The Pass-through of Vertical Cost Shocks: Evidence from Matched Scanner Data

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Motivation

- **Pass-through:** the rate at which firms pass changes in costs through to their prices
- The pass-through rate conveys the extent to which cost shocks are borne by consumers versus firms
- Pass-through is a key parameter for evaluating the incidence of cost shocks from **exchange rates** (Goldberg and Knetter, 1997), **commodity prices** (Nakamura and Zerom, 2010; Borenstein et al., 1997), **trade policy** (Amiti et al., 2019; Fajgelbaum et al., 2020), **subsidies** (Duggan et al., 2016), **minimum wages** (Renkin et al., 2020; Harasztosi and Lindner, 2019), and much more...

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- Most studies analyze pass-through at a single stage of the supply chain
- The implications of 'vertical' shocks are not well-understood

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2. The indirect effect can further bias pass-through estimates by contaminating the control group
3. Heterogeneous price response among firms with otherwise identical direct exposure to the policy or cost shock
4. The burden of the shock falls more heavily on consumers for the direct shock compared to the indirect shock

Literature

1. **Pass-through of cost shocks:** Borenstein et al. (1997); Nakamura and Zerom (2010); Miller et al. (2017); Marion and Muehlegger (2011); Genakos and Pagliero (2022); Ganapati et al. (2020); Goldberg and Knetter (1997); Renkin et al. (2020); Harasztosi and Lindner (2019); MaCurdy (2015); Leung (2021), and more...

   - I estimate the pass-through of a cost shock that directly affects multiple stages of the production process

2. **Strategic complementarity in prices:** Amiti et al. (2019); Muehlegger and Sweeney (2022)

   - I expand on these studies by investigating strategic complementarities in the context of a vertical cost shock

IO papers using cannabis industry: Hollenbeck and Uetake (2021); Hollenbeck and Giroldo (2022); Hollenbeck et al. (2024); Hansen et al. (2022)

Cannabis industry background

- Approx. 50% of U.S. states have legal recreational cannabis markets, $25 billion in annual sales
- 30-40% of adults in WA regularly consume cannabis (Washington State Department of Health, 2024)
- Market is regulated by the Liquor and Cannabis Board (LCB)
- Two types of firms: manufacturers (i.e. cultivators) and retailers, no vertical integration allowed
  - 508 cannabis retailers and 692 manufacturers in WA

Usage Categories Descriptive stats

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   - Upstream and downstream firms subject to same set of MW hikes (no cross-border trade allowed)

Price data

- Source: Top Shelf Data, June 2018-August 2021
- **Dependent variable**: establishment-level Young price index that aggregates price changes across product subcategories (see Renkin et al., 2020; Leung, 2021; Harasztosi and Lindner, 2019)

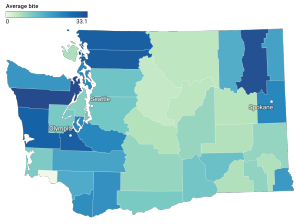
$$\pi_{j,t} = \ln I_{j,t}, \text{ with } I_{j,t} = \prod_{c} I_{c,j,t}^{\omega_{c,j,y(t)}} \tag{1}$$

- $\pi_{j,t}$: the month-over-month change in prices at a given establishment

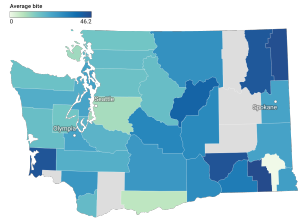
Sample overview

DiD with continuous treatment

- **MW bite**: share of FTE workers earning below the new minimum wage two quarters before the hike, at the industry-by-county level (Card, 1992)
- **Main identifying assumption**: price changes at low-bite establishments serve as a valid counterfactual for price changes at high-bite establishments



(a) NAICS 111 (crop production, incl. marijuana)



(b) NAICS 453 (misc. store retailers, incl. marijuana stores)

Figure 1: Avg. bite two quarters before MW hike

Compliance | Balance check

Empirical strategy - effect of MW on wholesale prices

- Assumption: cannabis manufacturers only subject to a direct cost shock from MW hikes

$$\pi_{j,t} = \sum_{l=-5}^{6} \beta_l Direct_{j,t-l} + \gamma_t + \epsilon_{j,t}. \tag{2}$$

- where $Direct_{j,t} = \Delta \log MW_{j,e(t)} \times Bite_{k(j),e(t)}$ (Renkin et al., 2020)
- Report cumulative effects relative to normalized baseline period—numerically equivalent to event study coefficients (Schmidheiny and Siegloch, 2023)
  - Treatment effect on price *level*: $E_L = \sum_{l=-1}^{L} \beta_l$. Pre-treatment effects: $P_{-L} = -\sum_{l=-2}^{-L+1} \beta_l$
- SE clustered at county level (Bertrand et al., 2004)

Empirical strategy - effect of MW on retail prices

- DiD with a continuous treatment + shift-share instrument

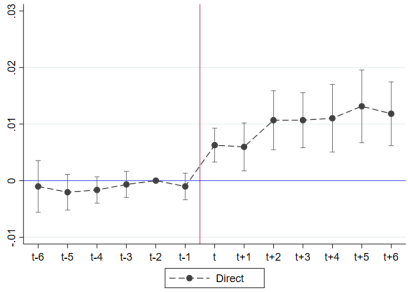
$$\pi_{j,t} = \sum_{l=-5}^{6} \beta_l Direct_{j,t-l} + \sum_{l=-5}^{6} \psi_l Indirect_{j,t-l} + \gamma_t + \epsilon_{j,t}. \tag{3}$$

- $Indirect_{j,t-l}$: expenditure weighted avg. MW bite of the manufacturers that retailer j purchases from

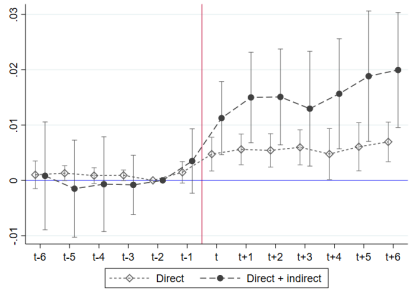
$$Indirect_{j,t} = \sum_{m=s}^{S} \alpha_{j,m} \Delta MW_{m,e(t)} \times \sum_{m=s}^{S} \alpha_{j,m} Bite_{k(m),e(t)} \tag{4}$$

- Total (direct + indirect) effect of MW hike on retail prices: $\beta_l + \psi_l$

Main results



(a) Effect on the wholesale price level



(b) Effect on the retail price level

- A 10% MW hike increases wholesale cannabis prices by 1.2% at the avg. bite
- Retail prices increase by 0.6% from the direct shock and 1.5% from the indirect shock (2.1% overall effect)

▸ W/out indirect ▸ Trend check 1 ▸ Trend check 2

Robustness checks and alternative specifications

- Testing for selection bias in continuous treatment (Callaway et al., 2024) ▸ Selection bias
- Shift-share instrument validity: first-stage relevance and share exogeneity (Goldsmith-Pinkham et al., 2020) ▸ First stage ▸ Share exogeneity
- Further robustness checks: Longer event window, Q4 bite (instead of Q3), balanced panel, alt. price index weights, accounting for MW non-compliance, Seattle endogeneity ▸ Extended window ▸ Wholesale robust ▸ Retail robust
- Alternative specifications: trim bite variable (Callaway et al., 2024), region-time FE, controls, dropping indirect treatment from retail regression ▸ Wholesale alt. specs ▸ Retail alt. specs
- Indirect effect similar when estimating a canonical wholesale cost pass-through regression

Heterogeneity analysis

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- The indirect shock is idiosyncratic to specific retailers, whereas the direct cost shock is an aggregate shock in local markets
- Retailers are able to pass more of the direct shock through to consumers than the indirect shock

Conclusion and discussion

The vertical scope of a policy or cost shock affects the pass-through rate recovered

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Conclusion and discussion

- The implications of my findings extend beyond the context of this paper
  - High pass-through rates are observed in many settings (Leung, 2021; Renkin et al., 2020; Marion and Muehlegger, 2011; Conlon and Rao, 2020)
  - Differences in tradability upstream vs. downstream are common in many sectors
    - In many manufacturing and wholesale trade sectors, the majority of goods produced are shipped to distributors or retailers located in other regions Commodity flows
    - 80% of retail sales are in brick-and-mortar stores (Statista, 2023)
- The cannabis industry similar to traditional retail sectors in terms of variable cost structure and (to a certain extent) demand elasticities (Hollenbeck and Uetake, 2021)

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Appendix

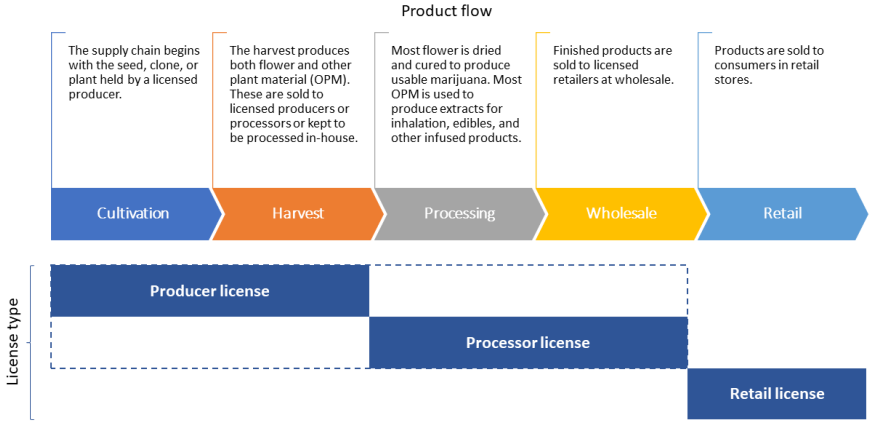

Figure 3: Cannabis supply chain and market structure in WA state

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Table 1: Sample overview

	Retail	Wholesale
Establishments	508	692
Units sold	232,133,427	228,423,415^{+}
Distinct products	172,688	147,273
Total revenue	$4.47 billion	$1.46 billion
Monthly revenue per establishment	$304,032	$106,634

Data source: Top Shelf Data (August 2018 - July 2021).

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Table 2: Market share by product category

	Retail	Wholesale
Usable marijuana	0.53	0.61
Concentrate for inhalation	0.31	0.28
Solid edible	0.07	0.03
Liquid edible	0.03	0.02
Infused mix	0.04	0.04
Other	0.02	0.02

Notes: This table shows market shares for the product categories defined by the LCB. Market shares are calculated using the estimation sample which runs from August 2018 through July 2021. "Other" includes any category with less than 1 percent market share. These are: topical, packaged marijuana mix, capsules, tinctures, transdermal patches, sample jar, and suppository. Sales from processor-only licenses are excluded. Sales between wholesalers are included. Data source: Top Shelf Data.

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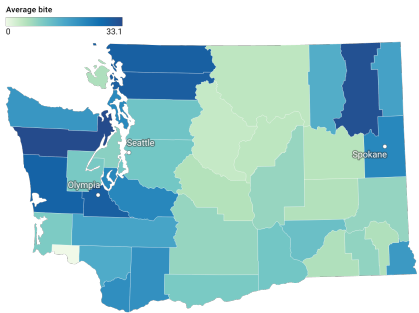
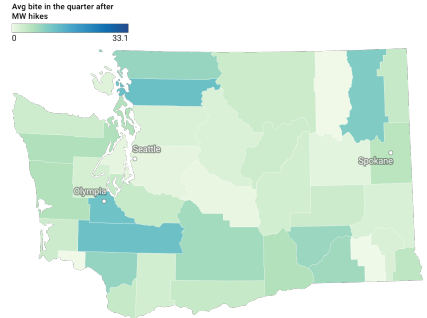


(a) Avg. bite two quarters before MW hikes



(b) Avg. bite in the quarter after MW hikes

Figure 4: Avg. bite for NAICS 111 (crop production subsector)

Notes: Data from Washington ESD, 2018-2021.

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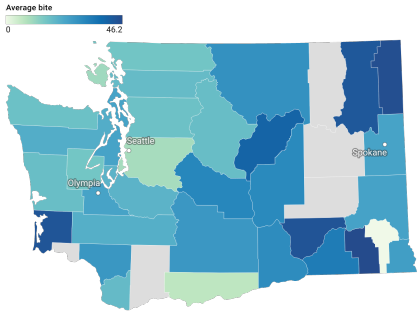
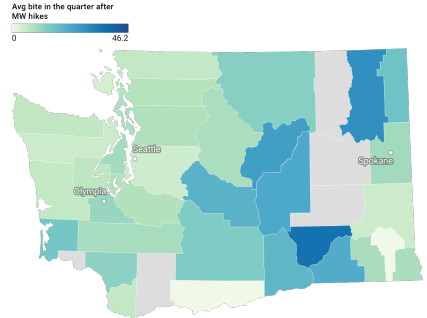


(a) Avg. bite two quarters before MW hikes



(b) Avg. bite in the quarter after MW hikes

Figure 5: Avg. bite for NAICS 453 (misc. store retailers)

Notes: Data from Washington ESD, 2018-2021.

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Table 3: Annual gross wages in the Washington state cannabis industry

	Wholesale			Retail				
Year	Cannabis Whole-sale	NAICS 111	NAICS 111419	Cannabis Retail	NAICS 453	NAICS 453998	All private inds.	Min. wage
2018	$27,906	$28,804	$28,371	$26,126	$28,116	$31,848	$66,156	$23,920
2019	$29,713	$30,499	$30,417	$27,468	$29,798	$32,922	$57,185	$24,960
2020	$32,315	$33,026	$33,459	$29,534	$32,847	$34,847	$76,801	$28,080

Notes: This table compares average annual gross wage for workers at cannabis establishments for the years 2018-2020. Average annual gross wage is obtained by dividing total wages by average covered employment. Minimum wage is based on 2,080 hours per year. Data for 2021 is not available. Data from Washington state ESD.

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Main identifying assumption: price changes at low-bite establishments serve as a valid counterfactual for price changes at high-bite establishments

Table 4: Pre-treatment summary statistics

	Retailers		Manufacturers	
	(1) Low bite	(2) High bite	(3) Low bite	(4) High bite
Unit price (in dollars)	26.85	26.59	11.41	11.68
	(4.83)	(5.13)	(11.04)	(5.90)
Unit price growth (percent)	0.2	0.1	0.2	0.2
	(3.5)	(3.0)	(6.3)	(6.6)
Monthly revenue (in dollars)	223,571	254,589	76,305	81,795
	(258,136)	(245,064)	(215,746)	(238,092)
Unique products per month	381	410	62	45
	(316)	(345)	(170)	(127)

Selection bias

Table 5: Pre-treatment summary statistics

	Retail					Wholesale		
	(1) Below 50th pctile	(2) Above 50th pctile	(3) Below 25th pctile	(4) Above 75th pctile	(5) Below 50th pctile	(6) Above 50th pctile	(7) Below 25th pctile	(8) Above 75th pctile
Unit price (in dollars)	26.85	26.59	27.65	26.29	11.41	11.68	11.80	11.04
	(4.83)	(5.13)	(5.04)	(5.38)	(11.04)	(5.90)	(11.55)	(5.23)
Unit price growth (percent)	0.2	0.1	0.2	0.1	0.2	0.3	0.2	0.2
	(3.5)	(3.0)	(3.4)	(3.1)	(6.6)	(6.2)	(6.3)	(6.6)
Units sold per month	11,436	13,385	13,056	11,995	65,998	12,328	88,074	10,377
	(12,779)	(12,544)	(10,670)	(12,989)	(570,332)	(42,921)	(667,509)	(24,719)
Monthly revenue (in dollars)	223,571	254,589	259,780	225,179	76,305	81,795	95,126	65,397
	(258,136)	(245,064)	(217,614)	(249,569)	(215,746)	(238,092)	(352,091)	(124,818)
Unique products per month	381	410	448	354	62	45	47	32
	(316)	(345)	(336)	(313)	(170)	(127)	(83)	(52)

Notes: The table summarizes establishment-level variables over all pre-treatment periods.

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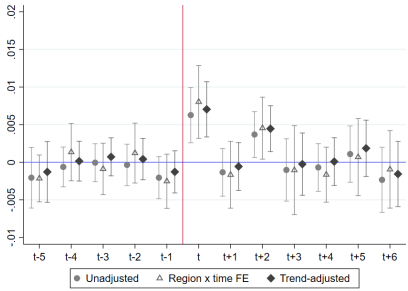
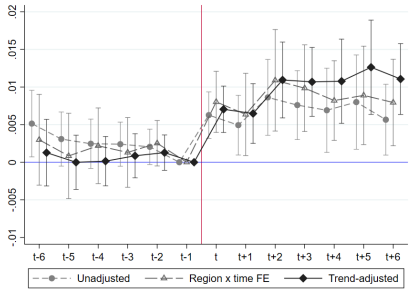
Trend adjustment - wholesale prices



(a) Effect on wholesale inflation rate



(b) Effect on wholesale price level

Figure 6: Effect of minimum wage hikes on wholesale cannabis prices

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Direct effect when controlling for indirect effect

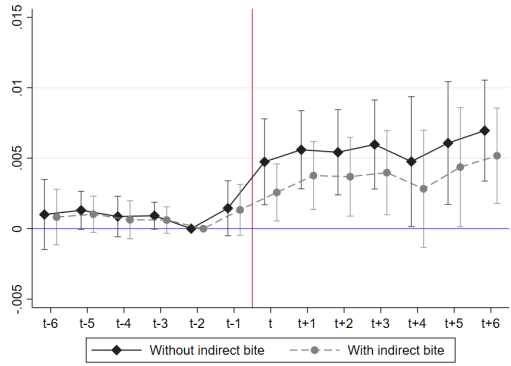

Figure 7: Effect on retail price level

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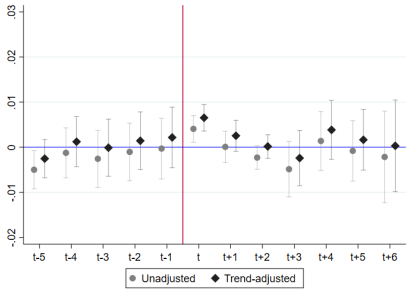
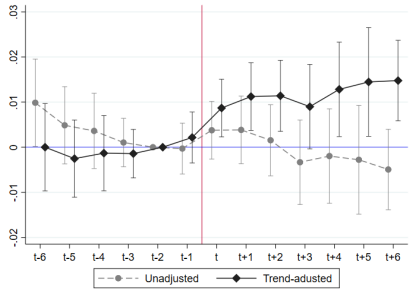
Trend adjustment - retail indirect



(a) Effect on retail inflation rate



(b) Effect on retail price level

Figure 8: Indirect effect of minimum wage hikes on retail cannabis prices

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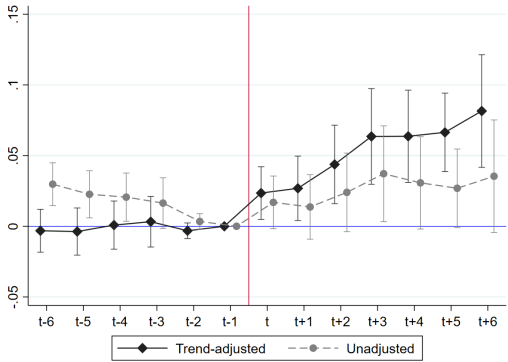
Shift share instrument - First-stage relevance

Figure 9: Effect of indirect cost instrument on retailers' wholesale cost



Notes: The figure shows estimates from equation 3 where the dependent variable is the establishment-level wholesale cost index for cannabis retailers (in logs).

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Share exogeneity

(A) Summary of top 5 Rotemberg weights

Manufacturer county	Event	α_k	Bite$_k$	β_k
Thurston	2	0.158	37.7	0.0001
Whitman	2	0.129	12.1	-0.0043
Jefferson	3	0.112	24.4	0.0022
Yakima	2	0.109	16.5	-0.0011
Pierce	2	0.098	28.2	-0.0007

(B) Relationship between manufacturer county shares and retail store characteristics

	(1) Thurston county (event 2)	(2) Whitman county (event 2)	(3) Jefferson county (event 3)	(4) Yakima county (event 2)	(5) Pierce county (event 2)
Bite	0.0019**	-0.0009*	-0.0013	-0.0010	0.0005
	(0.0009)	(0.0005)	(0.0019)	(0.0009)	(0.0009)
Unemp. rate	-0.0109	0.0073	0.0092	0.0203*	0.0164**
	(0.0102)	(0.0055)	(0.0107)	(0.0118)	(0.0083)
Log home value	-0.0525	0.0183	-0.0302	0.0443	0.0551
	(0.0487)	(0.0257)	(0.0381)	(0.0314)	(0.0428)
Independent	0.0034	-0.0063	-0.0072	0.0022	0.0163*
	(0.0095)	(0.0054)	(0.0060)	(0.0065)	(0.0088)
Focal market HHI	-0.0226	0.0250**	-0.0118	0.0195	-0.0114
	(0.0193)	(0.0125)	(0.0161)	(0.0194)	(0.0222)
Product variety	0.000003	-0.000009	-0.00002***	-0.00004***	-0.00002***
	(0.000009)	(0.000008)	(0.000008)	(0.00001)	(0.000007)
R^2	0.068	0.210	0.169	0.149	0.116
N	369	80	113	251	309

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Table 6: Robustness checks - wholesale prices

	Alternate bite variable		Reverse causality		Other	
	(1)	(2)	(3)	(4)	(5)	(6)
	Q4 bite	Com-pliance	No Seattle	No King county	Balanced panel	Alt. weights
E_0	0.006**	0.006***	0.006***	0.006***	0.006***	0.008**
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)
E_2	0.011**	0.011***	0.010***	0.010***	0.008***	0.013***
	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)
E_4	0.009**	0.011**	0.010***	0.010***	0.008**	0.018***
	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)	(0.006)
$\sum$ Pre -event	-1.4e-07	2.1e-08	-1.2e-07	-1.7e-07	1.7e-07	-1.0e-07
	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.006)
N	14,777	14,699	14,622	14,506	12,900	14,819
Time FE	YES	YES	YES	YES	YES	YES
Controls	NO	NO	NO	NO	NO	NO
Trend-adjusted	YES	YES	YES	YES	YES	YES

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Table 7: Robustness checks - retail prices (direct effect)

	Alternate bite variable		Reverse causality		Other	
	(1)	(2)	(3)	(4)	(5)	(6)
	Q4 bite	Com-pliance	No Seattle	No King county	Balanced panel	Alt. weights
E_0	0.003**	0.004	0.003***	0.003***	0.003**	0.004***
	(0.001)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)
E_2	0.003**	0.006**	0.003**	0.003***	0.004**	0.004**
	(0.002)	(0.003)	(0.001)	(0.001)	(0.002)	(0.002)
E_4	0.004*	0.008**	0.004**	0.005***	0.005**	0.005**
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
$\sum$ Pre -event	-7.6e-04	0.002	-6.0e-05	-7.7e-04	-0.001	2.8e-04
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
N	14,044	13,859	13,422	12,995	13,390	14,042
Time FE	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES

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Table 8: Alternative specifications - wholesale prices

	Trend-adjusted				Unadjusted		
	(1) Base-line	(2) Reg.-time FE	(3) Out-liers	(4) Trim-med bite	(5) Base-line	(6) t-1 base	(7) Reg.-time FE
E_0	0.006***	0.007***	0.005**	0.006***	0.004**	0.006***	0.006**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
E_2	0.010***	0.01***	0.010***	0.010***	0.007**	0.009***	0.008*
	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)
E_4	0.009***	0.01***	0.01***	0.010***	0.005	0.007**	0.006
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)
$\sum$ Pre-event	1.0e-07	-0.003	2.0e-07	2.0e-07	0.003	0.005*	0.001
	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
N	14,777	14,777	14,932	14,735	14,777	14,777	14,777

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Table 9: Alternative specifications - retail prices

	Direct					Indirect				Combined
	(1) Base-line	(2) Reg.-time FE	(3) Winsor-ized	(4) Trim-med bite	(5) De-trend	(6) Base-line	(7) Reg.-time FE	(8) Winsor-ized	(9) Un-adjusted	(10) Base-line
E_0	0.005**	0.002	0.003**	0.005**	0.003**	0.009**	0.010***	0.008**	0.005	0.011***
	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)
E_2	0.005***	0.003	0.003**	0.005***	0.004**	0.011**	0.012**	0.010**	0.002	0.015***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)
E_4	0.005*	0.004	0.003	0.004	0.003	0.013**	0.013**	0.011**	-0.002	0.016***
	(0.003)	(0.004)	(0.002)	(0.003)	(0.003)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
$\sum$ Pre	0.001	0.002	0.001	0.001	0.001	1.24e-07	-0.001	-0.001	0.010	0.001
	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)
N	14,189	14,189	14,189	14,095	13,689	13,689	13,689	13,689	13,689	13,689

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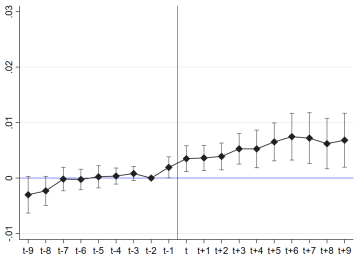
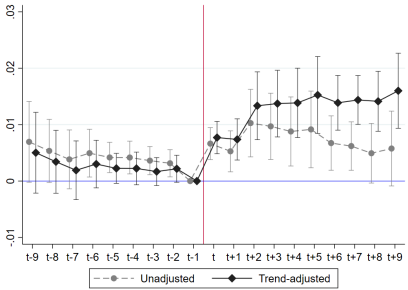


(a) Retail prices



(b) Wholesale prices

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Table 10: COGS and the labor share of costs for cannabis retailers

	Average expenditure		Variable cost share	
Year	Labor	COGS	Labor	COGS
2018	$324,582	$702,358	0.32	0.68
2019	$370,897	$1,187,462	0.24	0.76
2020	$407,273	$1,584,301	0.20	0.80

Notes: This table compares average annual labor expenditure and COGS expenditure for cannabis retail establishments in Washington state for the years 2018-2020. Labor expenditure equals total wages divided by the number of active retail establishments. Establishments with missing UI data are excluded from total wages and establishment counts. COGS is the average annual wholesale expenditure for cannabis retailers in the estimation sample. Wholesale purchases from processor-only licenses are included. Data from Washington state ESD, Top Shelf Data, and High Peak Strategy (2018-2020).

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Table 11: Wholesale prices

	Trend-adjusted						Unadjusted		
	(1) Baseline	(2) Controls	(3) County trends	(4) Wins-orized	(5) Outliers	(6) Trim-med bite	(7) Reg.-time FE	(8) Baseline	(9) t-1 base
E_0	0.006***	0.006***	0.004**	0.006***	0.005**	0.006***	0.006**	0.004**	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
E_2	0.010***	0.010***	0.006**	0.010***	0.010***	0.010***	0.009**	0.007**	0.009***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.003)
E_4	0.009***	0.010***	0.005	0.010***	0.010***	0.010***	0.006	0.005	0.007**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)
$\sum$ Pre-event	1.0e-07	-2.0e-04	0.003	1.0e-07	2.0e-07	2.0e-07	1.0e-04	0.003	0.005*
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
N	14,777	14,777	14,777	14,932	14,932	14,735	14,777	14,777	14,777
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	NO	YES	YES	NO	NO	NO	YES	NO	NO

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Data from Washington ESD and Top Shelf Data, July 2018-August 2021.

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Table 12: Retail prices

	(1) Baseline	(2) Estab. trends	(3) Reg.-time FE	(4) Winsor-ized	(5) Outliers	(6) Trim-med bite
E_0	0.005**	0.005**	0.004**	0.003**	0.003**	0.005**
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)
E_2	0.005***	0.006**	0.005**	0.003**	0.003**	0.005***
	(0.002)	(0.003)	(0.002)	(0.001)	(0.002)	(0.002)
E_4	0.005*	0.005	0.005	0.004**	0.003	0.004
	(0.003)	(0.004)	(0.003)	(0.002)	(0.002)	(0.003)
$\sum$ Pre-event	0.001	0.001	0.001	-0.0002	0.0008	0.001
	(0.002)	(0.002)	(0.001)	(0.0009)	(0.001)	(0.002)
N	14,189	14,189	14,189	14,044	14,189	14,095

Notes: $^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$. Data from Washington ESD and Top Shelf Data, July 2018-August 2021.

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Table 13: Alteriative specifications for rival bite

	Wholesale		Retail			
			Direct		Indirect	
	(1)	(2)	(3)	(4)	(5)	(6)
	No rivals	30 miles, distance weights	No rivals	30 miles, distance weights	No rivals (indirect)	30 miles, distance weights (indirect)
Estimation summary						
$\sum$ Pre-event	0.00000010	-0.000024	0.0010	-0.000021	0.00000012	0.00011
	(0.0028)	(0.0031)	(0.0015)	(0.0024)	(0.0059)	(0.0071)
$E_0^o + E_0^r$	0.0058***	0.0070**	0.0047**	0.0094**	0.0087**	0.0072
	(0.0018)	(0.0029)	(0.0019)	(0.0047)	(0.0039)	(0.0048)
$E_2^o + E_2^r$	0.0097***	0.011***	0.0054***	0.011**	0.011**	0.0074
	(0.0032)	(0.0040)	(0.0018)	(0.0043)	(0.0048)	(0.0064)
$E_4^o + E_4^r$	0.0095***	0.0081*	0.0048*	0.0087*	0.013**	0.0074
	(0.0036)	(0.0045)	(0.0028)	(0.0052)	(0.0064)	(0.0080)
N	14,777	13,621	14,189	13,632	13,689	13,152

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Shift-share instrument

- Weighted avg. MW exposure of wholesalers that retailer r purchases from:

$$\pi_{r,t} = \sum_{l=-6}^{5} \beta_l \Delta MW_{r,t-l} \times Bite_{k(r),t-l} + \sum_{l=-6}^{5} \psi_l JB_{r,P,t-l} + X_{k(r),t} + \theta_{k(r)} + \gamma_t + \epsilon_{r,t} \quad (5)$$

where

$$JB_{r,P,t-l} = \sum_{p=s}^{S} \alpha_{r,p} \Delta MW_{p,t-l} \times \sum_{p=s}^{S} \alpha_{r,p} Bite_{k(p),t-l} \quad (6)$$

- $\alpha_{r,p}$: share of retailer r's wholesale expenditures going to wholesaler p from $t-4$ through $t-2$

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Shift-share instrument

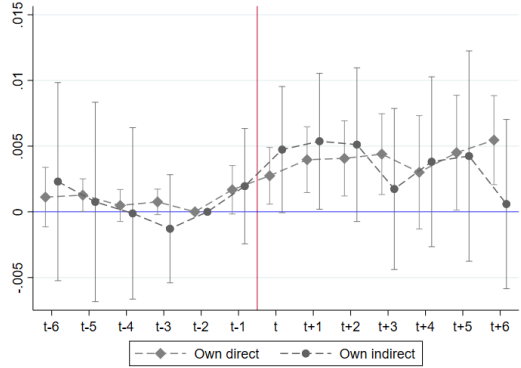

Figure 11: Indirect effect on retail prices

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Table 14: Subsample analyses

	Wholesale		Retail			
	(1) Small	(2) Large	(3) Indep.	(4) Chains	(5) Low con-centr.	(6) High con-centr.
E_0	0.007*	0.003	0.003	0.004**	0.005***	0.002
	(0.003)	(0.003)	(0.001)	(0.002)	(0.001)	(0.002)
E_2	0.013**	0.0002	0.002	0.005***	0.004***	0.002
	(0.004)	(0.004)	(0.002)	(0.001)	(0.001)	(0.002)
E_4	0.012*	-0.0006	0.003	0.006***	0.007***	9.24e-6
	(0.006)	(0.007)	(0.002)	(0.002)	(0.002)	(0.003)
$\sum$ Pre-event	2.05e-08	-1.28e-08	-0.0004	0.001	-0.0002	-6.53e-5
	(0.003)	(0.005)	(0.001)	(0.003)	(0.0008)	(0.002)
N	9,641	5,136	9,289	4,755	7,288	6,756

Notes: SE clustered at the county level and are shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The effect of MW hikes on wholesale cannabis prices decreases with scale of production, consistent with high fixed costs of cannabis cultivation (Caulkins et al., 2018) Back

Table 15: Share of retailers' wholesale costs by geographic proximity

	(1) Same city	(2) Same county	(3) Same 3-digit zip code	(4) Same region	(5) Non-contiguous region	(6) Same state
Percent of wholesale expenditures	5.22%	14.67%	15.59%	62.08%	23.90%	100%

Notes: This table shows the share of retailers' wholesale expenditure according to wholesalers' geographic proximity. The shares are based on 5.92 million unique wholesaler-retailer-product-month observations from August 2018 through July 2021. Retailers are located in 14 3-digit zip codes and 35 counties. Region groups counties into three categories: west, central, or east. Data from Top Shelf Data.

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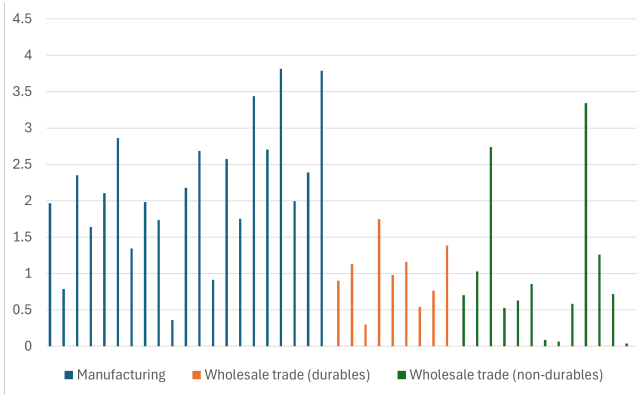

Figure 12: Ratio of out-of-state to within-state commodity flows in the 2017 Commodity Flow Survey

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Theoretical model

- Model similar to Renkin et al. (2020)
  - Homogeneous production function with competitive labor markets
  - Production technology $Q = F(L; X)$, $L = G(L_1, L_2, ..., L_N)$, $X = H(X_1, X_2, ..., X_N)$, with factor prices $P_1, P_2, ...P_N$ and $W_1, W_2, ...W_N$
  - F is homogeneous of degree h; G and H are linearly homogeneous

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Estimating η_L^{mc}

- From FOCs of the firm cost minimization problem, I can derive elasticity of MC wrt MW keeping output constant
- Minimum wage elasticity of marginal cost (via labor cost):

$$\eta_L^{mc} = \frac{\partial MC}{\partial MW}\frac{MW}{MC} = \underbrace{\frac{\overline{W}L}{C}}_{(i)} \cdot \underbrace{\frac{\partial \overline{W}}{\partial MW}\frac{MW}{\overline{W}}}_{(ii)} \tag{7}$$

(i) Retailers' labor share of costs (equals 0.25)

(ii) MW elasticity of the average wage

- Estimate (ii) using TWFE as in (Renkin et al., 2020)

$$\Delta log\overline{W}_{c,q} = \beta \Delta MW \times Bite_{c,q} + \Delta\gamma_t + \Delta\epsilon_{c,q} \tag{8}$$

- $\hat{\beta} = 0.27$ (P-value: .001)

- $\hat{\eta}_L^{mc} = 0.25 \times 0.27 = 0.067$

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Estimating η^{mc}_{cogs}

- Minimum wage elasticity of marginal cost (via COGS):

$$\eta^{mc}_{cogs} = \frac{\partial MC}{\partial MW}\frac{MW}{MC} = \underbrace{\frac{COGS}{C}}_{(i)} \cdot \underbrace{\frac{\partial P_w}{\partial MW}\frac{MW}{P_w}}_{(ii)} \tag{9}$$

(i) Retailers' COGS share of costs (equals 0.75)

(ii) MW elasticity of COGS $= 0.17$ (from main DiD analysis)

- $\hat{\eta}^{mc}_{cogs} = 0.75 \times 0.17 = 0.13$

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