Do consumers prefer the chicken or the egg? The cost of Proposition 12 in California

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Note: All material presented are my own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. The conclusions drawn from the NielsenIQ data are mine and do not reflect the views of NielsenIQ. NielsenIQ is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein. This work used computational and storage services associated with the Hoffman2 Shared Cluster provided by UCLA Office of Advanced Research Computing's Research Technology Group. All errors belong to me.

Introduction

Background:

- California banned all cage eggs in November 2018
- 91% (cage eggs' market share) vs. 62.6% (voted yes)

Questions:

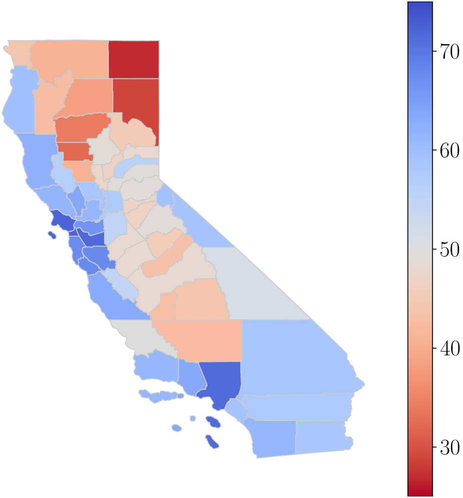
- What was the cost of the ban on cage eggs?
- How did the ban affect different groups of consumers?
- Do consumers vote for policies based on their expected gains/losses?

Approach:

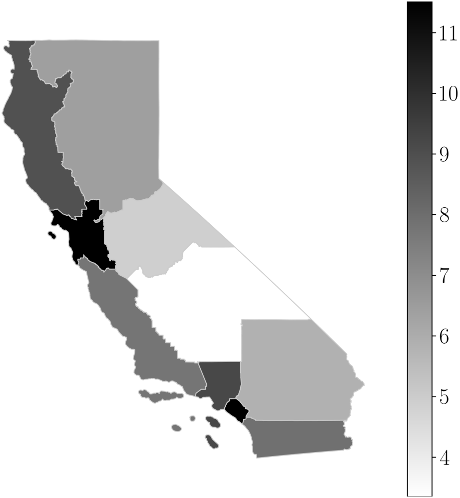
- Estimate consumer demand for different eggs (PyBLP)
- Estimate impact of ban on egg prices (Diff-in-Diff)

Contribution:

- Calculate benefits/costs across counties in California (consumer surplus)
- Compare consumers' expectations of benefits/costs to voting behavior

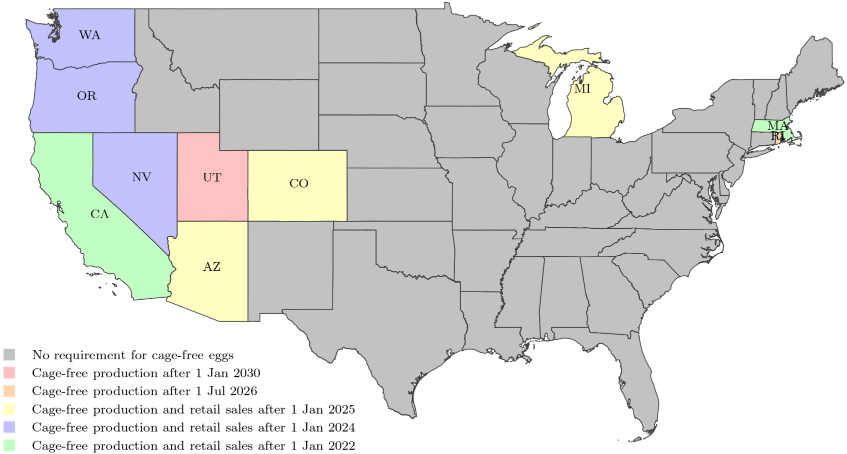


(a) Voted Yes for Proposition 12 (%)



(b) Volume Share of Non-Cage Eggs (%)

To date, 10 US states have some policy on cage eggs



More countries are restricting the use of cages on egg farms

FUTURE PERFECT THE FUTURE OF MEAT

The worst horrors of factory farming could soon be phased out in Europe

Europe is on track to ban cages for farm animals as soon as 2027. The US could take much longer.

By Jonathan Moens | Sep 29, 2021, 1:30pm EDT

New Zealand bans battery cages for hens – but replacement 'just as bad'

Colony cages are larger but animal welfare campaigners say the birds are still not able to behave naturally

Why the 2036 phaseout of cage eggs has Australia's industry in a flap
Calla Wahlquist

A battery egg ban in 13 years is far too soon, say farmers. Animal welfare advocates say it's long overdue

Data

(1) NielsenIQ Retail Scanner Dataset

- Weekly prices and quantities of eggs sold
- Location of store (3-digit zipcode and county)
- Product characteristics (cage, cage-free, organic etc.)

(2) NielsenIQ Consumer Panel Dataset

- Demographics (income, age, education, etc.)
- Purchases of eggs, type purchased, date of purchase, store visited

(3) UC Berkeley California Statewide Database

- Ballot results by voting precinct in California, including Proposition 12 (2018)

Note: The retailer and consumer data can be matched on the store and date.

Random Coefficients Multinomial Logit

A product $j \in \mathcal{J}_t$ is a UPC for eggs; t denotes a market (store and week).

V_{ijt}	Indirect utility of i who chooses j in t
$= (\alpha + \alpha_2 \mathbb{1}_{i \in inc_2} + \alpha_3 \mathbb{1}_{i \in inc_3}) P_{jt} + \beta' \mathrm{X_j}$	$=$ Income $\times$ price $+$ Product features
$+ \gamma_{cg}^{\mathrm{region}(t)} \mathbb{1}_{j \in cg} + \gamma_{cf}^{\mathrm{region}(t)} \mathbb{1}_{j \in cf} + \gamma_{og}^{\mathrm{region}(t)} \mathbb{1}_{j \in og}$	$+$ Different tastes across counties
$+ \sigma_{cg} \nu_{cg(i)} \mathbb{1}_{j \in cg} + \sigma_{cf} \nu_{cf(i)} \mathbb{1}_{j \in cf} + \sigma_{og} \nu_{og(i)} \mathbb{1}_{j \in og}$	$+$ Random household taste shocks
$+ \xi_{jt} + \varepsilon_{ijt}$	$+$ Unobserved terms

Outside Good Instruments Model Fit

Micro Moment	Prob i buys	Conditional on...	Data	Model	Diff.
$E(j = cg \mid \mathbb{1}\{i \in inc_2\})$	Cage eggs	Income (\$40,000 to \$99,999)	0.0848	0.1184	0.0336
$E(j = cg \mid \mathbb{1}\{i \in inc_3\})$		Income (\$100,000 and above)	0.0829	0.1256	0.0427
$E(j = cg \mid \mathbb{1}\{i \in age_2\})$		Age (35 to 64)	0.0831	0.1199	0.0368
$E(j = cg \mid \mathbb{1}\{i \in age_3\})$		Age (65 and above)	0.0836	0.1187	0.0351
$E(j = cg \mid \mathbb{1}\{i \in col\})$		College	0.0827	0.1196	0.0370
$E(j = cg \mid \mathbb{1}\{i \in chd\})$		Children	0.0961	0.1215	0.0254
$E(j = cg \mid \mathbb{1}\{i \in wht\})$		White	0.0851	0.1201	0.0351
$E(j = cf \mid \mathbb{1}\{i \in inc_2\})$	Cage-free eggs	Income (\$40,000 to \$99,999)	0.0056	0.0054	-0.0002
$E(j = cf \mid \mathbb{1}\{i \in inc_3\})$		Income (\$100,000 and above)	0.0077	0.0072	-0.0005
$E(j = cf \mid \mathbb{1}\{i \in age_2\})$		Age (35 to 64)	0.0058	0.0057	-0.0001
$E(j = cf \mid \mathbb{1}\{i \in age_3\})$		Age (65 and above)	0.0036	0.0058	0.0022
$E(j = cf \mid \mathbb{1}\{i \in col\})$		College	0.0057	0.0058	0.0001
$E(j = cf \mid \mathbb{1}\{i \in chd\})$		Children	0.0062	0.0056	-0.0006
$E(j = cf \mid \mathbb{1}\{i \in wht\})$		White	0.0056	0.0058	0.0003
$E(j = og \mid \mathbb{1}\{i \in inc_2\})$	Organic eggs	Income (\$40,000 to \$99,999)	0.0032	0.0041	0.0009
$E(j = og \mid \mathbb{1}\{i \in inc_3\})$		Income (\$100,000 and above)	0.0062	0.0058	-0.0004
$E(j = og \mid \mathbb{1}\{i \in age_2\})$		Age (35 to 64)	0.0039	0.0044	0.0005
$E(j = og \mid \mathbb{1}\{i \in age_3\})$		Age (65 and above)	0.0026	0.0044	0.0019
$E(j = og \mid \mathbb{1}\{i \in col\})$		College	0.0038	0.0046	0.0007
$E(j = og \mid \mathbb{1}\{i \in chd\})$		Children	0.0048	0.0043	-0.0004
$E(j = og \mid \mathbb{1}\{i \in wht\})$		White	0.0037	0.0046	0.0009

Parameter	Estimate	Parameter	Estimate
σ_{cg}: Cage	0.120***	Cage	-6.087***
	[0.006]		[0.017]
σ_{cf}: Cage-free	0.000	Cage-free	-6.324***
	[0.006]		[0.019]
σ_{og}: Organic	0.000	Organic	-6.312***
	[0.014]		[0.019]
α : Price	-0.218***	Brown	-0.516***
	[0.002]		[0.003]
α_2: Price $\times inc_2$	0.014***	Package count	0.005***
	[0.002]		[0.000]
α_3: Price $\times inc_3$	0.053***	USDA Grade A/AA	1.295***
	[0.002]		[0.015]
		Extra large eggs	-0.342***
			[0.002]
		Store brand	0.556***
			[0.002]
Type-by-region fixed effects			
$\gamma_{cg}^{\text{region}(t)}$: Cage $\times$ region(t)			Yes
$\gamma_{cf}^{\text{region}(t)}$: Cage-free $\times$ region(t)			Yes
$\gamma_{og}^{\text{region}(t)}$: Organic $\times$ region(t)			Yes

Robust standard errors reported in brackets.

*** p<0.01, ** p<0.05, * p<0.1

- Eggs are differentiated products; consumers value attributes including cage-free/organic
- Low-income are most price sensitive
- No heterogeneous preferences for cage-free or organic eggs, after accounting for price $\times$ income effects

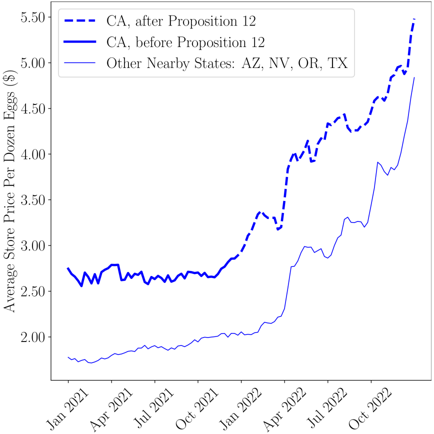
Optimization Details

Region	Own			Cross					
	$\varepsilon_{(cg,cg)}$	$\varepsilon_{(cf,cf)}$	$\varepsilon_{(og,og)}$	$\varepsilon_{(cg,cf)}$	$\varepsilon_{(cg,og)}$	$\varepsilon_{(cf,cg)}$	$\varepsilon_{(cf,og)}$	$\varepsilon_{(og,cg)}$	$\varepsilon_{(og,cf)}$
Superior California	-0.811	-0.864	-0.832	0.004	0.004	0.006	0.004	0.006	0.004
	(0.18)	(0.188)	(0.178)	(0.004)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)
North Coast	-0.875	-0.887	-0.850	0.005	0.005	0.006	0.005	0.006	0.005
	(0.168)	(0.19)	(0.193)	(0.004)	(0.004)	(0.002)	(0.004)	(0.003)	(0.004)
San Francisco Bay Area	-0.820	-0.832	-0.798	0.004	0.004	0.005	0.004	0.005	0.004
	(0.169)	(0.17)	(0.167)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)
Northern San Joaquin Valley	-0.820	-0.858	-0.839	0.003	0.004	0.007	0.004	0.007	0.003
	(0.167)	(0.175)	(0.182)	(0.004)	(0.005)	(0.003)	(0.005)	(0.003)	(0.004)
Central Coast	-0.803	-0.840	-0.804	0.004	0.005	0.007	0.005	0.007	0.004
	(0.174)	(0.2)	(0.192)	(0.004)	(0.005)	(0.003)	(0.004)	(0.003)	(0.004)
Southern San Joaquin Valley	-0.742	-0.831	-0.838	0.004	0.004	0.008	0.004	0.008	0.004
	(0.195)	(0.167)	(0.185)	(0.006)	(0.006)	(0.006)	(0.006)	(0.004)	(0.005)
Inland Empire	-0.721	-0.794	-0.771	0.004	0.005	0.006	0.005	0.006	0.004
	(0.173)	(0.203)	(0.193)	(0.005)	(0.005)	(0.003)	(0.005)	(0.003)	(0.005)
Los Angeles County	-0.734	-0.819	-0.776	0.004	0.005	0.006	0.004	0.006	0.004
	(0.167)	(0.213)	(0.192)	(0.004)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
Orange County	-0.744	-0.805	-0.750	0.004	0.005	0.006	0.005	0.006	0.004
	(0.153)	(0.199)	(0.177)	(0.003)	(0.004)	(0.002)	(0.004)	(0.002)	(0.003)
San Diego-Imperial	-0.766	-0.841	-0.804	0.003	0.004	0.006	0.004	0.006	0.003
	(0.173)	(0.208)	(0.197)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.003)

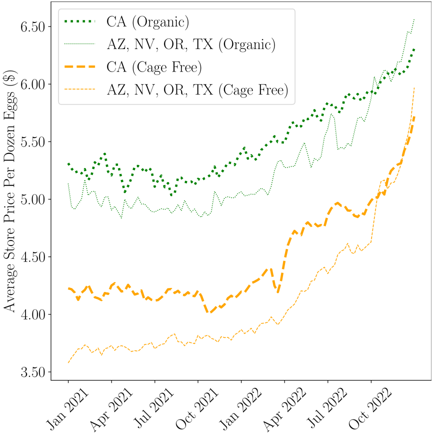
Note: $\varepsilon_{(j,k)} = \%\Delta Q_j / \%\Delta P_k$. Standard deviation reported in parentheses.

What was the impact of Proposition 12 on the price of eggs in California?

- Egg prices increased across the United States in 2022
  - Jan 2022: CA and MA ban on cage eggs
  - Feb - Dec 2022: Bird flu outbreak in US (suppliers mainly in the Midwest)
- I estimate a difference-in-differences regression to **isolate the effect of Proposition 12 on the price of eggs**
  - Treatment group: grocery stores in CA
  - Control group: grocery stores in AZ, NV, OR, TX
- Dependent variable: log (price per 12 eggs); control for product characteristics, year-month, and store fixed effects
  - Treatment = California $\times$ 2022
  - Each observation is a UPC (retailer barcode) of eggs in a given store and week
  - Interact treatment with egg types to estimate price effects separately
  - Break down effects by California region



(a)



(b)

Figure 2: Average (Unweighted) Price of Egg UPCs

Note: Figure 2a consists of all UPCs without cage-free or organic labels.

Difference-in-Differences

$$\log P_{jsw} = \sum_{region=1}^{10} \beta_1^{region} T_{prop12}^{region} + \beta_2^{region} \left(T_{prop12}^{region} \times \mathbb{1}_{j=cf}^{re} \right) + \beta_3^{region} \left(T_{prop12}^{region} \times \mathbb{1}_{j=og}^{re} \right)$$
$$+ \beta_4 \mathbb{1}_{w \in 2022} + \beta_5 \mathbb{1}_{j=cf}^{re} + \beta_6 \mathbb{1}_{j=og}^{re}$$
$$+ \beta' \mathrm{X}_j + \delta_{ym} + \gamma_s + \varepsilon_{jsw}$$

- P_{jsw}: Price per 12 eggs of UPC j in store s and week w
- T_{prop12}^{region}: Treatment effect by region
- $\mathbb{1}_{j=cf}^{re}$,$\mathbb{1}_{j=og}^{re}$: cage-free and organic products that remain
- X_j: product characteristics (cage-free, organic, color, count, grade, size, store-brand)
- δ_t,γ_s: time (Jan-2021, . . . , Dec-2022), store fixed effects
- ε_{jsw}: OLS residual

More

Region	Stores	Observations	Estimates β_1^{region}	β_2^{region}	β_3^{region}	$\%\Delta P$ (i)	(ii)	(iii)
Superior California	157	298,032	0.080***	-0.160***	-0.226***	8.3	-7.7	-13.6
			(0.009)	(0.008)	(0.006)			
North Coast	54	117,155	0.011	-0.139***	-0.222***	1.1	-12.0	-19.0
			(0.014)	(0.011)	(0.010)			
San Francisco Bay Area	303	599,671	0.031***	-0.150***	-0.245***	3.1	-11.2	-19.3
			(0.007)	(0.006)	(0.005)			
Northern San Joaquin Valley	67	118,254	0.136***	-0.198***	-0.257***	14.6	-6.0	-11.4
			(0.008)	(0.007)	(0.006)			
Central Coast	121	221,172	0.071***	-0.193***	-0.285***	7.4	-11.5	-19.3
			(0.017)	(0.018)	(0.016)			
Southern San Joaquin Valley	86	135,405	0.153***	-0.228***	-0.311***	16.5	-7.2	-14.6
			(0.010)	(0.011)	(0.012)			
Inland Empire	232	399,573	0.175***	-0.288***	-0.402***	19.1	-10.7	-20.3
			(0.014)	(0.013)	(0.012)			
Los Angeles County	417	654,675	0.119***	-0.237***	-0.328***	12.6	-11.1	-18.9
			(0.017)	(0.016)	(0.016)			
Orange County	159	285,305	0.109***	-0.237***	-0.336***	11.5	-12.0	-20.3
			(0.023)	(0.022)	(0.021)			
San Diego-Imperial	151	259,524	0.137***	-0.265***	-0.360***	14.7	-12.0	-20.0
			(0.016)	(0.016)	(0.015)			
Arizona, Nevada, Oregon, Texas	1,459	3,022,472						
Total	**3,206**	**6,111,238**						

Robust standard errors reported in brackets.

*** p<0.01, ** p<0.05, * p<0.1

Questions

1. **How did Proposition 12 affect consumer surplus from eggs in 2022, without the bird flu?** → Simulate market with 2021 consumption + estimated counterfactual prices

2. **Can voting behavior can be explained by the expected change in consumer surplus?** → Simulate market with 2017 consumption + estimated counterfactual prices; compare with 2018 vote

Year	Stores	Markets	Households
2017	784	40,582	5,329
2021	969	50,220	4,856

Table 1: No. of Stores, Markets, Households in Simulation

Methodology

For each store:

1. Pool all households that ever visited in the year (purchase data)
2. Take R random draws with replacement to simulate visits to store

For each market t and price scenario P^s:

3. For each product j, calculate $CS^s_{jt} = \frac{1}{R}\sum_{i=1}^{R}\left(-\frac{1}{\alpha_i}\hat{V}_{ijt}(P^s_t)\right)$ (PyBLP estimates)
4. Calculate expected consumer surplus from egg consumption in market t

$$E[CS^s_t] = \sum_{j\in\mathcal{J}^s_t} \omega^s_{jt} CS^s_{jt}$$

   where ω^s_{jt} is a volume-share weight (retailer data + estimates of ε and P^s)

5. Calculate county-level average $E[CS^s]$
6. Plug in prices with/without Prop 12 (DiD estimates)

How did Proposition 12 change consumer surplus?

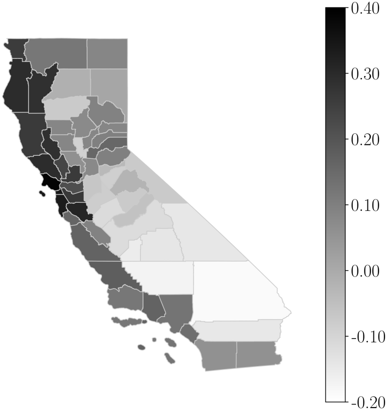


Figure 3: $\Delta E(CS)$ by county, 2021 data

	per HH, per week	CA, annual
$\uparrow P_{cg}$	$-\$0.15$	$-\$1{,}962{,}296$
$\downarrow P_{cf}$	\$0.13	\$1,785,966
$\downarrow P_{og}$	\$0.11	\$1,496,627
Total	\$0.10	\$1,320,298

But Proposition 12 would have reduced consumer surplus in 2017

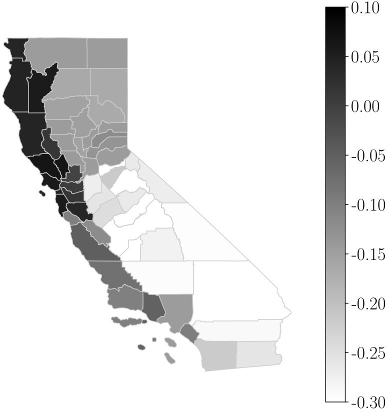
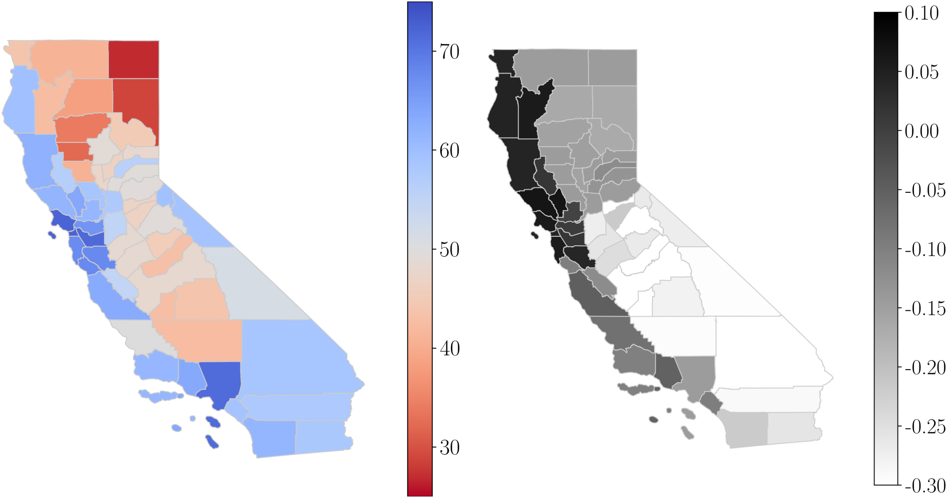


Figure 4: $\Delta E(CS)$ by county, 2017 data

	per HH, per week	CA, annual
$\uparrow P_{cg}$	$-\$0.23$	$-\$2,941,755$
$\downarrow P_{cf}$	$0.03	$437,977
$\downarrow P_{og}$	$0.06	$732,445
Total	$-\$0.14$	$-\$1,771,333$

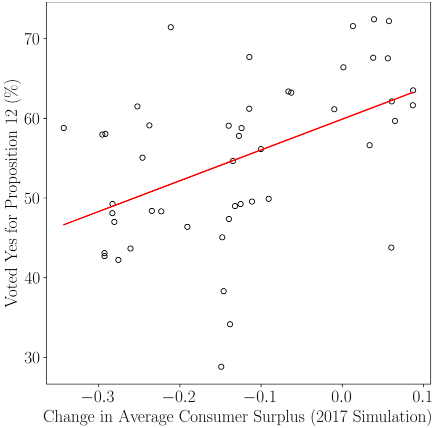
Does change in consumer surplus explain voting behavior?



(a) Voted Yes for Proposition 12 (%)

(b) $\Delta E(CS)$ by county, 2017 data

A 1 SD increase in expected consumer surplus is associated with a 5.7% increase in support for Proposition 12



	Voted Yes for Prop. 12 (%)
$\Delta E(CS)$	44.24***
	(9.81)
Constant	60.89***
	(1.81)
Observations	48
R-squared	0.307

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

More

Appendix

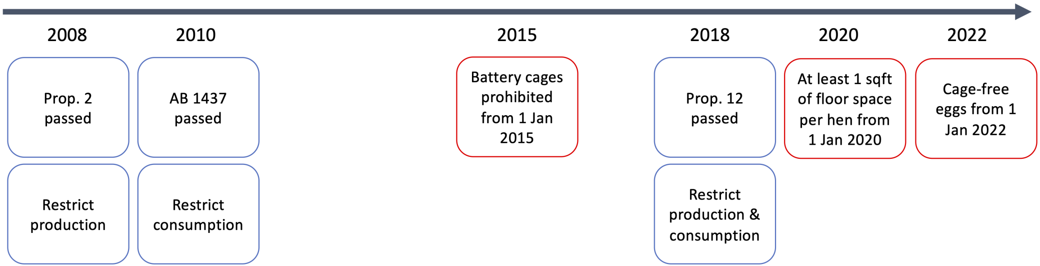


Figure A1: Timeline of Policy Changes

Clockwise from top left: battery cage, enriched colony, aviary (barn), free-range/pasture-raised

Clockwise from top left: battery cage, enriched colony, aviary (barn), free-range/pasture-raised

Clockwise from top left: battery cage, enriched colony, aviary (barn), free-range/pasture-raised

Type of Hen Housing	Cage: Battery Cage[1]	Cage: Enriched Cage[2]	Cage-free: Aviary	Cage-free: Free-range	Cage-free: Pasture-raised
Min. space per hen (sq ft)	0.5	0.8	1	2*	108*
Perching/scratching	×	✓	✓	✓	✓
Access to outdoors	×	×	×	✓	✓
Unit cost[3] ($)	0.670	0.756	0.913		

[1] Banned in California by Proposition 2 with effect from 1 January 2015.

[2] Banned in California by Proposition 12 with effect from 1 January 2022.

[3] Capital and operating costs per dozen eggs (Matthews & Sumner, 2015).

* Refers to outdoor space where hens spend at least 6 hours per day.

Table A1: Key Characteristics of Hen Housing Systems

Figure A2: California Counties and Census Regions

Year	Vol. (m)	Market Share (%)			Avg Price per Dozen ($)		
		Regular	Cage-free	Organic	Regular	Cage-free	Organic
2011	1063	98.1	0.9	1.0	2.14	4.41	4.74
2012	1035	97.5	1.2	1.3	2.11	4.38	5.01
2013	1026	97.0	1.5	1.5	2.19	4.25	4.70
2014	970	95.9	2.2	1.9	2.49	4.45	4.97
2015	924	93.2	4.0	2.8	3.73	5.19	5.74
2016	978	93.0	4.6	2.4	2.77	4.97	5.84
2017	949	91.4	4.6	4.1	2.40	5.00	5.61
2018	1397	90.9	5.0	4.1	2.71	5.11	5.59
2019	1587	90.5	5.2	4.3	2.47	5.03	5.58
2020	1786	88.4	6.5	5.1	2.64	5.05	5.74
2021	1523	57.7	31.9	10.5	2.59	5.21	5.82
2022	1426		88.7	11.3		4.02	6.41

Table A2: Retail Sale of Eggs in California Grocery Stores

1. Cage-free eggs refer to products with 'cage-free', 'free-range', or 'pasture-raised' labels
2. All organic eggs are cage-free by definition

	Households		Grocery Shopping Trips	
Year	All	Purchased Eggs (%)	All	Purchased Eggs (%)
2011	5,314	4,343 (81.7%)	309,386	33,294 (10.8%)
2012	5,466	4,317 (79.0%)	300,817	32,925 (10.9%)
2013	5,584	4,151 (74.3%)	293,670	29,901 (10.2%)
2014	5,558	4,045 (72.8%)	288,566	27,659 (9.6%)
2015	5,452	3,917 (71.8%)	276,971	25,571 (9.2%)
2016	5,248	4,059 (77.3%)	273,136	28,056 (10.3%)
2017	5,365	4,132 (77.0%)	277,795	31,159 (11.2%)
2018	5,276	3,891 (73.7%)	273,215	28,736 (10.5%)
2019	5,243	3,881 (74.0%)	275,338	29,727 (10.8%)
2020	4,865	3,765 (77.4%)	263,211	28,307 (10.8%)
2021	4,668	2,968 (63.6%)	157,491	16,797 (10.7%)
2022	4,370	2,524 (57.8%)	147,924	13,206 (8.9%)

Table A3: Frequency of Egg Purchases in California

		2021 Consumption (%)		
		Regular	Cage-free	Organic
All Households		69.3	26.1	4.6
Income	Less than $40,000	73.6	22.9	3.4
	$40,000 to $99,999	70.9	25.7	3.5
	Above $100,000	65.7	28.2	6.1
Age	Less than 35	71.6	21.8	6.6
	35 to 64	69.4	26.3	4.4
	65 and above	68.1	27.4	4.5
Education	High School and below	74.0	23.9	2.1
	College and above	67.9	26.8	5.4
Children	No	68.6	26.4	5.0
	Yes	70.5	25.6	3.8
Race	Non-white	70.3	24.5	5.2
	White	68.7	27.0	4.3

Table A4: Egg Consumption in California by Type of Household

Year	Type	No. of UPCs (Vol. Share) Remain	Switch	Exit	Enter	Total
2021	Cage		88 (52.98%)	35 (1.42%)		336
	Cage-free	133 (33.44%)		15 (0.04%)		
	Organic	53 (11.89%)		12 (0.23%)		
2022	Cage-free	133 (73.07%)	88 (10.44%)		42 (4.01%)	327
	Organic	53 (12.15%)			11 (0.32%)	

Table A5: Entry and Exit of Egg UPCs in California

$\log P_{jsw}$	(a)	(b)	(c)	(d)
T_{prop12}	-0.095***	0.032***	0.063***	0.093***
	(0.003)	(0.005)	(0.005)	(0.006)
$T_{prop12} \times \mathbb{1}^{re}_{j=cf}$		-0.137***	-0.169***	-0.205***
		(0.004)	(0.004)	(0.006)
$T_{prop12} \times \mathbb{1}^{re}_{j=og}$		-0.243***	-0.271***	-0.298***
		(0.004)	(0.004)	(0.005)
$\mathbb{1}_{s \in CA}$	0.286***	0.243***	0.243***	
	(0.004)	(0.004)	(0.004)	
$\mathbb{1}_{w \in 2022}$	0.274***	0.269***	0.300***	0.301***
	(0.002)	(0.002)	(0.003)	(0.003)
$\mathbb{1}^{re}_{j=cf}$		0.280***	0.280***	0.278***
		(0.004)	(0.004)	(0.003)
$\mathbb{1}^{re}_{j=og}$		0.499***	0.500***	0.488***
		(0.003)	(0.003)	(0.003)
Controls	Yes	Yes	Yes	Yes
Year-month fixed effects			Yes	Yes
Store fixed effects				Yes
Observations	6,111,238	6,111,238	6,111,238	6,111,238
Number of stores	3,206	3,206	3,206	3,206
R-squared	0.567	0.642	0.675	0.711

Robust standard errors reported in brackets.
Standard errors are clustered by stores.
*** p<0.01, ** p<0.05, * p<0.1

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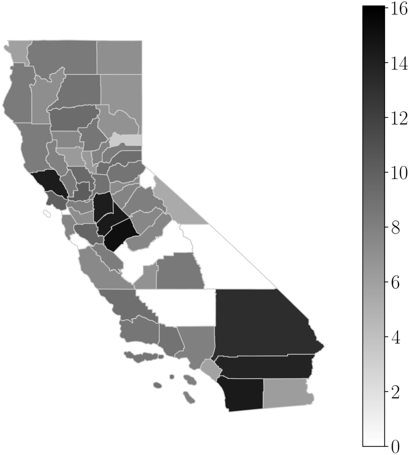
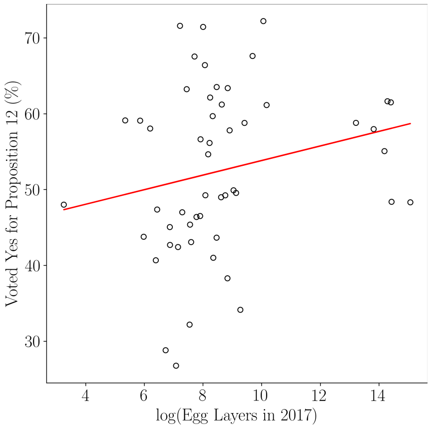


(a) log(Egg Layers in 2017)



(b) Prop 12 Vote vs. Egg Production

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	Size of Egg-laying Flock	%
Merced County	3,410,713	33.9
San Joaquin County	1,242,185	12.3
Sonoma County	1,196,304	11.9
San Diego County	1,094,318	10.9
Riverside County	984,579	9.8
Stanislaus County	972,924	9.7
San Bernardino County	860,010	8.5
California	10,060,125	100
United States	388,509,039	

Figure A4: Top Egg Producing Counties by Flock Size

Outside Good

- Outside good : no purchase of eggs
- I can write the market share of product j in market t as

$$share_{jt} = \underbrace{\Pr\left(i \text{ bought } j \text{ from } t \mid i \text{ bought eggs from } t\right)}_{\text{Taken from retailer data: Volume } (j_t)/\text{Volume } (\mathcal{J}_t)} \times \underbrace{\Pr\left(i \text{ bought eggs from } t\right)}_{\text{Not directly observed}}$$

- I use a linked subsample of grocery store trips (includes no eggs purchased):

$$\hat{\Pr}(i \text{ bought eggs from } t) = \frac{\text{No. HHs bought eggs in } region(t) \text{ and } week(t)}{\text{No. HHs bought groceries in } region(t) \text{ and } week(t)}$$

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Instruments

Instrument	No.	Source
Ban on 'battery cages' in 2015	1	
Store promotions	2	NielsenIQ
Monthly corn prices	1	USDA
Monthly soybean prices	1	USDA
Weekly prices of US highway diesel	1	US EIA
Average price of product in other markets	1	Methodology
Optimal instruments $\mathbb{Z}^{opt} = E\left(\frac{\partial \xi_{jt}}{\partial \theta} \middle| \mathbb{Z}\right)$	1	Reynaert and Verboven (2014)

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Hausman Price

- For each market t,
  - Define a group of markets $\mathcal{G}(t)$ based on the 3-digit zipcode of the store
  - $t' := \{\mathcal{G}(t) \setminus t\}$
  - P_{jt}: price of product j in market t
  - Q_{jt}: quantity of product j in market t
- Calculate the average price of product j in markets t' with a 'leave out' method

$$P_{jt}^{Hausman} = \frac{\left(\sum_{s\in\mathcal{G}(t)} P_{js}Q_{js}\right) - P_{jt}Q_{jt}}{\left(\sum_{s\in\mathcal{G}(t)} Q_{js}\right) - Q_{jt}}$$

$$\text{Hausman price} = \frac{\text{Group revenues} - \text{Store revenues}}{\text{Group quantities} - \text{Store quantities}}$$

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Model Fit

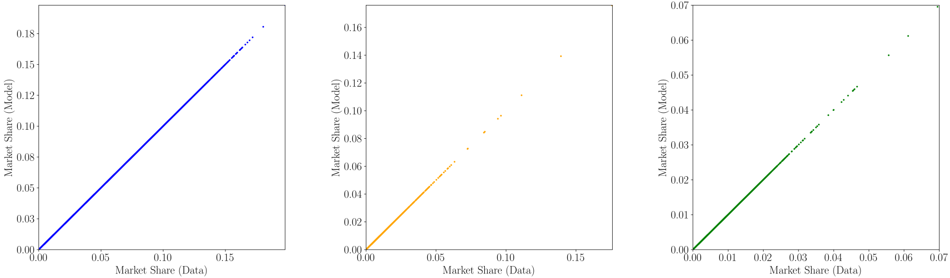

Figure A5: Model Predicted Market Shares vs. Data

Each dot represents a product from a store-week in California from 2014 to 2015.

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Key statistics from L-BFGS-B routine:

Number of products across all markets	1,471,579
Number of markets (store-weeks)	92,143
Optimizer converged	Yes
gtol	1.00×10^{-5}
ftol	1.00×10^{-5}
GMM objective value	7.60×10^{3}
Optimization iterations	38
Objective evaluations	58
Computation time (HH:MM:SS)	13 : 39 : 38

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Matthews, W. A., & Sumner, D. A. (2015). Effects of housing system on the costs of commercial egg production. *Poultry Science*, *94*(3), 552-557.

Reynaert, M., & Verboven, F. (2014). Improving the performance of random coefficients demand models: the role of optimal instruments. *Journal of Econometrics*, *179*(1), 83-98.