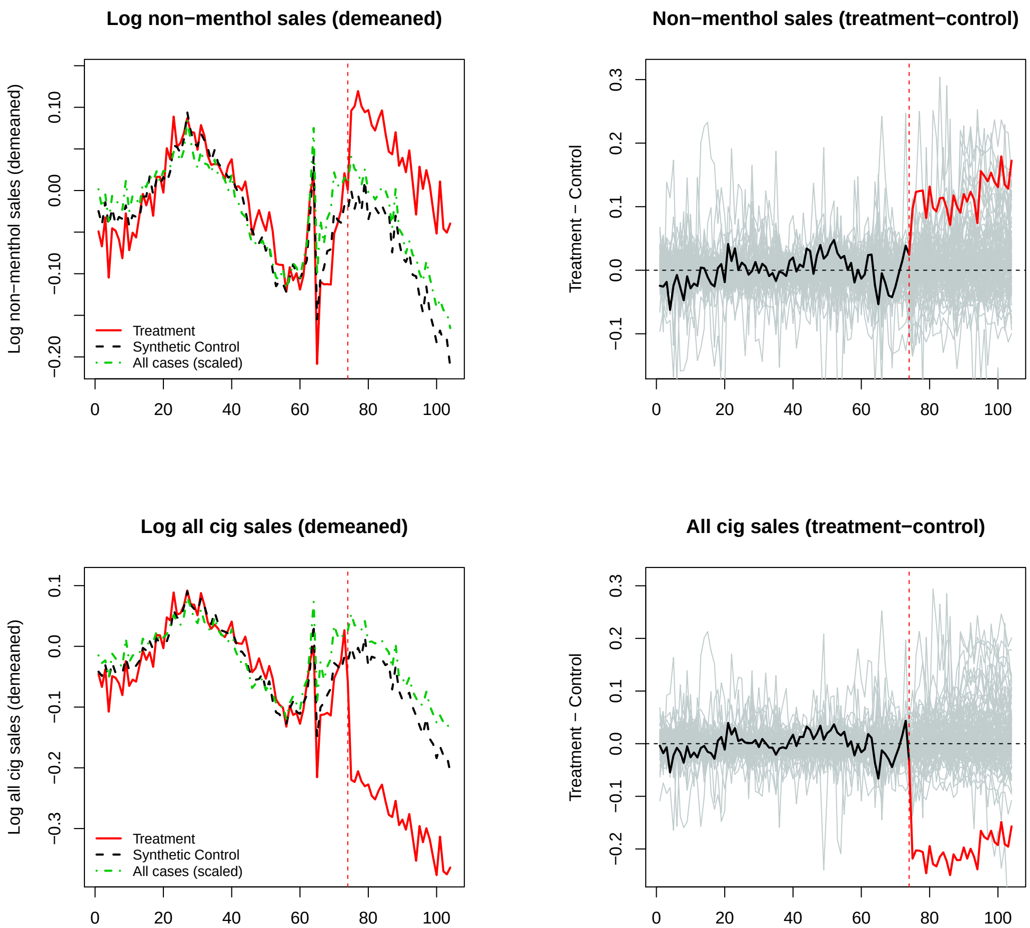



Figure A3: Synthetic control for Massachusetts as treatment and the DMAs outside New York and New England as control units. The synthetic control and treatment for demeaned log sales are plotted on the left panels. The treatment effect estimates along with spaghetti plots for permutations are presented on the right panels.

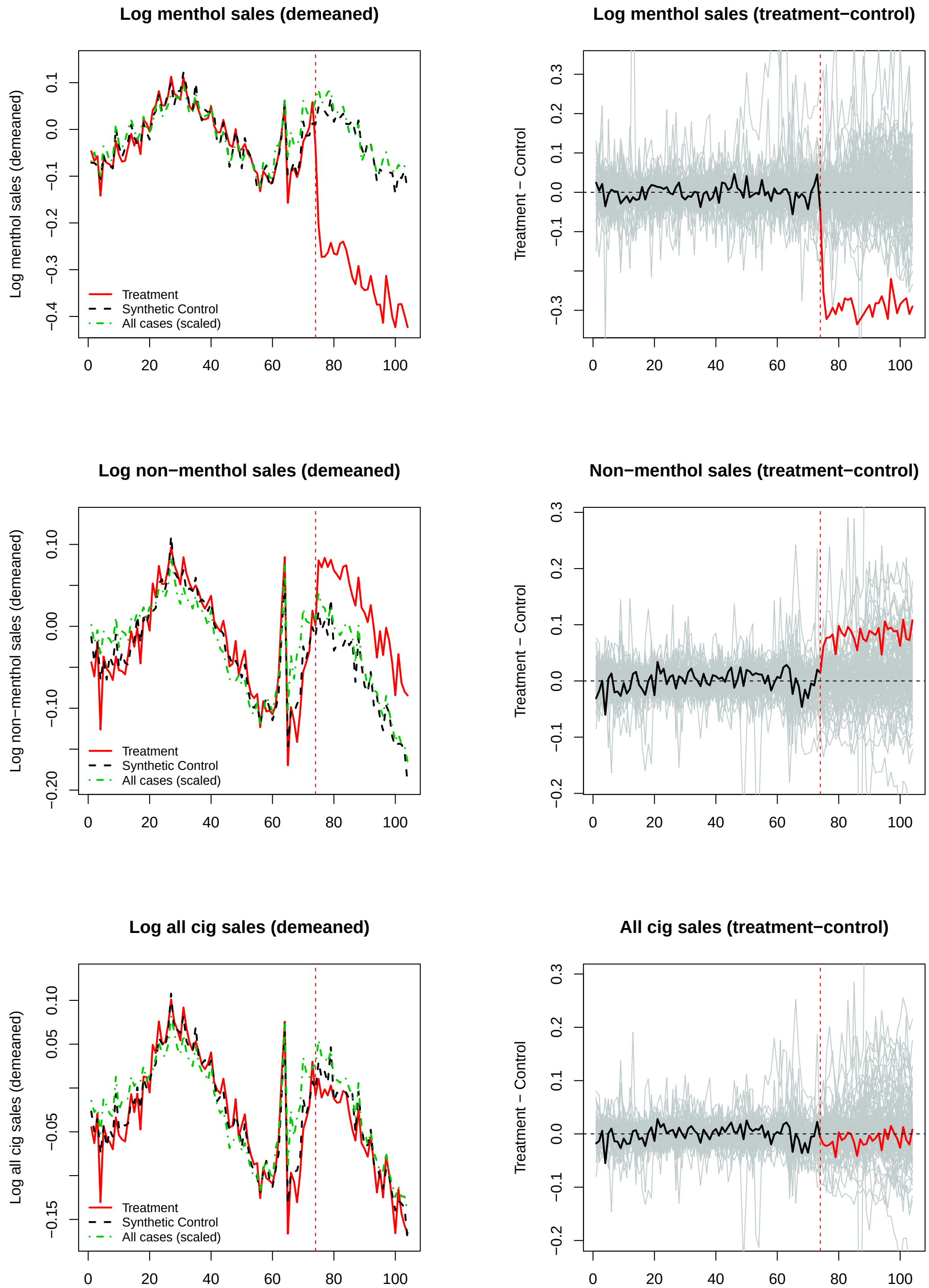



Figure A4: Synthetic control for MA+30 as treatment and the DMAs outside New York and New England as control units. The synthetic control and treatment for demeaned log sales are plotted on the left panels, along with the treatment effect estimates along with spaghetti plots for permutations on the right panels.

Table A2: The summary of the effects of Massachusetts Menthol ban on cigarette sales in MA and the 30 mile surrounding area from synthetic control analysis.

| Variable | Menthol | Non-menthol | All |
|---|---|---|---|
| Share (2019) in Massachusetts | 27.90 | 72.10 | 100.00 |
| Change (%) in sales post ban in MA | -99.08*** | 12.78** | -18.40*** |
| Change (%) in sales post ban in MA+30 | -25.19*** | 8.56* | -1.07 |
| Portion of volume sold (2019) in MA relative to MA+30 | 0.46 | 0.44 | 0.45 |
| Implied change (%) relative to sales that took place in MA | -54.81*** | 19.23* | -2.38 |

*Note:* *p<0.1; **p<0.05; ***p<0.01

All p-values are calculated based on permutation tests.

## E Robustness: linear demand model and store-level data

Since our goal is to evaluate the overall change in consumption of cigarettes in Massachusetts and its neighboring areas, our analysis in section 4.1 aggregates the data to the state level. In this appendix, we now replicate our analysis from section 4.1 using store-level data. Using store-level data here requires a trade-off: the benefit is that it yields more observations for our regression, but the downside is that it also adds noise to our analysis because individual stores may have idiosyncratic factors that affect consumers' purchasing decisions.

Since our goal is to understand the overall change in consumption, we need to aggregate the results from our store-level regression to Massachusetts or the greater MA+30 region. One option would be to estimate a log-log demand model for each store and then aggregate these results; however, this would create aggregation bias from aggregating non-linear demand models.[24] To avoid this aggregation bias issue, we instead use a linear demand model at the store level for cigarette sales. We consider the following difference-in-differences specification:

$$\begin{aligned} Q_{st} =& \alpha \cdot \mathbb{1}_{\{s \in \text{MA}\}} \cdot \mathbb{1}_{\{t \geq \text{June 1, 2020}\}} + \gamma \cdot \mathbb{1}_{\{s \in \text{MA}\}} + \\ & \delta \cdot \mathbb{1}_{\{t \geq \text{June 1, 2020}\}} + \beta \cdot P_{st} + \eta_s + \eta_t + \epsilon_{st} \end{aligned} \tag{A2}$$

where $s$ and $t$ index store and week, respectively. $Q_{st}$ is the outcome of interest, which is the number of cigarette packs sold in store $s$ during week $t$ in our analyses.

We run this regression twice: once for non-menthol cigarette sales, and once for total cigarette sales.[25] Table A3 reports the estimates from equation (A2). The results in columns (1) and (4) report the difference-in-differences estimates without fixed effects or price controls. The average number of non-menthol cigarette packs sold in that analysis is 601, and on-average stores in Massachusetts sold 43.41 fewer non-menthol packs than those in other states. Our full specification with price controls and store/week fixed effects are presented in columns (3) and (6). We find that the sales of non-menthol cigarettes in Massachusetts increase by 53.88 packs on average, which can be converted to percentages as follows:

$$\% \text{ change in demand in MA} = \frac{\text{change in number of packs sold}}{\text{baseline sales in MA (in packs)}} = \frac{53.88}{601.04 - 43.41} = 9.66\%.$$

[24]See Seiler, Tuchman, and Yao (2021) for a similar application of linear demand models for evaluating the effect of Philadelphia's sugar tax, and Allenby and Rossi (1991) for a discussion on bias that could arise due to linear aggregation of non-linear models.

[25]Our regressions also include store-level weights to account for the fact that we do not observe all stores within each state, as described in section B of the online appendix.

Table A3: The impact of the Massachusetts menthol ban on non-menthol and overall cigarette sales in Massachusetts' stores relative to those outside New England and New York.

| | *Dependent variable:* | | | | | |
|---|---|---|---|---|---|---|
| | Non-menthol packs | | | Total packs | | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| MA x Post June 2020 ($\alpha$) | 55.786*** | 53.272*** | 53.880*** | −159.050*** | −162.319*** | −161.869*** |
| | (7.165) | (7.162) | (7.160) | (12.633) | (12.604) | (12.607) |
| MA ($\gamma$) | −43.408 | | | −54.061 | | |
| | (26.915) | | | (38.418) | | |
| Post June 2020 ($\delta$) | −20.782*** | −8.429*** | | −18.306*** | −2.245 | |
| | (0.775) | (1.061) | | (1.383) | (1.682) | |
| Non-menthol price index ($\beta$) | | −39.269*** | −29.775*** | | −51.052*** | −44.036*** |
| | | (2.490) | (2.388) | | (3.263) | (3.563) |
| Constant | 601.043*** | | | 825.918*** | | |
| | (4.511) | | | (6.086) | | |
| Store FE | | X | X | | X | X |
| Week FE | | | X | | | X |
| Observations | 3,890,640 | 3,890,640 | 3,890,640 | 3,890,640 | 3,890,640 | 3,890,640 |
| $R^2$ | 0.0001 | 0.972 | 0.973 | 0.0002 | 0.951 | 0.952 |
| Adjusted $R^2$ | 0.0001 | 0.971 | 0.972 | 0.0002 | 0.950 | 0.951 |
| Residual Std. Error | 2,132.053 (df = 3890636) | 361.154 (df = 3853227) | 354.720 (df = 3853125) | 2,949.155 (df = 3890636) | 656.821 (df = 3853227) | 650.310 (df = 3853125) |

*Note:* *p<0.1; **p<0.05; ***p<0.01

Table A4: The effect of the Massachusetts menthol ban on cigarette sales in stores in the agglomerated MA+30 region compared to those outside New England and New York.

| | *Dependent variable:* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Non-menthol packs | | | Menthol packs | | | Total packs | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| (MA + 30) x Post June 2020 ($\alpha$) | 46.171$^{***}$ | 44.727$^{***}$ | 45.076$^{***}$ | −69.533$^{***}$ | −60.110$^{***}$ | −59.436$^{***}$ | −23.362 | −25.224 | −24.962 |
| | (7.568) | (7.565) | (7.563) | (17.570) | (17.939) | (18.016) | (22.342) | (22.352) | (22.350) |
| MA + 30 ($\gamma$) | 81.184$^{**}$ | | | 31.274$^{**}$ | | | 112.458$^{**}$ | | |
| | (39.620) | | | (13.168) | | | (51.829) | | |
| Post June 2020 ($\delta$) | −20.782$^{***}$ | −8.401$^{***}$ | | 2.477$^{***}$ | 6.697$^{***}$ | | −18.306$^{***}$ | −2.339 | |
| | (0.775) | (1.057) | | (0.919) | (1.159) | | (1.383) | (1.674) | |
| Non-menthol price index ($\beta$) | | −39.356$^{***}$ | −29.860$^{***}$ | | −10.622$^{***}$ | −11.382$^{***}$ | | −50.755$^{***}$ | −43.618$^{***}$ |
| | | (2.473) | (2.371) | | (1.703) | (2.083) | | (3.217) | (3.495) |
| Constant | 601.043$^{***}$ | | | 224.875$^{***}$ | | | 825.918$^{***}$ | | |
| | (4.511) | | | (1.838) | | | (6.086) | | |
| Store FE | | X | X | | X | X | | X | X |
| Week FE | | | X | | | X | | | X |
| Observations | 3,954,808 | 3,954,808 | 3,954,808 | 3,954,808 | 3,954,808 | 3,954,808 | 3,954,808 | 3,954,808 | 3,954,808 |
| $R^2$ | 0.0004 | 0.973 | 0.974 | 0.0002 | 0.794 | 0.795 | 0.0002 | 0.951 | 0.952 |
| Adjusted $R^2$ | 0.0004 | 0.973 | 0.974 | 0.0002 | 0.792 | 0.793 | 0.0002 | 0.951 | 0.952 |
| Residual Std. Error | 2,254.468 (df = 3954804) | 373.270 (df = 3916778) | 366.971 (df = 3916676) | 1,090.687 (df = 3954804) | 496.973 (df = 3916778) | 496.101 (df = 3916676) | 3,121.782 (df = 3954804) | 692.621 (df = 3916778) | 686.359 (df = 3916676) |

*Note:* $^{*}$p<0.1; $^{**}$p<0.05; $^{***}$p<0.01

Similar to our analyses in section 4.1, we repeat this exercise by comparing cigarette sales between stores in the MA+30 region and those outside New York and New England. The results of this exercise are reported in A4. We convert all estimates to percentages and report them in Table A5. These results in Table A5 remain consistent with those reported in Table 4 of the paper.

Table A5: The summary of the effects of Massachusetts menthol ban on cigarette sales in MA and the 30 mile surrounding area from store-level data.

| Variable | Menthol | Non-menthol | All |
|---|---|---|---|
| Share (2019) in Massachusetts | 27.90 | 72.10 | 100.00 |
| Change (%) in sales post ban in MA | -94.04*** | 9.66*** | -20.97*** |
| Change (%) in sales post ban in MA+30 | -23.20*** | 6.61*** | -2.66 |
| Portion of volume sold (2019) in MA relative to MA+30 | 0.46 | 0.44 | 0.45 |
| Implied change (%) relative to sales that took place in MA | -50.48*** | 14.85*** | -5.92 |

*Note:* *p<0.1; **p<0.05; ***p<0.01

## F Impact of the Massachusetts menthol ban on cigarette prices

One potential threat to our modeling framework would be if retailers responded to the Massachusetts ban by changing their prices. For instance, if retailers in Massachusetts significantly reduced their prices after the ban or retailers outside the state significantly increased their prices, then this kind of price response would need to be modeled and accounted for in our analysis.

To examine this issue, we estimate a series of difference-in-differences regressions to evaluate whether there were price changes in response to the Massachusetts menthol ban. We consider the following specification:

$$\begin{aligned}\log(P_{st}) = &\alpha \cdot \mathbb{1}_{\{s=\mathcal{S}\}} \cdot \mathbb{1}_{\{t \geq \text{June 1, 2020}\}} + \gamma \cdot \mathbb{1}_{\{s=\mathcal{S}\}} + \\ &\delta \cdot \mathbb{1}_{\{t \geq \text{June 1, 2020}\}} + \eta_s + \eta_t + \epsilon_{st}\end{aligned} \tag{A3}$$

where $s$, and $t$ index region/state, and week, respectively. The rest of the parameters are defined similar to specification (2). We estimate two sets of regressions using this difference-in-differences specification. First, we set $\mathcal{S}$ = Massachusetts as the treatment region and compare the price of non-menthol cigarettes in Massachusetts with states outside New England and New York before and after the menthol ban. These regressions are reported in columns (1)-(3) of Table A6. Second, we calculate a price index for menthol and non-menthol cigarettes in the 30 mile ring around Massachusetts and compare them for states outside New York and New England before and after the ban. These estimates are reported in columns (4)-(9) of Table A6. We find that there were two statistically significant decreases in prices: a decrease in non-menthol prices in Massachusetts as well as a decrease in menthol prices in the 30 mile ring bordering the state.

Although these two coefficient values are statistically significant, they are very small in magnitude. The effect sizes correspond to roughly a 1 percent price reduction. Given these small magnitudes, we conclude that there was no major price response by retailers after the Massachusetts menthol ban was instituted.

Table A6: Change in menthol and non-menthol cigarette prices in Massachusetts and the 30 mile surrounding ring before and after the June 2020 menthol ban relative to states outside New York and New England.

| | *Dependent variable:* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Massachusetts | | | 30 mile ring around Massachusetts | | | | | |
| | Non-menthol price index | | | Non-menthol price index | | | Menthol price index | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Treated region x Post June 2020 ($\alpha$) | $-0.012^{***}$ | $-0.012^{***}$ | $-0.012^{***}$ | 0.001 | 0.001 | 0.001 | $-0.006^{***}$ | $-0.006^{***}$ | $-0.006^{***}$ |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| Treated region ($\gamma$) | $0.402^{***}$ | | | $0.259^{***}$ | | | $0.299^{***}$ | | |
| | (0.026) | | | (0.026) | | | (0.025) | | |
| Post June 2020 ($\delta$) | $0.043^{***}$ | $0.043^{***}$ | | $0.043^{***}$ | $0.043^{***}$ | | $0.052^{***}$ | $0.052^{***}$ | |
| | (0.002) | (0.002) | | (0.002) | (0.002) | | (0.002) | (0.002) | |
| Constant | $-1.156^{***}$ | | | $-1.156^{***}$ | | | $-1.120^{***}$ | | |
| | (0.026) | | | (0.026) | | | (0.025) | | |
| State FE | | X | X | | X | X | | X | X |
| Week FE | | | X | | | X | | | X |
| Observations | 4,264 | 4,264 | 4,264 | 4,264 | 4,264 | 4,264 | 4,264 | 4,264 | 4,264 |
| $R^2$ | 0.136 | 0.981 | 0.994 | 0.070 | 0.979 | 0.994 | 0.097 | 0.973 | 0.993 |
| Adjusted $R^2$ | 0.135 | 0.981 | 0.994 | 0.069 | 0.979 | 0.994 | 0.097 | 0.973 | 0.993 |
| Residual Std. Error | 0.162 (df = 4260) | 0.024 (df = 4221) | 0.014 (df = 4119) | 0.162 (df = 4260) | 0.024 (df = 4221) | 0.014 (df = 4119) | 0.157 (df = 4260) | 0.027 (df = 4221) | 0.014 (df = 4119) |

*Note:* $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

All standard errors are clustered at the state/region level.

## G Measuring the effect of a national ban using a reduced form approach

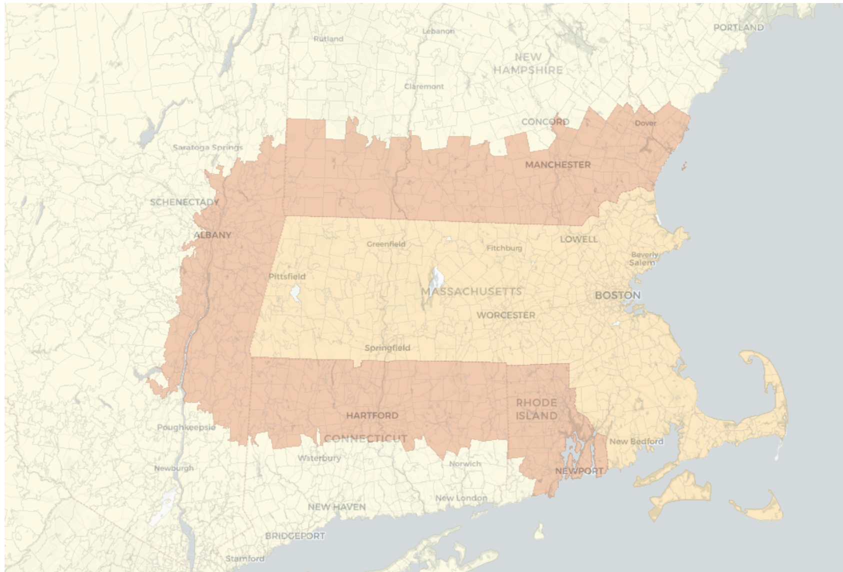
At first glance, one might think that the effect of a national ban can be measured by comparing two regions: parts of the state where people could not travel to purchase cigarettes vs. parts of neighboring states where stores did not receive additional traffic. In our setting, the latter would be represented by areas outside New York and New England as discussed described above. However, defining a region where people could not travel to buy menthols is challenging in our context.

The issue with defining a region that is representative of a national ban is that Massachusetts is a geographically small state, and the vast majority of the state lives a relatively short drive away from the state border. In the Massachusetts data that we examine, people living in "inner" parts of the state are likely still able to purchase menthols from out-of-state. The analysis in section C of the online appendix shows that the spillover effect of Massachusetts menthol ban is limited to a 30 mile radius around state borders. One might argue that this observation shows that smokers are willing to travel at most 30 miles to get menthol cigarettes when they are banned. Therefore, stores within Massachusetts that are located farther than 30 miles from state borders could be used to examine what would happen under a national ban. We perform this hypothetical excercise here and illustrate why this approach is inappropriate and could be misleading.

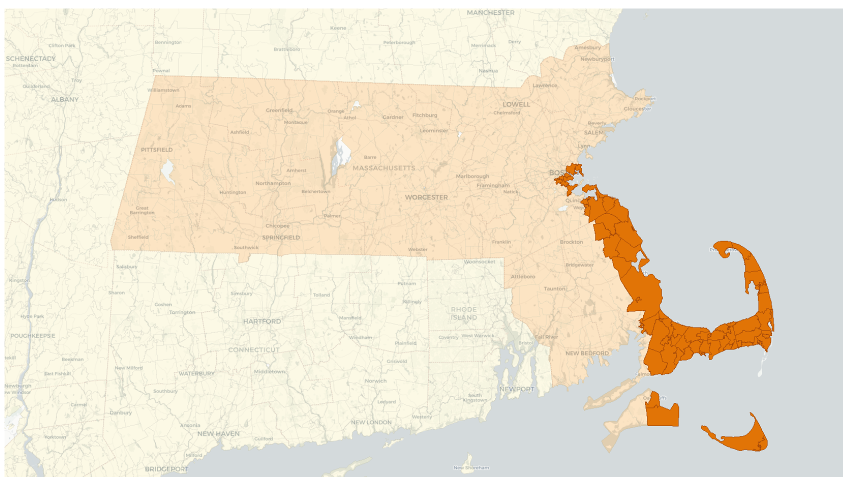
To illustrate that a reduced form approach is not ideal for investigating the effect of a national ban, we partitioned stores into four zones: (i) inner MA stores (farther than 30 miles), (ii) border-neighboring MA stores (within 30 miles of the border), (iii) border-neighboring non-MA stores within 30 miles of the border, (iv) outer non-MA stores (outside New England and New York). Table A7 presents summary statistics on stores located in these zones and Figure A5 illustrates the geographic landmass of zones (i), (ii), and (iii). Below we perform a difference-in-differences analysis between zones (i) and (iv) as a way to measure the effect of a national ban and we discuss its limitations.

Table A7: Summary of store-level variables used in our analyses. The stores are located across four regions: (i) Massachusetts stores farther than 30 miles from the state border, (ii) Massachusetts stores closer than 30 miles from the state border, (iii) non-Massachusetts stores closer than 30 miles from the Massachusetts border, and (iv) stores located outside of New England and New York. Note that stores in groups (i), (ii), and (iii) are affected by Massachusetts' menthol ban, and stores in (iv) serve as the control group.

| Variable | > 30 miles from border inside Massachusetts (i) | 30 mile ring inside Massachusetts (ii) | 30 mile ring around Massachusetts (iii) | Outside New York & New England (iv) |
|---|---|---|---|---|
| Number of stores | 59.00 | 499.00 | 617.00 | 36852.00 |
| Number of weeks | 104.00 | 104.00 | 104.00 | 104.00 |
| Number of flavors | 2.00 | 2.00 | 2.00 | 2.00 |
| Number of store-flavor-weeks | 12272.00 | 103792.00 | 128336.00 | 7665216.00 |
| Share of menthol (%) | 21.02 | 28.88 | 26.73 | 27.02 |
| Avg. pre-tax price (2019) | 9.69 | 9.59 | 8.56 | 6.41 |
| Avg. post-tax price (2019) | 13.20 | 13.10 | 11.75 | 7.80 |
| Avg. # of packs sold per week (2019) | 462.45 | 387.55 | 577.68 | 417.37 |




(a) Massachusetts and the 30 mile surrounding area. The darker shade is the 30 mile surrounding area, i.e., zone (iii).




(b) Massachusetts and areas farther than 30 miles from any border, zone (i), in darker shade. The lighter shade corresponds to areas within 30 miles of the Massachusetts border, i.e., zone (ii).

Figure A5: Massachusetts' outer 30 mile ring, inner 30 mile ring, and areas of Massachusetts farther than 30 miles from state borders.

If we define region (i) as parts of the state that are at least 30 miles from the state border, then we are left only with a small sliver of the state's Eastern and Southeastern coastal region that includes Cape Cod, Nantucket, and Martha's Vineyard (see figure A5b). This area contains only about 10% of the Massachusetts stores in our data, and these stores are also quite different from stores located in the rest of the state. For instance, as Table A7 shows, the share of menthol cigarettes in this area is 21% compared to 29% in the rest of Massachusetts.

We estimate a difference-in-differences specification similar to specification (1) in the manuscript to compare cigarette sales across zones (i) and (iv) before and after the menthol ban. The counterpart of Table 2 for this estimation task is presented in Table A8. Our results show that the overall cigarette sales drop by exp(-0.098) $-$ 1 = -9.3%, which is significantly smaller than the exp(-0.237) $-$ 1 = -21.1% decline in overall cigarette sales that we documented for Massachusetts in Table 2 of the manuscript. The relative magnitude of these two effects is $\frac{21.1}{9.3} = 2.26$. While some of this large gap is due to the fact that stores in region (i) are farther away from the border, part of this difference is simply because of taste differences between smokers located in region (i) vs. Massachusetts overall. Note that the share of menthol cigarettes in region (i) is significantly lower than the share of menthols in Massachusetts (21% versus 28%)[26].

To examine this issue further, we can normalize the overall decline in sales in region (i) and in Massachusetts by the share of menthol cigarettes in these regions. For region (i) this exercise yields $\frac{-9.3\%}{21.02\%} = -44.2\%$. This means that 44.2% of menthol sales in region (i) was not substituted with local non-menthol cigarettes and for Massachusetts this figure is $\frac{-21.1\%}{27.9\%} = -75.2\%$. The relative gap now shrinks to $\frac{75.2}{44.2} = 1.7$ from 2.26. This back-of-the-envelope calculation highlights the fact that a reduced form analysis that is agnostic to differences in tastes across geographic areas could overstate the effect of distance from the borders.

As we discuss in section 4.2, we use a structural model because it can account for three types of heterogeneity that affect the analysis of this policy: (a) heterogeneity in distance from borders, (b) heterogeneity in menthol shares, and (c) heterogeneity in prices across states. Given these geographic issues, our data does not allow us to construct a sizable region of representative stores (considering the three dimensions of heterogeneity) in which consumers do not have the ability to engage in cross-border shopping. We believe that zone (i) is a small portion of Massachusetts and would not be a good stand-in for examining what would happen under a national menthol ban; this also means that it would not be possible to calculate a credible reduced form causal estimate of a national menthol ban. Instead, our structural model is necessary if we wish to comment on the effect of a national ban or any other counterfactual outcome as it factors in all these dimensions of heterogeneity (distance, menthol share, variation in prices across the borders).

Table A8: The impact of the Massachusetts menthol ban on non-menthol and overall cigarette sales in Inner Massachusetts' stores (farther than 30 miles from the border) relative to those outside New England and New York.

| | *Dependent variable:* | | | | | |
|---|---|---|---|---|---|---|
| | log(Non-menthol packs + 1) | | | log(Total packs + 1) | | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Inner MA x Post June 2020 ($\alpha$) | 0.129*** | 0.128*** | 0.131*** | −0.101*** | −0.100*** | −0.098*** |
| | (0.008) | (0.005) | (0.006) | (0.009) | (0.006) | (0.006) |
| Inner MA ($\gamma$) | −1.944*** | | | −1.996*** | | |
| | (0.316) | | | (0.324) | | |
| Post June 2020 ($\delta$) | −0.005 | −0.0002 | | 0.007 | 0.003 | |
| | (0.031) | (0.005) | | (0.033) | (0.006) | |
| Log non-menthol price index ($\beta$) | −0.799 | −0.902*** | −0.499*** | −0.832 | −0.755*** | −0.411*** |
| | (0.710) | (0.101) | (0.105) | (0.737) | (0.093) | (0.106) |
| Constant | 13.846*** | | | 14.105*** | | |
| | (0.824) | | | (0.851) | | |
| State FE | | X | X | | X | X |
| Week FE | | | X | | | X |
| Observations | 4,264 | 4,264 | 4,264 | 4,264 | 4,264 | 4,264 |
| $R^2$ | 0.169 | 0.995 | 0.998 | 0.171 | 0.995 | 0.998 |
| Adjusted $R^2$ | 0.168 | 0.995 | 0.998 | 0.170 | 0.995 | 0.998 |
| Residual Std. Error | 0.820 (df = 4259) | 0.063 (df = 4220) | 0.039 (df = 4118) | 0.860 (df = 4259) | 0.064 (df = 4220) | 0.040 (df = 4118) |

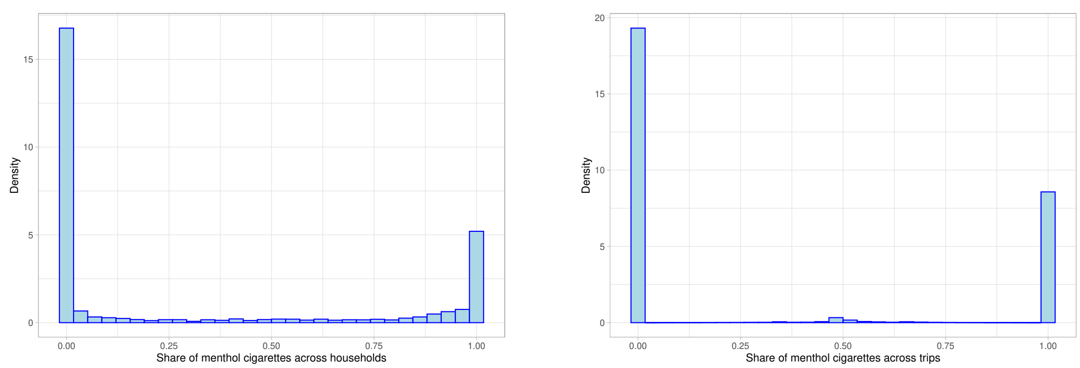
*Note:* *p<0.1; **p<0.05; ***p<0.01
All standard errors are clustered at the state level.

[26] See Table A7 and Table 1 in the manuscript

## H Examining customer trips

### Customer trips: buying menthols and non-menthols

We use the Nielsen HomeScan panel data to analyze the variation of menthol cigarette share among households and the frequency of co-purchase of menthol and non-menthol cigarettes. This analysis focused on households that spent at least $100 on cigarettes during 2018 – 2020. The histogram in Figure A6 presents the distribution of menthol share among households and the proportion of menthol spending across trips made by these households. The portion of households that buy either menthol, non-menthol, or both kinds of cigarettes is presented in Table A9. These patterns show that about 15% of households consume both menthol and non-menthol cigarettes, but the purchases tend to be separate – less than 4% of consumer cigarette shopping trips involve purchasing both types. The rarity of households buying menthols and non-menthols together in the same shopping trip supports our decision to model consumers as buying either menthols or non-menthols in each purchase occasion.




(a) Menthol share across households

(b) Menthol share across trips

Figure A6: The distribution of menthol share across households and trips. Although some households may consume both menthol and non-menthol cigarettes, there are very few shopping trips that involve purchasing both types.

Table A9: The portion of households that buy either menthol, non-menthol, or both kinds of cigarettes. While there are households that may consume both types, the number of shopping trips involving the purchase of both is limited.

| Variable | Both | Only menthol | Only non-menthol |
|---|---|---|---|
| Percentage of households | 14.90 | 23.47 | 61.63 |
| Percentage of trips | 3.77 | 29.59 | 66.64 |

### Customer trips: purchase frequency and stockpiling in Massachusetts

The menthol ban may have affected the frequency with which consumers make cigarette purchases. To examine this issue, we filter the data to examine households that met the following conditions: they are located in Massachusetts, they are active during the period of 2019-2020, and they have spent at least $100 on cigarettes prior to June 2020. Of these households, those that had a share of menthols exceeding 50 percent were designated as menthol households. This process resulted in a total of 41 households, with only 13 being classified as menthol households. In order to assess the impact on trips, we aggregated the monthly trip counts for each household and estimated the following difference-in-differences model:

$$\mathbf{Y}_{ht} = \alpha \cdot \mathbb{1}_{\{t>June2020\}} \cdot \mathbb{1}_{\{h\in\text{menthol}\}} + \delta \cdot \mathbb{1}_{t>June2020} + \gamma \cdot \mathbb{1}_{h\in\text{menthol}} + \eta_h + \eta_t, \tag{A4}$$

where $h$, and $t$ index households and months, respectively.

We define a "tobacco trip" as a household shopping trip in which they buy cigarettes. The variable $\mathbf{Y}_{ht}$ represents either the logarithm of tobacco trips plus one or simply the number of tobacco trips per month for household $h$ during month $t$ (we show results for both specifications). Furthermore, the fixed effects for households and months are represented by $\eta_h$ and $\eta_t$, respectively. The results of this analysis are presented in Table A10, and show a marginally significant decline ($P < 0.1$) in trips that involve tobacco purchases for households who buy menthols. This result suggests that households might be taking fewer trips to buy cigarettes, although our lack of statistical power does not allow us to make strong conclusions.

Table A10: Change in the frequency of trips that involve buying tobacco for households in Massachusetts who buy menthols compared to other smokers after Massachusetts menthol ban.

| | *Dependent variable:* | | | | | |
|---|---|---|---|---|---|---|
| | Tobacco trips | | | log(1 + Tobacco trips) | | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Menthol household × Post June 2020 | −1.035* | −1.035* | −1.035* | −0.317* | −0.317* | −0.317* |
| | (0.598) | (0.598) | (0.597) | (0.171) | (0.171) | (0.171) |
| Post June 2020 | −0.151 | −0.151 | | −0.052 | −0.052 | |
| | (0.384) | (0.384) | | (0.110) | (0.110) | |
| Menthol household | 0.530 | | | 0.230 | | |
| | (0.606) | | | (0.165) | | |
| Constant | 1.722*** | | | 0.691*** | | |
| | (0.375) | | | (0.098) | | |
| Household FE | | X | X | | X | X |
| Month FE | | | X | | | X |
| Observations | 1,025 | 1,025 | 1,025 | 1,025 | 1,025 | 1,025 |
| $R^2$ | 0.016 | 0.418 | 0.449 | 0.026 | 0.436 | 0.469 |
| Adjusted $R^2$ | 0.013 | 0.393 | 0.412 | 0.023 | 0.411 | 0.433 |
| Residual Std. Error | 2.537 (df = 1021) | 1.990 (df = 982) | 1.959 (df = 959) | 0.712 (df = 1021) | 0.553 (df = 982) | 0.543 (df = 959) |

*Note:* *p<0.1; **p<0.05; ***p<0.01
All standard errors are clustered at the household level.

## I Examining county-level heterogeneity

The descriptive evidence in the paper shows that after the Massachusetts menthol ban was enforced, there was a big increase in menthol cigarette sales in the 30-mile ring outside the state (see Figure 3). We interpret this as evidence of cross-border shopping among Massachusetts residents. In this section, we examine more granular county-level changes rather than evaluating the entire 30-mile ring as a whole.

### Counties outside Massachusetts

First, we examine whether different counties outside Massachusetts experiences different levels of a sales bump after the Massachusetts menthol ban was implemented. Our approach consists of the following steps:

1. We identify the set of counties in our data that share a border with Massachusetts and also had 10 or more stores selling cigarettes during the 2019-2020 period in our data.
2. For counties that share a border with Massachusetts but had fewer than 10 stores selling cigarettes, we merge them with an adjacent county in the same state that was also neighboring Massachusetts. This results in the merging of Columbia and Rensselaer counties in New York, Bennington and Windham counties in Vermont, and Bristol and Newport counties in Rhode Island.
3. We use the set of stores in each of these geographic areas as the treatment group and all stores from the same retail chains located farther than 50 miles from Massachusetts as the control group.
4. We use synthetic difference-in-differences (SDID; Arkhangelsky et al. (2021)) to measure the lift in the number of menthol cigarette packs sold after the Massachusetts menthol ban went into effect. This process is performed for each neighboring county (geographic area) separately, and we divide the estimates by the average number of menthol cigarette packs purchased at stores in that county to measure the increase in percentage terms.
5. We use these percentage increase values to create the heatmap presented in Figure A7.

Our main analysis in the paper shows that the highest increase in menthol cigarette sales was in counties in New Hampshire, likely due to lower taxes and tobacco prices (see Figure 7). That finding is echoed in the county-level heatmap in Figure A7 as well. Furthermore, we find that as we move eastward within New Hampshire and closer to the heavily-populated Greater Boston area, the lift becomes even larger. Among the other neighboring states, the eastern regions of Rhode Island saw the largest increase due to their proximity to densely populated areas in eastern Massachusetts.

### Counties in Massachusetts

We now examine whether different counties in Massachusetts experience different levels of a sales drop after the Massachusetts menthol ban was implemented. We conduct this analysis using a similar procedure as outlined above. To ensure that each geographic area has at least 10 stores, we combine Dukes and Nantucket counties (containing Martha's Vineyard and other islands near the coast of Cape Cod) with nearby Barnstable county (which includes Cape Cod). We then repeat the SDID analysis and present the change in overall cigarette sales by county in Figure A8. This figure displays the decrease in overall cigarette sales across various counties in Massachusetts. However,

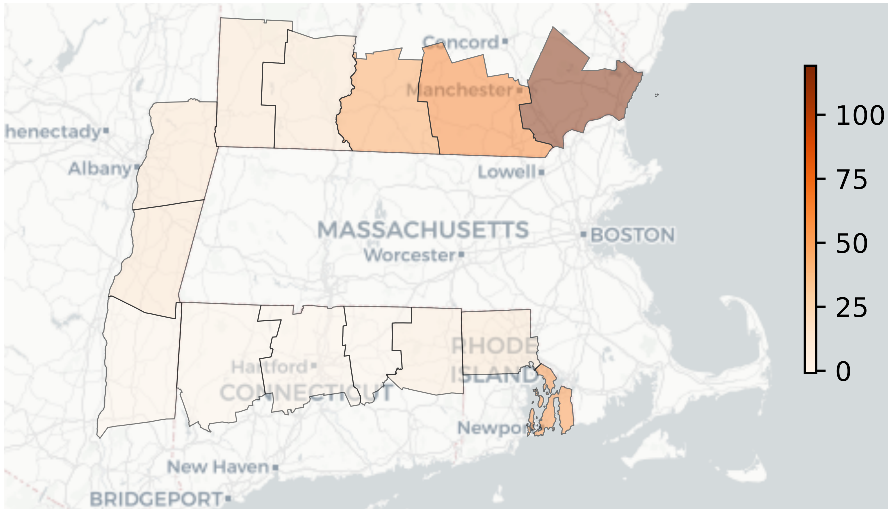



Figure A7: County-level increases in menthol cigarette sales after the Massachusetts menthol ban was enforced. Values are in percentage terms and are shown for counties neighboring Massachusetts.

interpreting Figure A8 is challenging because there are multiple factors that contribute to the differences we see across counties:

1. The proportion of menthol sales (vs. cigarette sales as a whole) varies across counties. We expect counties with high menthol sales in 2019 should see a larger decrease in total cigarette sales after the menthol ban.

2. Households' average distance from the state border varies across counties, and this serves as a measurement of how stringently the ban was felt in that area. People living farther from state borders should be more likely to switch to non-menthol cigarettes sold within the state after the menthol ban was implemented.

3. The prices available across the border vary across counties. Counties that are near the New Hampshire border have cheap cigarettes nearby, relative to counties that are near the New York border. Being close to low-priced cigarette options should increase the likelihood of substituting in-state menthol sales with out-of-state menthols after the Massachusetts menthol ban was implemented.

4. The level of customer loyalty (preference strength) to menthol cigarettes may vary across counties. Even if counties A and B have similar proportions of menthol sales, menthol smokers in county A might have a stronger preference for the product vs. menthol smokers in county B, in the sense that they would be willing to travel further and pay more money for it after the ban was implemented.

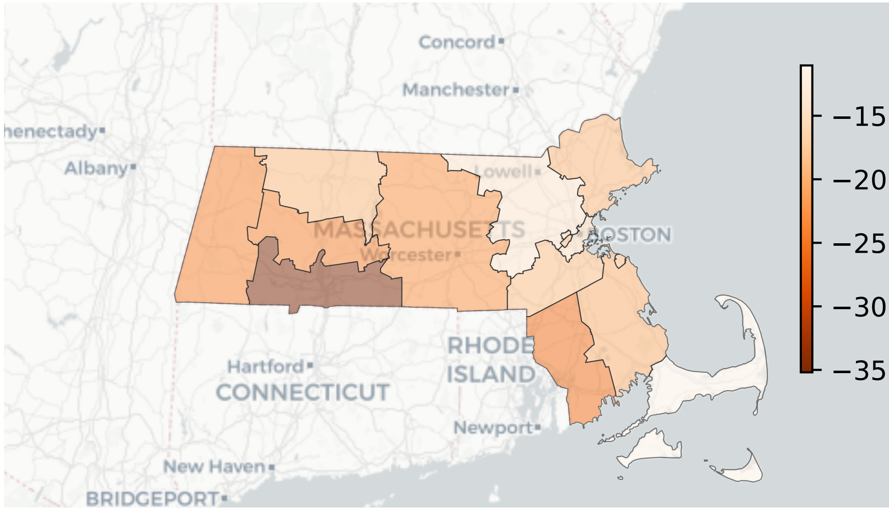



Figure A8: County-level reductions in total cigarette sales after the Massachusetts menthol ban was enforced. Values are in percentage terms and are shown for counties in Massachusetts.

To help clarify some of these issues, we now perform a similar analysis on non-menthol cigarette sales in order to measure the rise in non-menthol sales. This captures county-level differences in terms of their substitution to non-menthol cigarettes. We present the results in Figure A9. Combining the insights from Figures A8-A9 reveals interesting patterns in the data.

For example, we can examine Essex county, which is in the northeast corner of Massachusetts and shares a border with New Hampshire. Figure A8 shows us that overall cigarette sales in Essex county decreased by 19.3%. While this decrease may be smaller compared to other non-border counties, there was only a slight increase in non-menthol sales in Essex county (see Figure A9). This suggests that substituting in-state menthol cigarettes for out-of-state menthol cigarettes was less costly in this area. While combining Figure A9 with Figure A8 provides a more complete picture, it still fails to account for other cross-sectional differences such as loyalty to the category. These complexities demonstrate the need for a structural model that considers factors such as sales and substitution to different flavors, distances from state borders, and proximity to states with low tobacco prices.

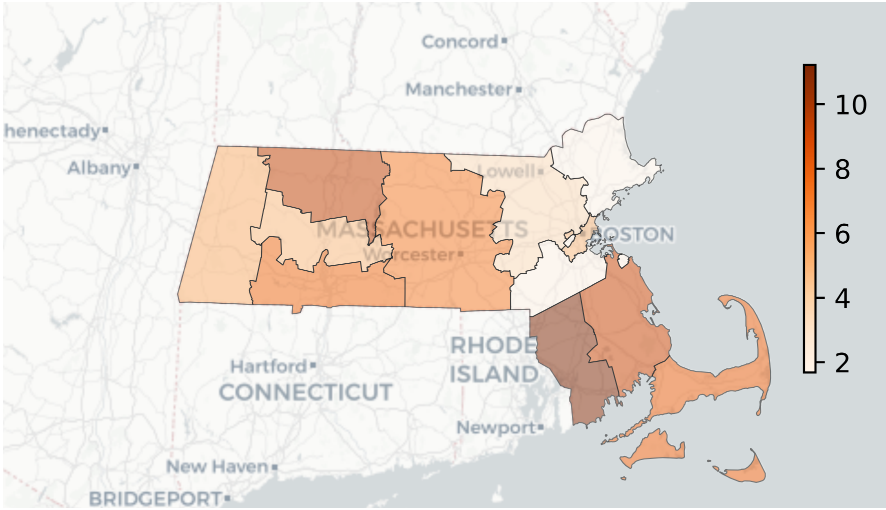



Figure A9: County-level increases in non-menthol cigarette sales after the Massachusetts menthol ban was enforced. Values are in percentage terms and are shown for counties in Massachusetts.

## J Robustness: heterogeneity in travel cost and price sensitivity parameters

In our main structural model, there is one travel cost parameter $\lambda$ and one price coefficient $\beta$. This may lead to concerns that our model is not fully capturing consumer preferences by forcing these parameters to be homogeneous.

To examine this concern, we modified the structural model to allow for heterogeneity in travel cost and price sensitivity using the following structure:

$$\beta, \gamma \sim \text{- log-normal} \left( \begin{bmatrix} \mu_\beta \\ \mu_\gamma \end{bmatrix}, \Gamma^T \Gamma \right), \text{where} \quad \Gamma = \begin{bmatrix} \Gamma_{11} & \Gamma_{12} \\ 0 & \Gamma_{22} \end{bmatrix}. \tag{A5}$$

We estimated this updated model and repeated the Massachusetts menthol ban counterfactual exercise from section 4.3. We find that the inclusion of this additional heterogeneity has a minimal effect on the structural model's predictions. The results of this analysis are presented in Table A11, and they are consistent with the counterfactual findings generated by the model that did not allow for heterogeneity, as reported in Table 7 of the paper.

Table A11: Comparing the effects of a state-specific Massachusetts menthol ban vs. a hypothetical national menthol ban, using the model that allows for heterogeneity in travel cost and price sensitivity. Values correspond to the percentage change in sales (packs sold) under two different policy scenarios, relative to the pre-ban status quo.

| | | Percentage change in sales | | |
|---|---|---|---|---|
| Scenario | Product | In-state | Out-of-state | All |
| Massachusetts ban | Menthol | -100 | 212.08 | -48.16 |
| | Non-menthol | 5.06 | 33.22 | 9.76 |
| | All | -24.81 | 83.94 | -6.7 |
| National ban | Menthol | -100 | -100 | -100 |
| | Non-menthol | 24.73 | 28.61 | 25.38 |
| | All | -10.74 | -7.86 | -10.26 |

## K Robustness: relaxing the aggregate constraints

When estimating the structural model, the available data for analysis only consists of aggregated purchases at the store level within Massachusetts. We do not directly observe the amount of sales from a particular store that may have shifted to other states after the menthol ban was implemented. However, the model can estimate the extent of substitution to out-of-state options at an aggregate level through the restrictions imposed in equation (5). Incorporating these constraints is critical because we can estimate the quantity of demand shifted to out-of-state options at the aggregate level using our reduced-form models, even though we cannot observe it at the individual store level. These constraints help calibrate the parameters of the structural model.

To demonstrate the importance of the constraints, we re-estimated model (5) without the constraints derived from the reduced-form model. In particular, we estimated the following model:

$$\begin{aligned} \underset{\eta_s,\eta_j,\eta_{w_t},\theta_{ik},\gamma,\beta,\lambda}{\text{minimize}} \quad & \sum_{j,k,t,s=\text{MA}} \|S_{jkst} - \hat{S}_{jkst}\|^2 \\ \text{subject to:} \quad & \frac{\sum_{jkst}\left(\hat{S}_{jkst} \cdot \mathbb{1}_{\{t=2019\}} \cdot \mathbb{1}_{\{s\in MA\}}\right)}{\sum_{jkst}\left(\hat{S}_{jkst} \cdot \mathbb{1}_{\{t=2019\}}\right)} = 0.8339, \end{aligned} \tag{A6}$$

where the remaining constraint calibrates the out-of-state purchase rate in the pre-ban period by comparing CDC tobacco consumption and state tobacco tax data, as explained in section 4.2.2 of the paper. Note that we removed the constraints that calibrate the model on the extent of substitution to out-of-state options after the ban goes into effect.

We estimated model A6 and repeated the counterfactual exercise of evaluating the effect of a national versus state-wide ban. We report the results of this analysis in Table A12. Interestingly, the results show a large substitution to out-of-state menthols, and some substitution to in-state non-menthols (even without imposing these constraints). However, without the constraints, the model overestimates the extent of consumers' loyalty towards menthols and their preference for local options. As a result, the estimated spillover to out-of-state non-menthols that we observed in the reduced form analysis is not produced by the unconstrained structural model, and the overall effect of the ban is also underestimated. Including the constraints helps the model better calibrate substitution patterns to menthol/non-menthol choices and in/out-of-state options.

Table A12: Comparing the effects of a state-specific Massachusetts menthol ban vs. a hypothetical national menthol ban, using a model without post-ban constraints (reduced-form constraints). Values correspond to the percentage change in sales (packs sold) under two different policy scenarios, relative to the pre-ban status quo.

| | | Percentage change in sales | | |
|---|---|---|---|---|
| Scenario | Product | In-state | Out-of-state | All |
| Massachusetts ban | Menthol | -100 | 286.38 | -36.46 |
| | Non-Menthol | 15.84 | 0.52 | 13.28 |
| | All | -18.94 | 85.34 | -1.62 |
| National ban | Menthol | -100 | -100 | -100 |
| | Non-menthol | 37.14 | 38.65 | 37.39 |
| | All | -4.04 | -2.49 | -3.78 |

## L Robustness: timing of menthol availability and price response

In Figure 8 of the paper, we find that there are small differences in cigarette sales that start to emerge between stores close to the New Hampshire border vs. stores far from the New Hampshire border before the ban was officially enforced on June 1, 2020.

To examine this issue more closely, we investigate whether retailers differ in terms of when they stop selling menthols. For each store in our sample, we found the last date they sold menthol cigarettes. We then plot the empirical cumulative distribution function (CDF) of this date for stores close to-NH and far-from NH in Figure A10. As the figure demonstrates, stores closer to New Hampshire stopped selling menthols slightly before stores that are farther away.

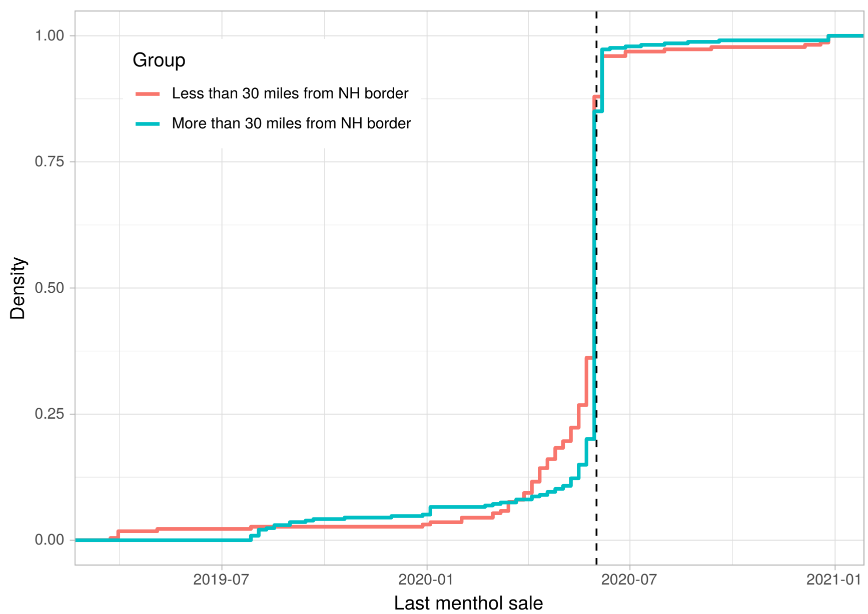



Figure A10: The empirical cumulative distribution function (CDF) of the final date when menthol cigarettes were sold in stores across Massachusetts, grouped based on proximity to New Hampshire. The results reveal that a greater proportion of stores located closer to New Hampshire (as indicated by the red line) ceased selling tobacco products prior to the deadline in June 2020.

These small differences in when retailers stop selling menthols may be caused by forward-planning behavior by retailers that wanted to avoid having menthol cigarettes that they could not legally sell after the ban officially went into place. For instance, imagine a retailer that usually receives a wholesale shipment of menthol cigarettes on the 20th of every month. That retailer may choose to cancel their May 20 menthol shipment, because they know that they would not be able to sell all that new inventory before the ban was enforced on June 1. This kind of forward-planning behavior is enabled by the fact that the menthol ban was signed into law in November 2019, so retailers had over six months to plan for it.

To further investigate these patterns, we divide the stores into two groups based on their retail format: grocery stores and non-grocery stores. The non-grocery store group includes gas stations, convenience stores, and smaller stores, which might be more reliant on tobacco sales to attract foot traffic. The empirical CDF of the final week of menthol cigarette sales for both grocery and non-grocery stores is shown in Figure A11. There is a notable wider range in the timing of the last week of sales for grocery stores compared to non-grocery stores (Figure A11a versus Figure A11b). Importantly, we do not observe a significant variation in the timing of the final week of menthol sales for non-grocery stores, most of which continue to sell menthol cigarettes until the ban is enforced. However, grocery stores show a wider variation, which is consistent with the fact that (a) grocery stores typically keep smaller tobacco inventories due to lower tobacco sales volume compared to other stores like convenience stores, and (b) cigarettes are not considered to be a significant driver of foot traffic for grocery stores, so early adoption of the ban is not expected to substantially affect their customer inflow. Given the relatively consistent timing of the last week of menthol sales across non-grocery outlets, we do not find evidence to support the hypothesis that stores are systematically changing their menthol sales strategies based on their proximity to New Hampshire.

Above we illustrate that stores farther away and closer to New Hampshire do not seem to strategically end menthol cigarette sales and dispersion mainly stems from grocery stores. Nonetheless, it is conceivable that stores could strategically change their prices as a function of distance to the New Hampshire border. To investigate this we consider the following differences-in-differences model:

$$\begin{aligned}\log(P_{it}) =& \alpha \cdot \mathbb{1}_{\{i \in \mathcal{T}\}} \cdot \mathbb{1}_{\{t \geq \text{June 1, 2020}\}} + \gamma \cdot \mathbb{1}_{\{i \in \mathcal{T}\}} + \\ & \delta \cdot \mathbb{1}_{\{t \geq \text{June 1, 2020}\}} + \eta_i + \eta_{r_i t} + \epsilon_{it},\end{aligned} \tag{A7}$$

where $i$ and $t$ serve as indices for the store and week, respectively. $\mathcal{T}$ denotes the set of stores within a 30-mile distance from New Hampshire. Additionally, $\eta_i$ and $\eta_{r_i t}$ are store and retailer-week fixed effects, respectively. The estimates from equation (A7) are displayed in Table A13.

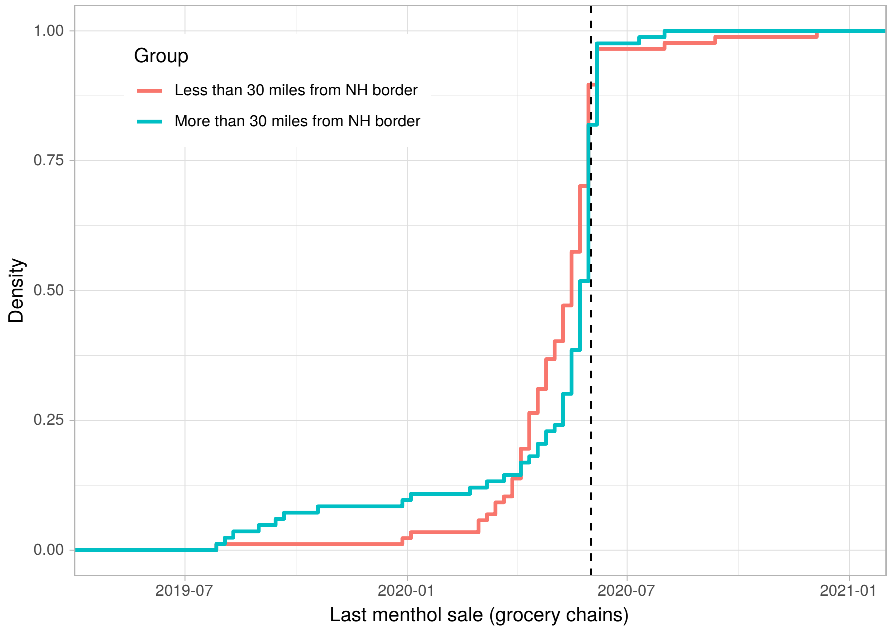
We progressively include more granular fixed effects as we move from column (1) to (3). Across all model specifications, the coefficient $\alpha$ remains statistically insignificant. These results suggest that there was no observable strategic pricing behavior by stores closer to the New Hampshire border when compared to those located farther away.

Table A13: Difference-in-differences analysis of the changes in non-menthol cigarette prices in Massachusetts. The analysis focuses on comparing stores within a 30-mile radius of the New Hampshire border (treatment) against those located more than 30 miles away from the border (control), both before and after the implementation of the menthol ban.

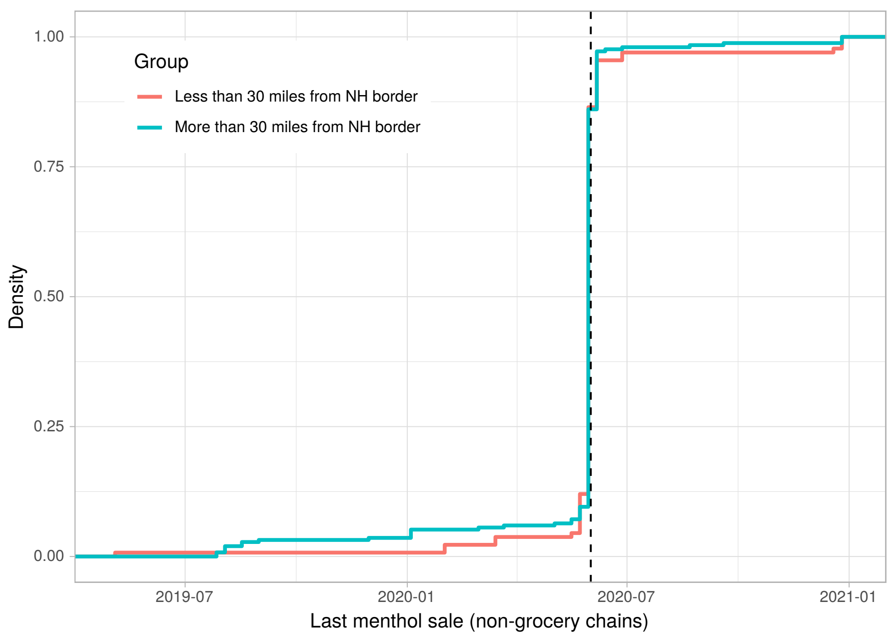
| | *Dependent variable:* | | |
|---|---|---|---|
| | Non-menthol price index | | |
| | (1) | (2) | (3) |
| Within 30 miles of NH X Post June 2020 ($\alpha$) | 0.001 | 0.001 | 0.002 |
| | (0.002) | (0.002) | (0.002) |
| Within 30 miles of NH ($\gamma$) | 0.027*** | | |
| | (0.006) | | |
| Post June 2020 ($\delta$) | 0.025*** | 0.025*** | |
| | (0.001) | (0.001) | |
| Constant | −0.717*** | | |
| | (0.004) | | |
| Store FE | | X | X |
| Retailer-Week FE | | | X |
| Observations | 58,032 | 58,032 | 58,032 |
| $R^2$ | 0.055 | 0.906 | 0.976 |
| Adjusted $R^2$ | 0.055 | 0.905 | 0.975 |
| Residual Std. Error | 0.073 (df = 58028) | 0.023 (df = 57472) | 0.012 (df = 55928) |

*Note:* *p<0.1; **p<0.05; ***p<0.01

All standard errors are clustered at the store level.




(a)




(b)

Figure A11: The empirical cumulative distribution function (CDF) of the final date of menthol cigarette sales in grocery and non-grocery stores in Massachusetts, categorized based on their distance from New Hampshire. The findings show a wider variation in the timing of stopping menthol cigarette sales ahead of the June 2020 deadline for grocery stores, whereas most non-grocery stores maintained menthol cigarette sales until the June 2020 cutoff.

## References

Abadie, A., Diamond, A., and Hainmueller, J. (2010). Synthetic control methods for comparative case studies: Estimating the effect of California's tobacco control program. *Journal of the American statistical Association* 105 (490): 493–505.

Allenby, G. M. and Rossi, P. E. (1991). There is no aggregation bias: Why macro logit models work. *Journal of Business & Economic Statistics* 9 (1): 1–14.

Arkhangelsky, D., Athey, S., Hirshberg, D. A., Imbens, G. W., and Wager, S. (2021). Synthetic difference-in-differences. *American Economic Review* 111 (12): 4088–4118.

Boesen, U., Nesbit, T., and LaFaive, M. D. (2021). America's Illicit Smokes Market Set to Get Larger. URL: `https://www.mackinac.org/americas-illicit-smokes-market-set-to-get-larger` (visited on 06/28/2022).

Bureau, U. S. C. (2021). 2019 State & Local Government Finance Historical Datasets and Tables. URL: `https://www.census.gov/data/datasets/2019/econ/local/public-use-datasets.html` (visited on 06/23/2022).

Cao, J. and Dowd, C. (2019). Estimation and inference for synthetic control methods with spillover effects. *arXiv preprint arXiv:1902.07343*.

Ferman, B. and Pinto, C. (2021). Synthetic controls with imperfect pretreatment fit. *Quantitative Economics* 12 (4): 1197–1221.

LaFaive, M., Nesbit, T., and Drenkard, S. (2016). Cigarette Taxes and Smuggling: A 2016 Update. Midland, MI: Mackinac Center for Public Policy. URL: `https://www.mackinac.org/archives/2016/s2016-09.pdf` (visited on 06/28/2022).

Rich, J. J. (2022). Estimates of Cross-Border Menthol Cigarette Sales Following the Comprehensive Tobacco Flavor Ban in Massachusetts. *medRxiv*. DOI: `10.1101/2022.04.24.22274236`. eprint: `https://www.medrxiv.org/content/early/2022/04/27/2022.04.24.22274236.full.pdf`. URL: `https://www.medrxiv.org/content/early/2022/04/27/2022.04.24.22274236`.

Seiler, S., Tuchman, A., and Yao, S. (2021). The impact of soda taxes: Pass-through, tax avoidance, and nutritional effects. *Journal of Marketing Research* 58 (1): 22–49.