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Putting the Chicken Before the Egg Price: An *Ex Post* Analysis of California's Battery Cage Ban

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California legislation outlawed the use and sale of battery cages for egg-laying hens in 2015. While a number of *ex ante* studies projected the effects of the housing prohibitions, the ultimate *ex post* effects are unknown. Using a price series reported by the USDA, we study the movement of daily egg prices in California and the United States before and after the law's implementation. Depending on the methods used, we find that Californians now pay between $0.48 and $1.08 more for a dozen eggs. The estimates suggest an annual reduction in California consumer surplus of between $400 million and $850 million.

Key words: animal welfare, cage free, egg, organic, Proposition 2, time series econometrics

Introduction

Although California's Prevention of Farm Animal Cruelty Act (Proposition 2) passed in 2008, debates about the effects of the measure continue to rage. Although less than 10% of all California egg sales had been cage free or organic before the vote, 63.5% of California voters opted to ban caged eggs (Norwood and Lusk, 2011). At the beginning of 2015, this act and corresponding Assembly Bill (AB) 1437 eliminated "battery cages" for egg-laying hens in the state. Whereas Proposition 2 outlawed the production of battery-cage eggs, AB 1437 went further and outlawed the sale of such eggs in the state (hereafter, we jointly refer to the two laws as Proposition 2). The new regulations specify a minimum amount of 116 square inches of floor space per bird (California Department of Food and Agriculture, Animal Health and Food Safety Services, 2015) as opposed to the industry standard of approximately 67 square inches (Laird, 2014). Essentially, producers had to make the choice between converting their operation to cage-free barn systems, adopting larger "colony cages," or reducing stocking density in existing cages (Laird, 2014). Production costs associated with these alternative, cage-free egg production systems are approximately 40% more than the common cage systems (Sumner et al., 2008; Coalition for a Sustainable Egg Supply, 2015).

After California implemented the law in early 2015, media commentators attempted to ascertain the effects, claiming that the law's implementation increased egg prices by $2/dozen or more (Karol, 2015; Wall Street Journal, 2015). One of the challenges of such casual observations is that they ignored the fact that national egg prices rose at the same time the law went into effect in California (see figure 1). Adding to the inference problem, other events such as the outbreak of avian influenza in the Midwest subsequently led to volatility in egg prices in California and nationwide (Gee, 2015; Parsons, 2015; U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 2015).

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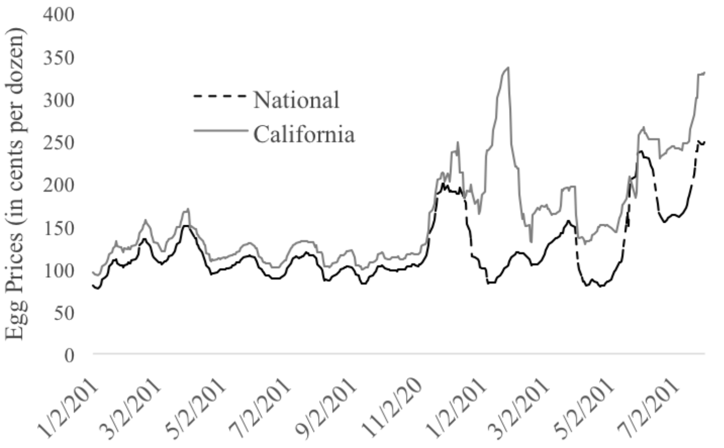

Figure 1. National and California Prices of White Large-Graded Loose Shell Eggs (in cents)
Source: USDA AMS National Shell Egg Index Price Report.

Despite these challenges, determining the actual effect of these egg laws is of high interest to other policy makers, consumers, and producers, as these effects have implications relevant to other governing bodies. Michigan and Ohio residents have passed their own restrictions on battery cages, and for a time the United Egg Producers and the Humane Society of the United States lobbied to pass federal legislation that would have phased out the use of the smallest battery cages. These ballot initiatives have even earned the attention of Congress. Although eventually defeated, the U.S. House of Representatives version of the 2014 Farm Bill included Section 12312, also known as the "King Amendment," which would have mandated that states could not regulate animal products produced in other states (Greene and Cowan, 2014; Kangas, 2014).

Naturally, egg producers are acutely concerned about the effects of such laws (United Egg Producers, 2009). Early research forecasted that most consumers would not bear increased production cost; rather, Proposition 2 would nearly eliminate poultry production in California (Sumner et al., 2008). Producers were concerned about an "unfunded mandate" that would require them to adopt more costly housing systems without the potential for a corresponding increase in demand. California producers responded by securing passage of a state law in 2010 (AB 1437) that also banned grocery stores from selling eggs that did not meet the new California standard. State attorneys general from Missouri, Nebraska, Alabama, Iowa, Kentucky, and Oklahoma challenged the law, primarily claiming that it protected California egg producers from interstate commerce and that no strong evidence links *Salmonella* to cage size or stocking density, but their attempts have so far been unsuccessful. The district court dismissed the suit and held that egg farmers, as opposed to the citizens of the state, were the relevant parties in the case (Wilson, 2014; Keady, 2015).

While such laws are drafted to affect animal welfare, the welfare effect on consumers depends on the extent to which egg prices rise. It is typically thought that there are few good demand substitutes for eggs, making demand highly inelastic (Kastens and Brester, 1996; Andreyeva, Long, and Brownell, 2010; Okrent and Alston, 2011). As such, even small changes in the cost of production could result in large changes in the retail price for eggs. To date, no rigorous *ex post* analysis has been published on the effects of such policies on egg prices. We are aware of only one other study targeted at estimating *ex post* changes in egg prices due to Proposition 2. Mullally and Lusk (2015) used retail scanner data to compare prices and quantities in three California markets (Los Angeles, San Francisco, and San Diego) to determine the overall economic consequences of the egg policy. Using a different dataset and employing a different approach, the authors found that the policy increased the price of eggs by over 20%. One benefit of our current approach is that we focus our analysis on data collected by the USDA to be representative of prices throughout the state of

California. Furthermore, our dataset extends to July 30, 2015, while the scanner data analyzed by Mullally and Lusk (2015) concludes in April, 2015.

The primary objective of this study is to provide an *ex post* estimate of Proposition 2's effects on egg prices. We utilize two different approaches, both of which rely on calculating a difference in differences (DD). We analyze how the spread between United States and California egg prices before January 1, 2015, compares with the same difference after that date. The first approach relies on a straightforward application of an econometric model fit to a reduced-form equation for the difference in egg prices between California and the United States. The second approach uses a time-series vector autoregressive model fit to data before January 1 to forecast counterfactual California and U.S. egg prices that would have been expected in the absence of the new law. The differences between the observed and counterfactual prices provide an estimate of the policy's impact. Regardless of the approach used, we find the law had a statistically and economically significant impact on California egg prices, ranging from about \$0.48 to \$1.08/dozen, representing anywhere from a 33% to a 70% price increase.

Background

Before a food policy is implemented, it is commonplace to forecast the effects *ex ante* using survey or experimental data; there have been such analyses of battery cage bans. One of the inputs used in such projections is consumer willingness-to-pay. Using an online choice experiment, Heng, Peterson, and Xianghong (2013) found that consumers perceive the basic living needs of hens to be the most important factor in layers' welfare. Using nationally representative survey data, the authors estimated that 85% of consumers were willing to pay about \$0.49/dozen more for cage-free eggs. Richards, Allender, and Fang (2013) used non-hypothetical experimental auctions and found a 65% value premium for cage-free eggs, while Norwood and Lusk (2009) used a similar approach and found a 70% value premium.

Even if consumers are willing to pay a premium for these types of eggs, research suggests that they do not understand standard production practices of the egg industry. Norwood (2012) notes, "if the numbers... are correct, and if they reflect consumer preferences at all times and in all contexts, there would be no need for Proposition 2, as grocery stores would readily sell cage-free eggs..." For example, one group of consumers believed on average that 37% of eggs were raised in cage systems, even though in reality more than 90% were (Lusk, 2011). It might be that this lack of knowledge that encouraged nearly 60% of consumers to agree that the government should "pass and enforce anti-cruelty legislation" (Norwood and Lusk, 2009).

Other *ex ante* studies have used secondary data to estimate changes in consumer and producer surplus resulting from animal welfare policies (Chang, Lusk, and Norwood, 2010). Allender and Richards (2010) used scanner data to estimate the *ex ante* welfare impacts of a change in egg prices due to the policy change. They found that only about 21% of households were willing to pay the premium for cage-free eggs, and they argued that the effect of the policy would be highly regressive. They projected that large households with lower incomes would experience the largest welfare loss from the policy change. Norwood and Lusk (2011) used equilibrium displacement models to project the consumer and producer surplus effects of a ban on battery cages. They calculated that converting all cage eggs to cage free in the United States would result in a \$1.87 billion decline in consumer surplus and a \$187 million decline in producer surplus, assuming no consumer demand shift in response to change in type of eggs sold.[1]

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[1] There is limited evidence on the extent to which the passage of such a policy might influence aggregate egg demand. Lusk (2010) showed that the debate leading up to Proposition 2 in California caused an increase in demand for cage-free and organic eggs. However, it is unclear how these estimates might correspond to a situation in which the policy ultimately goes into effect without the knowledge of many consumers and the cage free (or larger cage) eggs are now the commodity egg rather than a premium variety. As will be discussed in more detail later, there is no good evidence that California egg demand increased as a result of the new laws; instead, it seems to have remained constant over this period.

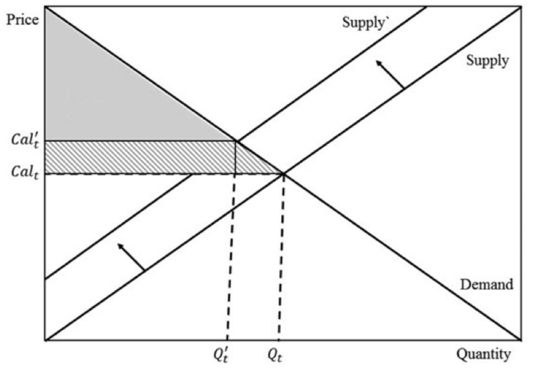

Figure 2. Effects of a Supply Shift Caused by Implementation of Proposition 2

Conceptual Framework

The passage and implementation of Proposition 2 is expected to increase the cost of production (Sumner et al., 2008, 2010, 2011). As shown in figure 2, the added cost of production shifts the California egg supply curve from $Supply$ to $Supply'$. As a result, prices will increase from Cal_t to Cal_t' and quantity consumed will decrease from Q_t to Q_t', causing a decrease in consumer surplus. The intersection of the supply and demand curves results in an equilibrium price, which is a function of the underlying demand and supply variables. Likewise, the intersection of aggregate supply and demand curves in the United States determines the nationwide price, and a nationwide reduced-form price equation can be specified as a function of the underlying supply and demand variables. Assuming consumers do not demand more eggs because of the policy, the change in consumer surplus from the policy change (ΔCS) is

$$(1) \qquad \Delta CS = [(Cal_t' - Cal_t) \times Q_t'] + \frac{1}{2}[(Cal_t' - Cal_t) \times (Q_t - Q_t')].$$

Rather than (at least initially) focusing just on the price that prevails in California, we focus on the spread in prices between California and the United States. Most eggs have a shelf life of three to five weeks, making the product easy to ship across state borders (U.S. Department of Agriculture, Food Safety and Inspection Service, 2011). By focusing on the difference between California and U.S. egg prices, we can partially control for any demand or supply shift that jointly affects demand and supply factors in both locations. The law of one price would suggest that arbitrage opportunities would eliminate price differences between California and other locations except for transfer costs, such as transportation costs and artificial barriers to entry. Thus, focusing on the difference between prices in two locations partially controls for issues raised by the avian influenza as well as the drought;[2] both of which have the potential to raise prices overall.

However, changes in variables that affect arbitrage opportunities (such as transportation costs or the cost of holding inventory) will affect the price spread. Moreover, unique demand or supply shifts that occur only in California and not in the rest of the United States, which would increase or decrease the difference in egg prices, are possible. The implementation of Proposition 2, for example, would represent a supply shock unique to California. This supply shock cannot be easily offset by arbitrage since producers in other states would presumably not (at least initially) be in compliance with California's hen-housing laws. Differential demand shocks would occur if, for example, incomes increased or fell in California more than was the case in the rest of the United

[2] For the results to be invalidated by California's drought, both the policy and the drought would have to have started at the same time. By contrast, California's drought has been ongoing since 2012 (California-Nevada Climate Applications Program, 2014). One benefit to only using data from 2014–2015 is that it avoids confounding results with the agricultural consequences of the California drought.

Table 1. Descriptive Statistics for National and California Large Graded Loose Shell Eggs for Before and After Implementation of Proposition 2 (cents/dozen)

	Before Implementation			After Implementation		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
National	113.51 (27.64)	76.51	199.98	138.59 (49.70)	79.08	248.80
California	131.05 (31.17)	92.04	247.70	209.00 (57.33)	129.01	335.17
Price Difference	17.54 (9.82)	−7.17	75.52	70.41 (51.03)	−27.03	232.05

Notes: Number of observations before and after implementation 256 and 147, respectively. "Before Implementation" includes data from January 2, 2014, until December 31, 2014, while "After Implementation" includes data from January 2, 2015, to July 30, 2015. The USDA does not provide data on holidays and weekends. Numbers in parentheses are standard deviations.

States. As such, the difference in the price of eggs in California and the United States will be a function of the cost of arbitrage, the implementation of Proposition 2 (a unique supply shock to California), and changes in other demand factors (like income) in California compared to the United States.

Data and Methods

Data

Our analysis primarily focuses on movements in daily egg prices (cents/dozen) obtained from the Agricultural Marketing Service of the USDA from January 2, 2014, through July 30, 2015 (U.S. Department of Agriculture, Agricultural Marketing Service, 2015). Around January 1, 2015, the AMS began reporting both California and U.S. price series in their online daily National Shell Egg Index Price Report. We contacted the AMS and obtained the data going back to January 2, 2014. Data from January–July 2015 were hand-collected from the AMS daily reports, which are posted for all federal workdays. About 93% of California egg production is shell eggs (Sumner et al., 2008), so we used California and National weighted average price estimates of white large-graded loose shell eggs. Figure 1 shows the price series for California and for the United States. The two series tracked each other closely until January 1, 2015, when Proposition 2 went into effect.

Methods

To provide a more robust investigation into the issue, we use two different approaches to identify the effect of the implementation of Proposition 2 on California egg prices. Both approaches rely on a difference in differences estimate to identify the effect.

Approach 1

Approach 1 relies on the reduced-form price equations motivated in the conceptual framework. Because the difference between California and the U.S. average is of focal importance to our methods, we select demand shifters available for both geographic regions that may affect the difference in prices between the two locations. The potential for differential demand shifts was measured by calculating the difference in the average hourly earnings of all employees in California and the United States as reported by the Bureau of Labor Statistics. In addition, we calculated the difference in the unemployment rate in California and the aggregate United States using data from the Bureau of Labor Statistics. Data on hourly earnings and unemployment were only available as monthly measures (Bureau of Economic Analysis, 2015). Variables that could serve as proxies for costs of arbitrage are the cost of fuel, the cost of storage and inventory, and the cost of feed (which represents a substantial cost of storage and inventory). Nationwide weekly prices for diesel fuel (\$/gallon) were obtained from U.S. Energy Information Administration. Daily values were determined through linear interpolation. Daily data on commercial interest rates (30-Day AA Financial Commercial Paper Interest Rate) were obtained from the Federal Reserve. We also obtained USDA data on corn prices (\$/bushel) from the Livestock Marketing Information Center associated with Chicago export grain bids.

By mid-February 2015, cases of avian influenza began to be reported in chicken flocks. While the outbreak did not affect any egg-laying hens in California, the states of Iowa, Minnesota, South Dakota, Wisconsin and Nebraska lost more than 40 million birds during the time series. It might be possible that the national price of eggs would increase and the California price would remain relatively unaffected. This supply shock should be somewhat controlled for by the difference in differences (DD) approach used here; however, there might be some residual effects in the differences between California and U.S. prices. To control for the effects of the outbreak, we obtained data on the number of chickens confirmed to have an avian influenza, as monitored by the Animal and Plant Health Inspection Service of the USDA. For each time period, we deleted all backyard outbreaks and outbreaks associated with turkeys and then calculated the cumulative number of birds infected (in millions) up to the date in question.

For this approach, we use OLS regressions to estimate variations of the following general model:

$$
\begin{aligned}
P_{CA,t} - P_{US,t} &= \gamma_0 + \gamma_1 Prop2_t + \gamma_2 pdiesel_t + \gamma_3 ir_t + \gamma_4 pcorn_t \\
&\quad + \gamma_5(w_{CA,t} - w_{US,t}) + \gamma_6(ur_{CA,t} - ur_{US,t}) + \sum_{k=1}^{11}\beta_k m_k + \sum_{j=1}^{4}\alpha_j d_j + \varepsilon_t,
\end{aligned} \tag{2}
$$

where the dependent variable, $P_{CA,t} - P_{US,t}$, is the difference in the price of eggs in California and the United States in time period t; $Prop2_t$ is a dummy variable that takes a value of 1 after January 1, 2015, and 0 beforehand; $pdiesel_t$, ir_t, and $pcorn_t$ are the prices of diesel fuel, interest, and corn; $w_{CA,t} - w_{US,t}$ is the difference in the hourly wage rate in California and the United States; $ur_{CA,t} - ur_{US,t}$ is the difference in the unemployment rate in California and the United States; m_k are monthly dummy variables; d_j are dummy variables indicating the day of the week (there are no data on weekends); and the γ's, β's, and α's are parameters to be estimated.

Like most DD methods, of primary interest is the sign and significance of γ_1, which represents the comparison of the difference in U.S. and California egg prices before and after the implementation of Proposition 2. The most basic estimation process is valid under the assumption that the price difference would have been constant between California and the United States had the policy not been implemented (Bertrand, Duflo, and Mullainathan, 2004). Unlike many DD papers, however, we are interested in the price difference of a product that can be easily shipped. Thus, our control variables deal primarily with factors that might change the rate of arbitrage between California and the rest of the United States across time and across space. For robustness and for sensitivity checks, several variations of equation (2) are estimated with one or more of the parameters set to zero. We also tested for seasonal effects following the approach proposed by Arnade, Pick, and Gehlhar (2005) but find monthly fixed effects that fit the data better than sine and cosine seasonal specification.

Approach 2

The reduced-form econometric model in equation (2) estimates the impact of Proposition 2 using a dummy variable identifying the California supply shock while controlling for other possible confounding factors. The time series nature of the data might result in serial autocorrelation that

Table 2. Factors Affecting the Difference in California and National Egg Prices (January 2, 2014–July 30, 2015)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept6a	17.536*	16.560*	−203.880*	1624.914*	1694.502*
	(1.992)	(6.117)	(82.281)	(134.557)	(151.179)
Proposition 2 Enforced	52.869*	55.435*	108.612*	96.789*	92.891*
	(3.299)	(2.962)	(24.483)	(18.905)	(19.295)
Diesel price	–	–	30.700	−77.923*	−80.390*
			(22.053)	(17.294)	(17.465)
Interest rate	–	–	83.292	−22.707	−26.173
			(77.132)	(57.047)	(57.149)
Corn price			30.788*	−13.587*	−17.267*
			(4.930)	(5.149)	(6.308)
Wage difference	–	–	–	−97.248*	−100.631*
				(5.893)	(6.779)
Unemployment rate difference	–	–	–	221.035*	225.459*
				(18.352)	(18.868)
Cumulative bird flu cases	–	–	–	–	0.099
					(0.098)
Day of the week effects	No	Yes	Yes	Yes	Yes
Month effects	No	Yes	Yes	Yes	Yes
Number of Parameters	2	17	20	22	23
Number of Observations	402	402	402	402	402
R^2	0.390	0.626	0.667	0.821	0.822
Adjusted R^2	0.386	0.608	0.649	0.810	0.810

Notes: Single asterisks indicate statistical significance at the 0.05 level or lower. Numbers in parentheses are standard errors.
[a] The intercept reflects the pre-Proposition 2 price difference; except for Model 1 on Wednesday in September, when other explanatory variables are zero.

would violate assumptions of those ordinary least squares estimates. For a more robust investigation into this issue, we also consider a completely different approach to identify the effect of the implementation of the egg laws. In particular, we estimate vector autoregressive (VAR) models for California and U.S. egg prices using only data before Proposition 2 went into effect. We then use this model to predict future egg prices, in essence creating a counterfactual scenario that might have occurred had Proposition 2 not gone into effect. By comparing the actual prices to those we predict would have occurred in the absence of Proposition 2, we can identify the effects of the policy. The advantage of this approach is that it makes no structural assumptions about the avenue through which Proposition 2 affects egg prices, relying on reduced-form correlations across time and variables to predict future values.

Ultimately, after some specification testing,[3] the following VAR models were estimated for each location k =CA and US:

$$P_{k,t} = \delta_{k,0} + \sum_{k=1}^{2}\sum_{j=1}^{8}\delta_{k,j}P_{k,t-j} + \delta_{k,9}pdiesel_t + \delta_{k,10}pcorn_t + \sum_{j=1}^{11}\varphi_{k,j}m_j + \epsilon_{k,t}, \quad (3)$$

where $P_{k,t}$ is the price of eggs in location k (either California or the United States) in time t. Thus, equation (3) models the price of eggs in a location as a function of eight lags of egg prices in that location and eight lags of prices in the other location in addition to the same period prices of diesel and corn and monthly dummy variables. We checked the model for stationarity by calculating

[3] To identify the appropriate lag length, we ran models with multiple numbers of lags and selected the lag length that minimized the AIC.

the eigenvalues associated with the sixteen lagged price coefficients and found the modulus of the eigenvalues to be less than one, indicating that the series are stationary.

Equation (3) was estimated using only data before Proposition 2 was implemented (prior to January 1, 2015). Once the estimates were obtained, they were used to forecast daily egg prices going forward from January 1 to July 30, 2015. Let $\hat{P}_{CA,t}$ and $\hat{P}_{US,t}$ be the forecasted prices for California and the United States at some period t after the policy was in place. Also, let $\overline{P}_{CA,t}$ and $\overline{P}_{US,t}$ be the actual, realized values observed on date t. The projected impact of the policy on date t can be calculated as

$$(4) \qquad Prop2Impact_t = (\overline{P}_{CA,t} - \overline{P}_{US,t}) - (\hat{P}_{CA,t} - \hat{P}_{US,t}).$$

Equation (4) measures the difference in actual California and national egg prices and the predicted (or counterfactual) difference that would have prevailed in the absence of the implementation of Proposition 2. The mean effect can be determined by calculating equation (4) for each out-of-sample period in question and averaging across all periods.

Results

All models indicate that the difference between egg prices in California and the United States is at least 48 cents more than it would have otherwise been. Table 2 shows the results from the first approach, which suggest that the implementation of Proposition 2 caused California egg prices to increase by 53–109 cents per dozen compared to the price beforehand. The simplest model that only includes the time period dummy variable estimates the cost of the law to be about 53 cents. Adding parameters that control for other changes in arbitrage possibilities increased the policy's effects. This occurs, for example, because the price of diesel fuel fell at about the same time the policy went into effect. The results in models 3–5 suggest that, had these changes not occurred, the effect of the implementation of Proposition 2 would have been much larger. Based on adjusted R^2 values, model 4 appears to have the best fit, and it estimates Proposition 2's effects to be approximately 97 cents per dozen eggs. This estimate is somewhat higher than that of Mullally and Lusk (2015), although the differences might be partially explained by the representativeness and time series of our dataset.

The signs on some of the coefficients on the control variables in models 4 and 5 are counterintuitive. This is perhaps not terribly surprising since this is a reduced-form model and we do not have a clear identification strategy regarding these variables that would yield structural interpretations. By contrast, we have a good identification strategy for the effect of Proposition 2, and the effect is significant and positive (and similar to the results from the entirely different second approach discussed below) across all the model specifications.

The second approach uses a Vector Auto Regression (VAR) model to forecast what prices might have been without the law's implementation. Table 3 reports the estimates of the VAR model. Using this model, we forecasted a counterfactual scenario predicting what the price difference would have been without the law's implementation. Figure 3 reports the predicted difference in California and U.S. egg prices that would have prevailed in the absence of the law's implementation. As shown in figure 3, the predicted counterfactual price difference lies almost exclusively below the actual price difference except for a few days in June. If the predictions were simply inaccurate, we would have expected forecasts above and below the actual, observed values, but because the predicted difference is systematically below the observed differences, we can be reasonably confident that the effect is due to the implementation of Proposition 2.

Using the data plotted in figure 3, we calculated the difference in differences estimates based on equation (4). While these difference in differences estimates have not been estimated like the traditional approach established by Card and Krueger (1994), the results can be interpreted in the same way. As shown in table 4, 48.83 cents of the observed 70.41 cent difference in national and California egg prices can be attributed to Proposition 2. This approach puts the mean estimated

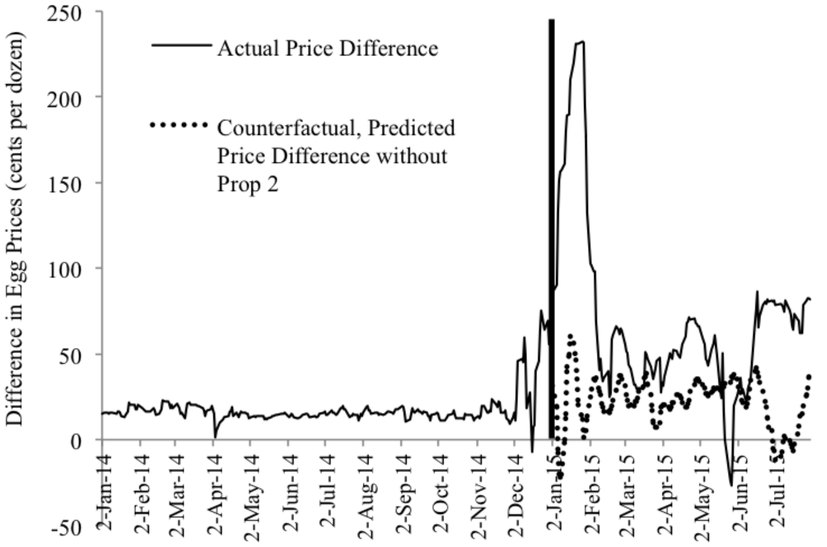

Figure 3. Difference in Actual California and National Egg Prices and the Predicted (or Counterfactual) Difference that Would Have Prevailed in the Absence of the Implementation of Proposition 2 (cents/dozen)

effect of Proposition 2 to be about 68.8% of the price gap per dozen from January 1 to July 30, with the largest costs of implementation coming initially after passage in January. These costs are likely highest at the beginning of the law's implementation, as producers had to retrofit their facilities to comply with the new legislation. The lowest difference in prices came in May. Although this reduction coincides with the majority of avian influenza cases, we do not find a statistically significant relationship between avian influenza outbreaks and differences in egg prices. Price differences rebounded to more than 30 cents by June and then increased to 68 cents by July.

Consumer Surplus Effects

The estimated price effects can be used to calculate changes in consumer surplus given an assumed own-price elasticity of demand and the assumption of no demand change. Previous literature estimates own-price elasticities of demand for eggs between −0.08 and −0.27 (Kastens and Brester, 1996; Andreyeva, Long, and Brownell, 2010; Okrent and Alston, 2011). From equation (1), Q_t and Q'_t are quantities of eggs demanded before and after the policy change. Assuming there are 38,802,500 residents in California (U.S. Census Bureau, 2014) who consume about 250 eggs per person annually (U.S. Department of Agriculture, Economic Research Service, 2015), the quantity of eggs demanded before the policy change (Q_t) was approximately 808 million dozen eggs.

To determine the change in quantity demanded, we first estimate the expected price change in a dozen eggs that results from the policy change (this is the estimated effect for γ_1 in equation 2). Average U.S. prices were approximately \$1.39/dozen after January 1, 2015. From the intercept from model 1 in table 1, we calculate California prices to be at least 17 cents higher than the national prices without the implementation of Proposition 2, making Cal_t equal to the sum of the national price average after implementation and the difference in prices before implementation (\$1.56). Estimates from table 2 suggest prices have increased by about \$0.52 to \$1.08/dozen due to the policy change, making Cal'_t between \$2.09 and \$2.65. Given that a 1% increase in the price of eggs will lead to a 0.08% to 0.27% decrease in the quantity of eggs demanded, Proposition 2 has decreased quantity demanded by between 2.71% and 18.78%. From equation (1), we estimate the dollar loss

Table 3. Vector Auto Regression Fit to Data Prior to Implementation of Proposition 2 (January 1, 2014–December 31, 2014)

Variable	U.S. Price	CA Price
Intercept	−40.022*(19.219)	101.348*(30.486)
$PriceCA_{t-1}$	0.131*(0.047)	0.735*(0.075)
$PriceCA_{t-2}$	−0.087(0.056)	0.163(0.089)
$PriceCA_{t-3}$	0.044(0.057)	−0.062(0.090)
$PriceCA_{t-4}$	0.003(0.055)	−0.298*(0.087)
$PriceCA_{t-5}$	0.126*(0.055)	−0.158(0.088)
$PriceCA_{t-6}$	−0.005(0.057)	0.035(0.090)
$PriceCA_{t-7}$	−0.281*(0.056)	0.075(0.089)
$PriceCA_{t-8}$	0.149*(0.052)	−0.172*(0.083)
$PriceUS_{t-1}$	0.906*(0.070)	0.484*(0.111)
$PriceUS_{t-2}$	0.390*(0.087)	−0.349*(0.138)
$PriceUS_{t-3}$	−0.079(0.095)	0.501*(0.151)
$PriceUS_{t-4}$	−0.202*(0.094)	−0.075(0.150)
$PriceUS_{t-5}$	−0.450*(0.101)	−0.354*(0.161)
$PriceUS_{t-6}$	0.113(0.104)	0.108(0.165)
$PriceUS_{t-7}$	0.391*(0.097)	0.235(0.154)
$PriceUS_{t-8}$	−0.224*(0.082)	0.049(0.130)
Corn Price	−0.980(1.309)	0.868(2.076)
Diesel	15.581*(4.942)	−20.188*(7.838)
January	−10.954*(2.723)	−6.098(4.319)
February	−10.807*(2.973)	−2.497(4.716)
March	−9.445*(3.158)	−1.258(5.009)
April	−9.087*(3.021)	−6.660(4.793)
May	−9.933*(3.021)	−7.634(4.793)
June	−10.146*(2.685)	−8.822*(4.259)
July	−10.329*(2.421)	−6.612(3.841)
August	−9.922*(2.334)	−7.825*(3.702)
September	−10.120*(2.370)	−9.021*(3.760)
October	−7.760*(2.013)	−12.356*(3.193)
November	−3.892*(1.608)	−6.861*(2.551)
R^2	0.993	0.987

Notes: Number of observations in each regression = 248. Single asterisks indicate statistical significance at the 0.05 level or lower. Numbers in parentheses are standard errors.

of consumer surplus to be between \$408 million and \$853 million (table 5). That loss in consumer surplus represents between 32% and 68% of California's total consumer surplus in the egg market.

Overall, our forecasted change in consumer surplus is contingent on there being no shifts in demand from the possible consumer perception that the legislation improved the quality of California's eggs. To investigate this no-demand-change assumption, we utilize the monthly Food Demand Survey (FooDS) collected by Lusk (2016), which identifies, among other things, how much respondents have heard or read about battery cages in the past two weeks using a five-point Likert scale (1=nothing, 2=a little, 3=a moderate amount, 4=quite a bit, and 5=a great deal). For a demand effect to invalidate our findings, Californians would at least need to be more aware of battery cages than non-Californians after the policy went into effect. That is, they would have to know there had been a change in the living conditions of hens in the state for their demand to change. Table 6 shows the means and standard deviations for both groups before and after the policy was implemented. The difference between Californian and non-Californian awareness and concern before and after January 1, 2015, is not statistically different from zero, suggesting that Californians are not any more aware of the policy being implemented than non-Californians. We take this finding to indicate

Table 4. Difference in Differences Estimate of Effect of Implementation of Proposition 2 Using Predictions from Vector Auto Regression (cents/dozen)

Time Frame	Mean Observed Difference	Mean Predicted Difference	Mean Estimated Effect of Proposition 2[a]	Lower 95% CI	Upper 95% CI
January 1–July 31	70.41	21.98	48.43	39.56	57.29
January	179.26	17.31	161.95	142.74	181.15
February	59.73	26.84	32.89	23.80	41.97
March	40.25	23.07	17.18	12.17	22.18
April	55.22	24.13	31.09	26.67	35.50
May	33.50	30.95	2.55	−10.98	16.08
June	55.72	24.90	30.82	18.30	43.33
July	74.94	6.79	68.15	61.74	74.57

Notes: Mean Estimated Effect of Proposition 2 is calculated as the difference in the observed difference in California and national egg prices and the predicted (or counterfactual) difference in California and national egg prices that would have prevailed in the absence of the implementation of Proposition 2. Standard errors for confidence intervals are calculated from the variation between the difference in the observed price difference and the predicted price difference.

Table 5. Change in Consumer Surplus due to Implementation of Proposition 2 under Different Demand Elasticity Assumptions

Price Elasticity of Demand	Change in Consumer Surplus when $\gamma_1 = 0.52$	Change in Consumer Surplus when $\gamma_1 = 1.08$
−0.08 (Kastens and Brester, 1996)	−421,596,261	−853,571,578
−0.18 (Okrent and Alston, 2011)	−414,359,979	−823,031,590
−0.27 (Andreyeva, Long, and Brownell, 2010)	−407,847,326	−795,545,600

Table 6. Comparison of Average Consumer Awareness of Battery Cages as Measured in the Food Demand Survey (FooDS)

	California			Rest of U.S.		
	Before	After	Dif	Before	After	Dif
Awareness of Battery Cages	1.826	2.054	0.228	1.596	1.773	0.177
	(1.246)	(1.330)		(1.106)	(1.232)	
Number of observations	2,254	1,303			17,147	8,968

Notes: Respondents identified how much they have heard or read about battery cages in the past two weeks on a five-point Likert scale (1=nothing, 2=a little, 3=a moderate amount, 4=quite a bit, and 5=a great deal). Numbers in parentheses are standard deviations.

that the policy has not changed the demand for eggs in California. However, the survey asks about awareness of battery cages; it does not explicitly ask about consumer preferences for eggs, and there remains a chance that demand did change due to the implementation of the law.

Conclusions

This research used data from the Agricultural Marketing Service of the USDA to estimate the consumer welfare effects of the price change associated with the implementation of California's Proposition 2. Using two separate approaches, our results are robust to multiple model specifications. Ballot initiatives that eliminate the use of battery cages may become more common in the future, suggesting the need for a deeper understanding of the policy's consequences. We find evidence suggesting that forced elimination of battery cages causes a significant increase in the price of eggs but that the price increase attributed to Proposition 2 is not as high as some popular press articles have suggested.

If more state ballot initiatives pass restrictions on battery cages, Americans in those states can likely expect to see egg prices rise—this study suggests a price increase between 33% and 70%. Given the inelasticity of demand for eggs, such price changes result in a sizable decrease in surplus. While this study does not offer any estimates of the benefits of such animal welfare policies, either to consumers or the animals themselves, it does provide an estimate of the potential losses of consumer surplus that could be compared against whatever benefits might arise.

Some economists have argued that animal welfare should be regulated because of various market failures, such as externalities (Harvey and Hubbard, 2013). Proposition 2 is, in effect, a command-and-control policy in that it dictates which production technology cannot be used. However, there may be alternative animal welfare-promoting policies available to state or federal regulators that entail fewer costs. Some animal advocacy groups have suggested meat taxes as an idea that may or may not influence the quality of animals' lives (Cowen, 2006). Another alternative proposed by Lusk (2011) is a market for animal welfare decoupled from animal consumption. He notes consumers absent from the marketplace (such as vegans) might have strong feelings regarding the buying and selling of animal products in general. Giving agricultural producers property rights over "animal well-being units" and allowing these farmers to sell those units independent of the actual product itself could create a direct means for passionate animal advocates to purchase the outcome they desire. Finally, it might be that the marketplace provides avenues for consumers to demand animal welfare-promoting products. As noted in Lusk (2010), increasing information involving animal production correlates with heightened consumer concern for animal welfare in their purchasing decisions. It might be that Veblen's theory of conspicuous consumption also motivates this effect (Bagwell and Bernheim, 1996); in some locations, it might be fashionable to buy animal welfare-promoting products in much the same way that Sexton and Sexton (2014) suggest conspicuous conservation increased demand for some hybrid automobiles.

It is important to note that this research does not include any analysis of producer welfare impacts. Future research might include the costs borne by producers due to the law's implementation. Moreover, this paper cannot rule out the possibility of consumer demand shifts because of the new regulation. Regardless, assuming consumer demand is unchanged, we find the cost to consumers to be substantial.

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References

Allender, W. J., and T. J. Richards. "Consumer Impact of Animal Welfare Regulation in the California Poultry Industry." *Journal of Agricultural and Resource Economics* 35(2010):424–442.

Andreyeva, T., M. W. Long, and K. D. Brownell. "The Impact of Food Prices on Consumption: A Systematic Review of Research on the Price Elasticity of Demand for Food." *American Journal of Public Health* 100(2010):216–222. doi: 10.2105/AJPH.2008.151415.

Arnade, C., D. Pick, and M. Gehlhar. "Testing and Incorporating Seasonal Structures into Demand Models for Fruit." *Agricultural Economics* 33(2005):527–532. doi: 10.1111/j.1574-0864.2005.00095.x.

Bagwell, L. S., and B. D. Bernheim. "Veblen Effects in a Theory of Conspicuous Consumption." *American Economic Review* 86(1996):349–373.

Bertrand, M., E. Duflo, and S. Mullainathan. "How Much Should We Trust Differences-in-Differences Estimates?" *Quarterly Journal of Economics* 119(2004):249–275. doi: 10.1162/003355304772839588.

Bureau of Economic Analysis. "Personal Income SQ1." 2015. Available online at http://www.bea.gov.

California Department of Food and Agriculture, Animal Health and Food Safety Services. "New Shell Egg Food Safety Regulations." 2015. Available online at https://www.cdfa.ca.gov/ahfss/mpes/pdfs/eggsafetyrule.pdf.

California-Nevada Climate Applications Program. "The California Drought of 2014: Record Hot, Record Dry." CNAP Observations 2, California-Nevada Climate Applications Program, La Jolla, CA, 2014. Available online at http://cpo.noaa.gov/sites/cpo/Publications/RISA/CNAP

Card, D., and A. B. Krueger. "Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania: Reply." *American Economic Review* 84(1994):772–793.

Chang, J. B., J. L. Lusk, and F. B. Norwood. "The Price of Happy Hens: A Hedonic Analysis of Retail Egg Prices." *Journal of Agricultural and Resource Economics* 35(2010):406–423.

Coalition for a Sustainable Egg Supply. *Research Results Report*. Gladstone, MO: Center for Food Integrity, 2015. Available online at http://www2.sustainableeggcoalition.org/document_center/download/public/CSESResearchResultsReport.pdf.

Cowen, T. "Market Failure for the Treatment of Animals." *Society* 43(2006):39–44. doi: 10.1007/BF02687369.

Gee, K. "Egg Prices Jump as Bird Flu Spreads." *Wall Street Journal* (2015). Available online at http://www.wsj.com/articles/bird-flu-outbreak-decimates-egg-laying-flocks-1432237046.

Greene, J. L., and T. Cowan. "Table Egg Production and Hen Welfare: Agreement and Legislative Proposals." CRS Report for Congress R42534, Congressional Research Service, Washington, DC, 2014. Available online at https://www.fas.org/sgp/crs/misc/R42534.pdf.

Harvey, D., and C. Hubbard. "Reconsidering the Political Economy of Farm Animal Welfare: An Anatomy of Market Failure." *Food Policy* 38(2013):105–114. doi: 10.1016/j.foodpol.2012.11.006.

Heng, Y., H. H. Peterson, and L. Xianghong. "Consumer Attitudes toward Farm-Animal Welfare: The Case of Laying Hens." *Journal of Agricultural and Resource Economics* 38(2013):418–434.

Kangas, C. "The Dangers of King's Farm Bill Amendment." *Huffington Post* (2014). Available online at http://www.huffingtonpost.com/cathy-kangas/king-farm-bill_b_4651649.html.

Karol, G. "Expert Says Record-High Average Price for Eggs in California Is around the Corner." 2015.

Kastens, T. L., and G. W. Brester. "Model Selection and Forecasting Ability of Theory-Constrained Food Demand Systems." *American Journal of Agricultural Economics* 78(1996):301–312. doi: 10.2307/1243704.

Keady, P. S. "Chickens and the Constitution: How California Hens Are Ruffling Feathers - Missouri v. Harris 1." *American Journal of Law & Medicine* 41(2015):509.

Laird, L. "California's Ban on Standard-Caged Birds Poses a Chicken-Egg Problem." 2014. Available online at http://www.abajournal.com/magazine/article/californias_ban_on_standard-caged_birds_poses_a_chicken-egg_problem/.

Lusk, J. L. "The Effect of Proposition 2 on the Demand for Eggs in California." *Journal of Agricultural & Food Industrial Organization* 8(2010):1–20.

———. "The Market for Animal Welfare." *Agriculture and Human Values* 28(2011):561–575. doi: 10.1007/s10460-011-9318-x.

———. *Food Demand Survey*. Stillwater, Oklahoma: Oklahoma State University, Department of Agricultural Economics, 2016. Available online at http://www.agecon.okstate.edu/agecon_research.asp.

Mullally, C., and J. L. Lusk. "Happy Hens, Sad Consumers? The Economic Impact of Restrictions on Farm Animal Housing in California." Unpublished Manuscript, 2015. Available online at http://agecon.okstate.edu/faculty/publications/5115.pdf.

Norwood, B. F. "The Private Provision of Animal-Friendly Eggs and Pork." *American Journal of Agricultural Economics* 94(2012):509–514. doi: 10.1093/ajae/aar073.

Norwood, B. F., and J. L. Lusk. "The Farm Animal Welfare Debate." *Choices* 24(2009):1–7. Available online at http://www.choicesmagazine.org/magazine/article.php?article=89.

———. *Compassion, by the Pound: The Economics of Farm Animal Welfare*. New York: Oxford University Press, 2011.

Okrent, A. M., and J. M. Alston. "Demand for Food in the United States: A Review of Literature, Evaluation of Previous Estimates, and Presentation of New Estimates of Demand." Giannini Foundation Monograph 48, Giannini Foundation of Agricultural Economics, Berkeley, CA, 2011. Available online at http://s.giannini.ucop.edu/uploads/giannini_public/54/99/54994570-7739-4f54-99d7-91dd4aca3762/48-fooddemand.pdf.

Parsons, R. "Why Eggs Have Gotten More Expensive in California." *Los Angeles Times* (2015). Available online at http://www.latimes.com/food/dailydish/la-dd-eggs-prices-expensive-california-20150617-story.html.

Richards, T. J., W. Allender, and D. Fang. "Media Advertising and Ballot Initiatives: The Case of Animal Welfare Regulation." *Contemporary Economic Policy* 31(2013):145–162. doi: 10.1111/j.1465-7287.2011.00292.x.

Sexton, S. E., and A. L. Sexton. "Conspicuous Conservation: The Prius Halo and Willingness to Pay for Environmental Bona Fides." *Journal of Environmental Economics and Management* 67(2014):303–317. doi: 10.1016/j.jeem.2013.11.004.

Sumner, D. A., H. Gow, D. Hayes, W. Matthews, B. Norwood, J. T. Rosen-Molina, and W. Thurman. "Economic and Market Issues on the Sustainability of Egg Production in the United States: Analysis of Alternative Production Systems." *Poultry Science* 90(2011):241–250. doi: 10.3382/ps.2010-00822.

Sumner, D. A., W. A. Matthews, J. A. Mench, and J. T. Rosen-Molina. "The Economics of Regulations on Hen Housing in California." *Journal of Agricultural and Applied Economics* 42(2010):429–438.

Sumner, D. A., J. T. Rosen-Molina, W. A. Matthews, J. A. Mench, and K. R. Richter. *UC Agricultural Issues Center*. Davis, CA: University of California Agricultural Issues Center, 2008. Available online at http://aic.ucdavis.edu/publications/eggs/egg_initiative.htm.

United Egg Producers. "Impacts of Banning Cage Egg Production in the United States." Tech. rep., United Egg Producers, Alpharetta, GA, 2009. Available online at http://www.unitedegg.org/information/pdf/Promar_Study.pdf.

U.S. Census Bureau. "State and Country Quickfacts: California." 2014. Available online at http://quickfacts.census.gov/qfd/states/00000.html.

U.S. Department of Agriculture, Agricultural Marketing Service. "National Shell Egg Index Price Report, Agricultural Marketing Service, Livestock, Poultry & Grain Market News." 2015. Available online at https://www.ams.usda.gov/mnreports/pydseindex.pdf.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service. "Update on Avian Influenza Findings Poultry Findings Confirmed by USDA's National Veterinary Services Laboratories." 2015. Available online at https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/animal-disease-information/avian-influenza-disease/sa_detections_by_states/.

U.S. Department of Agriculture, Economic Research Service. "Poultry and Eggs: Background." 2015. Available online at http://www.ers.usda.gov/topics/animal-products/poultry-eggs/.aspx.

U.S. Department of Agriculture, Food Safety and Inspection Service. "Food Safety Information: Shell Eggs from Farm to Table." 2011. Available online at http://www.fsis.usda.gov/wps/wcm/connect/5235aa20-fee1-4e5b-86f5-8d6e09f351b6/Shell_Eggs_from_Farm_to_Table.pdf?MOD=AJPERES.

Wall Street Journal. "California's Scrambled Eggs." *Wall Street Journal* (2015). Available online at http://www.wsj.com/articles/californias-scrambled-eggs-1422232494.

Wilson, R. "Chickens come before eggs in California case." *Washington Post* (2014). Available online at https://www.washingtonpost.com/blogs/govbeat/wp/2014/10/07/chickens-come-before-eggs-in-california-case/.