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Effect of a minimum floor price law for tobacco products on tobacco sales in Oakland, California, USA: a synthetic difference-in-differences analysis

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ABSTRACT

Background In May 2020, Oakland became the most populous city in California to implement a minimum floor price law (MFPL), requiring tobacco retailers to sell cigarettes and cigars at \$8 or more per pack/package. Policy enforcement began in August 2020.

Methods We estimated changes in cigarette and cigar prices and unit sales for Oakland versus a matched comparator during the first 20 months following MFPL implementation using a synthetic difference-in-differences approach. We estimated outcome changes overall and by lower-priced (<\$8) versus higher-priced (≥\$8) segments based on pre-MFPL prices. We also assessed retailer compliance with the MFPL. We further estimated cross-border shopping as a means of price increase avoidance and substitution to electronic nicotine delivery systems (ENDS) and nicotine replacement therapy (NRT) products as alternative consumer responses to the MFPL.

Results Retailer compliance was high for cigarettes (97.5%) but extremely low for cigars (7.4%). Lower-priced cigarettes in Oakland exhibited: increased median price per pack of 9.0%, a decline in mean monthly sales of 25.2%, and no evidence of significant cross-border shopping (−1.2%) following MFPL enforcement. Lower-priced cigars in Oakland experienced no price change, yet a large sales decline post-enforcement (−58.8%), with a partially-offsetting increase in cross-border shopping (11.0%) post-enforcement. We observed no significant product substitution to higher-priced cigarettes or cigars nor to ENDS or NRT products.

Conclusions Oakland's MFPL produced an aggregate decline in cigarette sales of 15%. MFPLs hold promise as a complement to tobacco taxation for reducing tobacco use, especially in localities that pre-empt local tobacco taxation.

INTRODUCTION

The use of minimum floor price laws (MFPLs) to establish a retail price below which tobacco products cannot be sold is a relatively new strategy for tobacco control policy in the USA. Pioneered by New York City in 2013,^{1,2} MFPLs for tobacco products have been implemented in local jurisdictions across nine counties in California. Oakland, the most populous city in California to have an MFPL, implemented it for tobacco products in May 2020, informed by projections that the policy would increase prices and reduce the use of targeted tobacco products.³ Enforcement of the MFPL began in August 2020. The ordinance requires that cigarettes, cigars (single or package), little cigars

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Three retrospective studies have been conducted on the impacts of local minimum floor price laws (MPFLs): one focused on cigars in Boston, one on cigars in three cities in Minnesota, and one focused on cigarettes in New York City.
- ⇒ Several additional studies have modelled the projected impact of state or federal MFPLs.

WHAT THIS STUDY ADDS

- ⇒ Oakland's MFPL resulted in reduced sales of cigarettes that were below the floor price prior to MFPL implementation and resulted in an overall decline in cigarette sales, after factoring in cross-border shopping and product substitution.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ Our research shows that local MFPLs can be effective at reducing tobacco sales. Local jurisdictions should consider adopting a local MFPL as a complementary regulation to tobacco excise taxation.

and cigarillos not be sold at a retail price, including taxes and fees, below \$8 per pack or package (\$0.40 per stick for a 20-cigarette pack). The ordinance further calls for the minimum price of \$8 to be adjusted annually for inflation, although as of 2024 this had yet to occur.

Tobacco researchers have argued in favour of MFPLs as a public policy tool to be used in combination with tobacco taxes.⁴ By making the lowest-priced tobacco products more expensive, an MFPL may deter tobacco initiation and continued use among price-conscious consumers, including youth and low-income individuals, with the potential to reduce smoking-related disparities.⁵ Lower-priced cigarettes are readily available in the USA, including in California, and the tobacco industry has used coupons, other price discounts and undershifting of tobacco tax increases to keep prices low.^{6–8} Stronger MFPLs have also banned price discounts, closing a loophole that tobacco manufacturers can exploit to circumvent a floor price. In addition, MFPLs may be an attractive policy alternative to taxes for local jurisdictions in states, such as California, where local governments are pre-empted from establishing a tobacco tax.⁹



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The recent wave of MFPLs follows an earlier generation of tobacco price policy in the form of state cigarette minimum markup laws. Those state laws, which established percentage minimum markups for all cigarettes sold by wholesalers or retailers, have been found to be largely ineffective because they have a small impact on the price of inexpensive products and often still allow cigarette price promotions.^{10–12} In contrast, simulation modelling studies have found that MFPLs with bans on price promotions would reduce tobacco use.^{5 13–15} However, little is known about whether MFPLs actually achieve their policy goals. There have been three retrospective evaluations of MFPLs of which we are aware. Two, focused on cigars only, found that MFPLs in Boston, Massachusetts, and three cities in Minnesota increased prices and reduced sales in that product category.^{16 17} A third study found that New York City's MFPL did not decrease cigarette consumption.¹⁸ Additional evaluations are required to build a body of evidence that policymakers can use to decide if MFPLs are an appropriate tool. This is especially true for cigarettes, by far the largest tobacco product category in the USA in terms of dollar sales.¹⁹

This study provides one of the first detailed analyses of MFPL effects on aggregate sales in multiple tobacco product categories, including cigarettes. We note that, in addition to Oakland's MFPL effects within city boundaries, the city's location at the centre of the San Francisco Bay Area region allowed us to consider whether the MFPL pushed retail tobacco sales into adjacent areas without an MFPL. Our findings have implications for the potential expansion of MFPLs in other jurisdictions in the USA.

METHODS

In theory, consumers could respond to the higher tobacco prices induced by an MFPL in several, non-mutually exclusive ways: (1) by reducing their purchases of previously low-priced tobacco products, (2) by substituting toward higher-priced tobacco products, (3) by substituting toward tobacco products not covered by the MFPL (eg, e-cigarettes), (4) by quitting smoking, including using smoking cessation products (eg, nicotine replacement therapy (NRT)) or (5) by purchasing tobacco in an MFPL-unexposed jurisdiction (cross-border shopping). Our analysis attempts to investigate each of these behavioural responses.

Retail scanner data on tobacco prices and unit sales and a synthetic difference-in-differences (SDID) model were used to estimate changes in cigarette and cigar prices and sales following Oakland's implementation of an MFPL in 2020. We also estimated substitution to electronic nicotine delivery systems (ENDS) products and NRT products, while changes in prices and sales in an adjacent, MFPL-unexposed region were estimated to examine possible cross-border shopping effects.

This study was determined not to meet the criteria for human participant research by the institutional review board at the University of California, San Francisco.

Data and study area

Our primary data set was retail scanner data on tobacco sales from NielsenIQ, provided by the Kilts Center at the University of Chicago Booth School of Business. This database, described as the industry standard for data in retail product movement, contains information from barcode scans of thousands of products sold in stores each week in every major consumer market in the USA. NielsenIQ data, collected from convenience stores, grocery stores, pharmacies and mass merchandisers, include approximately 84% of all cigarette sales nationwide and 60%

in California based on a tax gap analysis.²⁰ Our data draws from a sample of 27 stores (11 pharmacies, eight groceries, eight convenience stores) in Oakland, 89 stores in the surrounding Oakland-adjacent area and 3415 stores in the rest of the California. All tobacco products sold were included in the data set; our universal product code (UPC) universe is thus likely representative of the most popular products sold in Oakland.

We draw on 42 months of data from July 2018 through December 2021: 22 months pre-MFPL, 3 months post-MFPL but pre-enforcement and 17 further months post-MFPL. We selected the start month to bound the pre-MFPL era following a tobacco excise tax increase in California, effective July 2017,²¹ while allowing for adequate time series data to implement our statistical method, described below. Data were provided at the product level based on UPCs and aggregated to four weekly—hereafter monthly—store-level prices and unit sales for each tobacco product purchased. Our study assesses the sale of cigarettes and cigars (including little cigars and cigarillos) in primary analyses and ENDS (e-cigarettes and vaping products) and NRT products (eg, nicotine gum and patches) in secondary analyses designed to evaluate behavioural responses to the MFPL. Sales data on handrolled and smokeless tobacco products were too sparse for inclusion.

To maintain the confidentiality of store locations, only the county and the first three digits of the store's ZIP code (zip3) were provided in the NielsenIQ dataset. With its 14 ZIP codes, the Oakland area is well defined by the '946' zip3, as that unit is almost exclusively circumscribed by Oakland's city limits (online supplemental figure S1). To examine the role of cross-border shopping in consumers' potential efforts to avoid paying higher prices, we designated a portion of the '945' zip3 as a border area called *Oakland-adjacent*. This portion, containing 40 ZIP codes within Contra Costa County, lies immediately to the east of Oakland and is accessible by multiple highways and commuter rail. Many other neighbouring areas of Oakland were omitted for having implemented their own MFPLs (online supplemental figure S1), making them unsuitable to serve as a cross-border shopping destination. Details on sample construction and data processing are provided in the online supplemental file 1.

Outcome variables

Two primary outcome measures were examined: the monthly change in (i) median shelf price per unit of tobacco product (pack for cigarettes or package for cigars) and (ii) total number of units sold of tobacco products per store in the treated locality compared with the synthetic control locality following MFPL implementation. Monthly unit sales for each UPC were computed as the mean number of packs or packages sold per store. Units sold may include individual packs/packages, multi-packs or cartons. The same outcomes were used in the cross-border shopping and product substitution analyses.

Statistical analyses

This study used the recently developed SDID method.²² Similar to synthetic control analysis, SDID applies weights to control units in order to construct a synthetic version of the treated area that provides the closest match to outcomes and prognostic factors during the prepolicy period. SDID adds time weights that align pre-exposure trends in the outcome of unexposed units with those for exposed units, resulting in a more reliable counterfactual trend. SDID has been shown to produce less biased and more precise estimates than synthetic control and SDID approaches²² and relaxes certain assumptions required for both

alternatives. Our SDID model included fixed effects (ie, indicators) for zip3 and year-month, thereby adjusting for all time-invariant population characteristics and period-specific factors that affected all geographic areas.²³

Retailer compliance

We summarised retailer compliance with the MFPL as the percentage of individual cigarette products and cigar products with a median monthly price below \$8. We also created histograms to explore the price distribution in Oakland in 2018 (pre-MFPL) versus 2021 (post-MFPL).

Analysis of unit prices and unit sales in Oakland

Our primary analyses used SDID to evaluate changes in tobacco sales in Oakland in two product categories: (i) cigarettes and (ii) cigars (big, little and cigarillo). We evaluated the MFPL's impact on the sale of all cigarettes and all cigars. Further, as the MFPL's \$8 floor was expected to affect lower-priced UPCs more than higher-priced ones, we estimated the effect after stratifying our cigarette and cigar UPC universe into lower- and higher-priced segments based on their pre-MFPL price point. In both product segments, we restricted our universe to UPCs sold in Oakland during the 12 months prior to May 2020 and calculated the monthly median shelf price per pack (across stores) for each UPC. If the median of the monthly median prices was below \$8, the UPC was assigned to the lower-priced category. We did not estimate the model for high-priced cigars because the data were sparse.

Oakland's MFPL took effect on 15 May 2020, but was not enforced until 10 August; we therefore consider the 17-month period from August 2020 through December 2021 as the post-enforcement era and the 3 months prior as a transition period. In all product and price categories, SDID assessed the post-MFPL percent change in median prices and unit sales in Oakland compared with synthetic Oakland. These changes represent the average treatment effect on the treated (ATT) of the MFPL within each product category and price segment.

To examine changes in MFPL effects over time, we estimated an event study SDID regression.²⁴ The event study provided month-by-month estimated effects. The significance of the

pre-MFPL coefficients provided a diagnostic of model fit as an important SDID assumption (the parallel trends assumption).

To determine the statistical significance of the SDID effects, we used a permutation-based approach. Under this approach, placebo estimates were generated for randomly sampled zip3's in the potential pool of control zip3's as if that sampled zip3 had been subject to an MFPL. The placebo estimate factored in the unit and time weights used to construct the synthetic control according to the algorithm specified by Arkhangelsky and colleagues.²² We repeated this procedure for 200 iterations to generate 95% CIs from the SD of the placebo estimates.

Analysis of product substitution and cross-border shopping

We next used the SDID procedure to explore whether consumers substituted ENDS or NRT products or purchased tobacco products in the area next to Oakland instead. This involved the same SDID procedures as in the main analysis, except using ENDS or NRT products as the outcome variable.

For the cross-border shopping analyses, we reassigned treated status to the Oakland-adjacent area (Contra Costa County) and excluded the Oakland zip3 from analysis. This analysis repeated the same SDID procedure using this reassigned treatment group. Additional information on data processing, geographic units of analysis, samples and subsamples, and methods are provided in the online supplemental file 1.

Sensitivity analyses

We tested the robustness of our main results by repeating the analysis using a synthetic control approach, which has been used previously to analyse tobacco policies.^{25 26} Like SDID, synthetic control algorithmically found the weighted average of zip3's that best matched the pre-MFPL outcome trend in Oakland.

RESULTS

Sample composition and retailer compliance

The analytic sample comprised nearly 30 million UPC-by-store-by-month records across the 42-month observation period, collapsed to 26 498 zip3-by-month records for analysis. [table 1](#) provides summary information for these areas.

Table 1 Characteristics of areas in 2019

| Attribute | Oakland (zip3 '946') | Oakland-adjacent (zip3 '945') | Donor pool of potential controls |
|------------------------------|----------------------|-------------------------------|----------------------------------|
| Number of ZIP codes | 14 | 40 | 1371 |
| Number of zip3's included | 1 | 1 | 49 |
| Number of stores observed | 27 | 89 | 3415 |
| Number of cigarette products | 220 | 253 | 294 |
| Below \$8 per pack | 88 | 102 | 121 |
| \$8 or higher per pack | 132 | 151 | 173 |
| Number of cigar products | 79 | 102 | 108 |
| Below \$8 per package | 63 | 73 | 81 |
| \$8 or higher per package | 16 | 29 | 27 |
| Population | 465 800 | 1 050 000 | 713,583* |
| Proportion male | 0.483 | 0.492 | 0.496* |
| Median age | 37.0 | 39.9 | 36.9* |

The '946' zip3 encompasses the large majority of Oakland, plus the small cities of Emeryville and Piedmont, which have around 23 000 residents combined. The '945' zip3 includes all cities and unincorporated places in Contra Costa County minus the portion of the city of Richmond within the '948' zip3. Product counts are based on the universe of UPCs with sales in each of the 12 months preceding MFPL implementation in May 2020 and reflect the prices during that period. Population counts are approximate and based on postcensal forecasts from the 2010 Census.

*Average value per zip3.

zip3, three digits of the store's ZIP code.

Table 2 MFPL effects, expressed as percent changes, by product category in Oakland and the Oakland-adjacent area

| Product category/ price segment | ATT (% change, median monthly price/unit) | | | ATT (% change, mean monthly units/store) | | |
|------------------------------------|---|----------------------|---------------------|--|-------------------------|-------------------------|
| | Full post-MFPL period | Pre-enforcement | Post-enforcement | Full post-MFPL period | Pre-enforcement | Post-enforcement |
| A. City of Oakland | | | | | | |
| Cigarettes | 0.9* (-0.1, 2.0) | 0.8 (-0.2, 1.8) | 1.0* (-0.1, 2.1) | -15.5 (-40.2, 9.2) | -15.0*** (-25.7, -4.3) | -15.5 (-44.3, 13.3) |
| Under \$8 | 7.9*** (6.7, 9.1) | 1.7*** (0.7, 2.7) | 9.0*** (7.7, 10.3) | -24.9*** (-34.7, -15.0) | -25.1*** (-34.9, -15.3) | -25.2*** (-35.7, -14.8) |
| Above \$8 | 2.0*** (0.6, 3.5) | -0.4 (-1.9, 1.0) | 2.4*** (0.9, 3.9) | -14.0 (-46.1, 18.1) | -12.7* (-25.9, 0.5) | -13.8 (-51.5, 23.9) |
| Cigars | -3.8 (-50.4, 42.9) | -13.7 (-100.4, 72.9) | -0.9 (-50.5, 48.7) | -48.9*** (-55.6, -42.3) | -20.6*** (-27.8, -13.4) | -49.7*** (-56.8, -42.6) |
| Under \$8 | -2.2 (-15.5, 11.2) | -1.1 (-18.9, 16.7) | -2.6 (-16.3, 11.1) | -54.0*** (-62.0, -45.9) | -20.1*** (-26.9, -13.2) | -58.8*** (-67.4, -50.2) |
| ENDS | 8.1 (-3.7, 19.9) | -0.4 (-18.3, 17.4) | 10.3* (-1.6, 22.3) | -55.1 (-172.3, 62.1) | -46.6* (-101.5, 8.4) | -62.0 (-195.0, 71.1) |
| NRT | -4.8 (-10.9, 1.3) | 4.0 (-9.0, 17.0) | -6.5* (-13.4, 0.3) | -1.9 (-32.6, 28.7) | -1.5 (-20.6, 17.6) | -1.4 (-33.7, 31.0) |
| B. Oakland-adjacent | | | | | | |
| Cigarettes | -0.6 (-1.7, 0.4) | 0.1 (-0.9, 1.1) | -0.8 (-1.9, 0.4) | 1.5 (-24.2, 27.2) | -0.5 (-6.7, 5.6) | 1.6 (-29.3, 32.5) |
| Under \$8 | -0.9 (-2.2, 0.4) | -0.6 (-1.6, 0.4) | -0.9 (-2.3, 0.5) | -0.9 (-7.0, 5.1) | -0.6 (-6.7, 5.4) | -1.2 (-7.4, 5.0) |
| Above \$8 | -0.7 (-2.5, 1.1) | -0.2 (-1.9, 1.5) | -0.8 (-2.7, 1.1) | 1.7 (-30.0, 33.4) | -0.5 (-8.3, 7.4) | 1.8 (-36.6, 40.1) |
| Cigars | -12.2 (-35.1, 10.7) | -16.9 (-63.8, 30.1) | -10.3 (-34.7, 14.0) | 10.3** (1.6, 19.0) | 9.4 (-7.6, 26.5) | 11.0** (2.4, 19.5) |
| Under \$8 | 1.6 (-12.1, 15.2) | 1.5 (-14.5, 17.6) | 2.6 (-12.1, 17.4) | 12.2* (-0.5, 24.9) | 9.0 (-6.4, 24.4) | 12.7** (0.1, 25.2) |
| ENDS | 8.6 (-3.9, 21.0) | 2.8 (-16.0, 21.5) | 9.8 (-2.8, 22.4) | 1.4 (-39.5, 42.4) | 14.9 (-4.3, 34.1) | 1.9 (-44.6, 48.4) |
| NRT | -0.1 (-6.2, 6.0) | 2.4 (-10.7, 15.5) | -0.6 (-7.3, 6.2) | -7.2 (-33.5, 19.1) | 3.0 (-13.1, 19.1) | -8.6 (-36.5, 19.4) |

Point estimates and confidence intervals indicate the percent change in the treated zip3 relative to counterfactual expectations based on synthetic difference-in-differences estimates. The pre-enforcement period represents May–July 2020, the period between enactment and enforcement of the MFPL. The post-enforcement period represents August 2020–December 2021. Full post-enforcement period is May 2020–December 2021. 'Units' refer to packs containing 20 cigarettes or packages containing 1–6 cigars. Units in the electronic nicotine delivery system (ENDS) and nicotine replacement therapy (NRT) categories include any product packaged for individual sale at any price point. Median monthly price is the median value from the set of median prices contributed by each retail store in the analytic sample selling eligible products each month. Mean monthly units is the average number of units sold per store per month. Details on this terminology are available in the online supplemental file 1.

*p<0.1 **p<0.05 ***p<0.01.
MFPL, minimum floor price law.

Retailer compliance with the MFPL for cigarettes was high; 97.5% of individual cigarette products in Oakland had median price per pack above \$8 following MFPL enforcement compared with 60–80% pre-MFPL (online supplemental figures S2 and S3). In contrast, compliance for cigars (including little cigars and cigarillos) was extremely low; 7.4% of cigars had median price per package above \$8 post-enforcement, relatively unchanged from the pre-MFPL period.

Analyses of unit prices and sales of cigarettes and cigars in Oakland

Overall, median monthly cigarette prices per pack increased by \$0.08, or 1.0% (95% CI -0.01 to 0.17, p=0.08) in Oakland versus synthetic Oakland following MFPL enforcement in August 2020 (table 2). Next, we analysed the effects by product segment. Figure 1 depicts the trends for median cigarette prices per pack (top) and mean packs sold per store (bottom) for lower-priced cigarettes in Oakland. Median monthly price of lower-priced cigarettes (<\$8 pre-MFPL) in Oakland increased slightly during the 3-month transition period (1.7%; 95% CI 0.7 to 2.7; p<0.01) but jumped by 9.0% (95% CI 7.7 to 10.3, p<0.01) in Oakland versus synthetic Oakland post-enforcement (figure 1; table 2). This equated to a \$0.69 increase in Oakland versus synthetic Oakland (95% CI 0.58 to 0.79, p<0.01) post-enforcement. In contrast, the price of higher-priced cigarettes (≥\$8 pre-MFPL) in Oakland did not meaningfully change post-enforcement (2.4%; 95% CI 0.9 to 3.9; p<0.01) (table 2). Consistent with the low retailer compliance reported above, lower-priced cigars in Oakland showed no change in shelf prices post-enforcement (-2.6%; 95% CI -16.3 to 11.1; p=0.71; table 2).

Overall, monthly unit sales of cigarettes decreased by 15.5% (95% CI -44.3 to 13.3, p=0.29) in Oakland versus synthetic Oakland post-enforcement. Sales of lower-priced cigarettes decreased by 25.2% (95% CI -35.7% to -14.8%, p<0.01) in Oakland post-enforcement (figures 1 and 2; table 2). Indeed, there was a large and immediate decrease in unit sales in Oakland during the MFPL transition (-25.1%; 95% CI -34.9 to -15.3, p<0.01), when Alameda County officials were distributing information about how to implement the new MFPL to all tobacco retailers. The MFPL effect appeared to fade somewhat throughout the post-enforcement period. Sales of higher-priced cigarettes decreased slightly as well (table 2; online supplemental figure S4), although this was not statistically significant (-13.8%; 95% CI -51.5 to 23.9; p=0.47).

Cigar sales in Oakland decreased by 49.7% (95% CI -67.4 to -50.2; p<0.01) post-enforcement, driven by decreased sales of lower-priced cigars (58.8%; 95% CI -67.4 to -50.2; p<0.01) (table 2; online supplemental figure S5).

Product substitution and cross-border shopping

Our results suggest that consumers did not substitute toward other nicotine-containing products following MFPL implementation. Median ENDS prices in Oakland rose by 10.3% post-enforcement (95% CI -1.6 to 22.3; p<0.1), whereas ENDS sales dropped by 62.0% (95% CI -195.0 to 71.1; p=0.36) due in large part to Oakland's flavoured tobacco sales restriction implemented concurrently with the MFPL (table 2). Median NRT prices dropped 6.5% (95% CI -13.4 to 0.3; p<0.1), and sales remained flat post-MFPL.

SDID results revealed no significant changes in median unit prices or cross-border purchases of cigarettes, ENDS or NRT

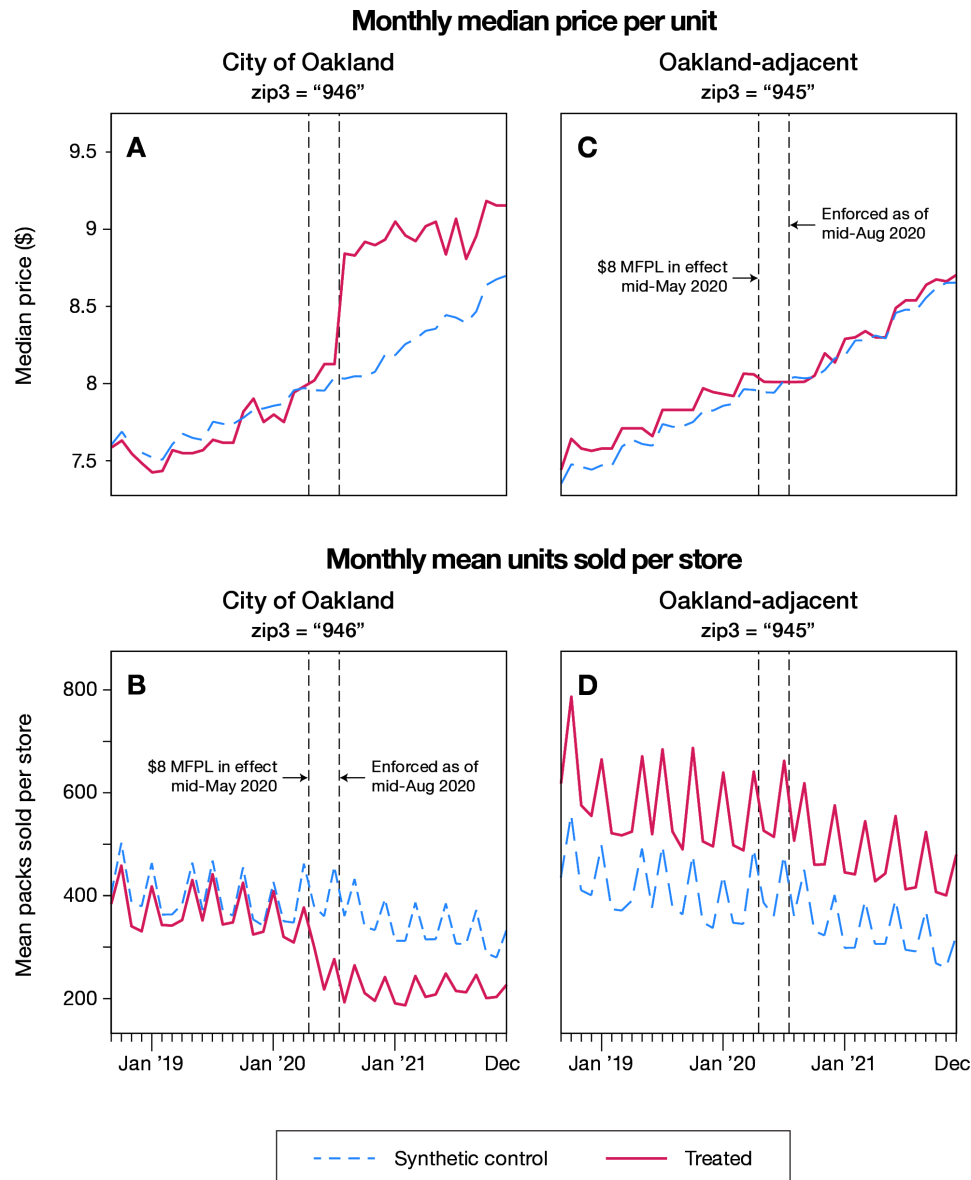


Figure 1 Trends in median cigarette price (top) and average packs sold (bottom) for lower-priced cigarettes between Oakland and Oakland-adjacent areas with their synthetic control. Note: This plot shows the change in median cigarette prices per unit in US dollars (top) and monthly mean packs sold per store (bottom) in response to implementing Oakland's MFPL, derived from synthetic difference-in-differences estimation. In each panel, the red solid line represents the treated unit, and the blue dotted line represents the synthetic control constructed from the donor pool of non-MFPL zip3's. The vertical dotted lines represent the MFPL's implementation (left) and enforcement (right). (A) (B) Estimates for cigarettes priced below \$8 pre-MFPL in Oakland. (C) (D) show estimates for cigarettes priced below \$8 pre-MFPL in the Oakland-adjacent border area. MFPL, minimum floor price law.

in the Oakland-adjacent area post-MFPL (online supplemental figures S6 and S7). However, cross-border purchases of lower-priced cigars increased 12.7% (95% CI 0.1 to 25.2; $p < 0.05$).

Sensitivity analyses

Results were relatively robust to estimating a synthetic control model instead (online supplemental tables S1–S5 and figures S8–S13).

DISCUSSION

Our findings show that Oakland's MFPL led to large, persistent declines in the sales of lower-priced cigarettes and cigars. During the first 17 months of MFPL enforcement, monthly unit sales in Oakland were, on average, one-quarter lower than expected

for lower-priced cigarettes and one-half lower than expected for cigars. Overall, we estimate that Oakland's MFPL led to an aggregate sales decline of lower-priced cigarettes and cigars of 32.8% in Oakland and an aggregate sales decline of all cigarettes and cigars of 15.6% to 18.2% during the first 17 months of the MFPL era, compared with the month prior (online supplemental table S6). This corresponds to approximately 8200 fewer units sold per store per month. We further found no corresponding increase in the sale of higher-priced cigarettes, no meaningful substitution with ENDS products and no increased cross-border shopping for cigarettes but some increase for cigars. These findings suggest that Oakland's MFPL resulted in a sharp, localised decrease in the number of cigarettes bought; we outline below the reasons for a nuanced interpretation of the effect for cigars.

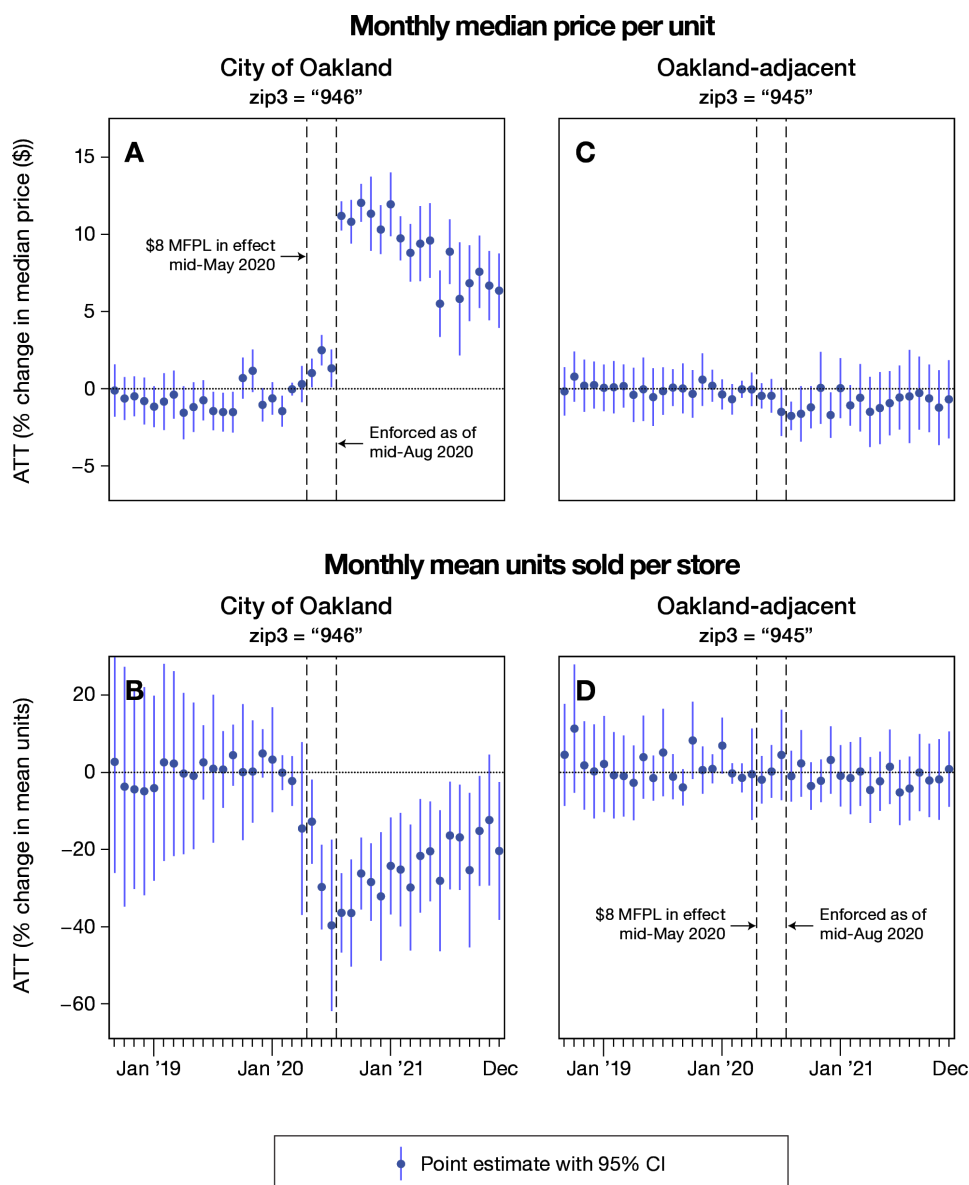


Figure 2 Percent change over time in the effects of the MFPL on median cigarette price (top) and average packs sold (bottom) for lower-priced cigarettes in Oakland and Oakland-adjacent areas. Note: This plot shows the ATT, expressed as a percent change in median cigarette prices (top) and cigarette units sold (bottom) in response to implementing Oakland's MFPL, derived from an event study specification of a synthetic difference-in-differences model. The horizontal axis represents months in calendar time. Each plotted point represents a coefficient estimate with its corresponding 95% CI. In each panel, the black line represents the treated unit, and the grey lines represent in-space placebo estimates from the donor pool of non-MFPL cities. The vertical dotted lines represent the MFPL's implementation (left) and enforcement (right). (A) (B) Estimates for cigarettes priced below \$8 pre-MFPL in Oakland. (B) Estimates for cigarettes priced at \$8 or higher pre-MFPL in Oakland. (C) (D) Estimates for cigarettes priced below \$8 pre-MFPL in the Oakland-adjacent border area. ATT, average treatment effect on the treated; MFPL, minimum floor price law.

Despite the drop in tobacco sales, nicotine replacement therapy product sales in Oakland showed no change following MFPL implementation, suggesting that the use of smoking cessation aids did not increase accordingly. This occurred despite a 4.8% price decrease for NRT products, which may have been a response by retailers to the MFPL. Nevertheless, the lack of increased NRT sales may indicate a gap in the integration of cessation promotion with tobacco regulations.

Although these findings suggest the MFPL largely worked as intended, they should be interpreted cautiously. First, Oakland's MFPL went into effect just 2 months after the onset of the COVID-19 pandemic, which disrupted tobacco use patterns and supply chains for tobacco products.^{27 28} We note, however,

that these time-specific events should apply roughly equally to Oakland, its border area and comparison areas, in which case they would be adjusted for in our analysis. The pandemic and associated stay-at-home orders also hampered the enforcement of tobacco retail licensing laws, including delaying the enforcement of Oakland's MFPL until August 2020. While retailer compliance for cigarettes was largely immediate, as seen by the cigarette price jump in August, compliance for cigars was non-existent. Public health officials in Alameda County (where Oakland is located) posit that MFPL enforcement for cigars may have been limited by competing demands during the pandemic, the city's staffing capacity being stretched, and prioritising enforcement of the flavoured tobacco restriction (Rachel Lazarus-Gratz,

personal communication, 30 September 2024). Moreover, retailers said they were not able to order larger package sizes of cigars and cigarillos from manufacturers, which could be sold for above \$8 and meet a minimum pack size requirement. Retailers were also not clear about how to comply or whether they were permitted to bundle (stapling, rubber bands, etc). As a result, city officials may have been less likely to enforce the MFPL. These issues highlight challenges with implementing MFPLs, particularly for the cigar product category with its considerable variability in package sizes and price points.

Second, coinciding with the MFPL's implementation and enforcement schedule, Oakland expanded its sales restrictions on flavoured tobacco products to remove the adult-only store exemption, in particular to cover tobacco specialty shops, banned tobacco sales at retail pharmacies and set a minimum pack size requirement for cigars. While the flavour restriction would have likely reduced cigarette and cigar sales in general because menthol cigarettes and flavoured cigars form a sizeable portion of total cigar sales, flavoured tobacco had already been restricted in the store types in our data set. Therefore, we would expect the new flavour restriction to increase cigarette and cigar sales in Oakland, leading us to understate the MFPL's impacts. The flavour restriction may also have dampened product substitution from cigarettes and cigars to ENDS, mitigating what might have otherwise been a rise in sales for this category. The pharmacy sales ban had limited impact on our estimates because pharmacies compromised a small share of all cigarette and cigar sales (online supplemental figure S14). Both Oakland's flavour restrictions and pharmacy sales ban would be expected to exacerbate cross-border shopping, making the limited amount of observed cross-border shopping more remarkable.

In contrast, the minimum pack size requirement for cigars coincided with convenience stores in our sample reducing the number of cigars UPCs offered (online supplemental figure S15), and this likely contributed to the cigar sales decline overall and in convenience stores in particular (online supplemental figure S16). As noted above, retailers said that manufacturers were not able to provide them with larger package sizes for some cigar and cigarillo products (Rachel Lazarus-Gratz, personal communication, 30 September 2024). Thus, given the lax MFPL enforcement for cigars, the minimum pack size requirement was likely a major factor in the change in cigar sales.

Finally, our data did not include tobacco specialty stores (ie, smoke shops and vape shops), and this leaves an incomplete picture of ENDS sales patterns, especially during the pandemic when sales patterns were shifting.

Nonetheless, this study indicates that Oakland's MFPL was a success. Indeed, the MFPL's impact on sales may have been even greater if the floor price had been set higher. By May 2020, most lower-priced cigarettes were already priced close to \$8 per pack, limiting the scope for influencing smoking behaviour. In addition, our SDID estimates of the price increase and corresponding sales decline correspond to a price elasticity of demand for lower-priced cigarettes of -2.8 ($= -25.2\%/9.0\%$) post-enforcement. This is far in excess of cigarette price elasticity estimates derived from tax changes, which tend to be in the range of -0.2 to -0.4 .^{29 30} The magnitude of our price elasticity estimates suggest the importance of generating comparable estimates from MFPLs in other localities. Yet, one potential reason for the large behavioural response in Oakland may lie in the MFPL's ability to target lower-priced products that are consumed disproportionately by price-sensitive groups such as racial/ethnic minority groups, lower-income individuals, and adolescents and young adults. All of these groups are well represented in Oakland (eg,

49% Black or Hispanic, 26% foreign-born, 13% in poverty).³¹ While our study used retail sales data rather than individual-level data, we would conjecture that Oakland's MFPL likely had equity-reducing impacts.

Limitations

This study has several limitations. First, the retail sales data identified purchasing behaviour and not direct consumption. It is possible that MFPL-affected populations consumed a different share of purchased tobacco products than did MFPL-unaffected control populations (eg, sharing with others). Any change in illicit tobacco use would similarly not be observed in our data and could (partially) offset our estimated MFPL effects. Simulation-based studies of MFPLs in California have assumed 15% as a high degree of tax evasion and tax avoidance.^{3 15} However, tax avoidance through cross-border shopping was likely curtailed in Oakland because several neighbouring municipalities had implemented MFPLs with the same or similar floor prices (online supplemental figure S1). Second, the retail sales data contain only a sample of stores in each zip3 and thus a portion of sales in the treated area. The incomplete sales coverage could introduce bias into our estimates to the extent that excluded stores experienced different customer responses than included stores or to the extent that sales shifted differentially over time from included stores to excluded stores in Oakland versus non-MFPL cities. Moreover, the Oakland sales data were drawn from chain stores, that is, pharmacies (until August 2020), grocery stores and convenience stores. These results may not extend to independent stores or tobacco specialty stores, nor to cities with a different socio-demographic profile or policy environment from Oakland, in part for the reasons previously stated. Third, Oakland's coinciding ban on tobacco sales at retail pharmacies may have led us to under-estimate the MFPL-attributable tobacco sales decline to the extent that consumers substituted to making tobacco purchases at other stores in our sample. We note, however, that the MFPL-attributable decline in cigarette sales cannot be attributed to the pharmacy sales ban, because tobacco sales in pharmacies were a small share of total Oakland volume and our estimates rely on average sales per store that remained in the sample. However, Oakland's minimum pack size requirement may have been an important component of the sales decline for cigars by reducing the number of cigar products offered. Oakland's coinciding new flavour restrictions may have led us to under-estimate the MFPL-attributable sales decline, as described above. Relatedly, pandemic-era population shifts in Oakland could have affected sales, although American Community Survey 1-year samples do not suggest any substantial changes in population size or composition between 2019 and 2021.³²

CONCLUSION

Excise taxation has been the overwhelmingly predominant strategy for regulating tobacco prices, leaving MFPLs relatively unexplored. By minimising the availability of lower-priced tobacco products, MFPLs hold promise for reducing smoking initiation and potentially for reducing smoking disparities. We find that MFPLs can achieve their policy objective of reducing cigarette use. Additional case studies and systematic evaluations are needed.

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