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The Price of Happy Hens: A Hedonic Analysis of Retail Egg Prices

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This paper analyzes price differentials among conventional, cage-free, organic, and Omega-3 eggs using retail scanner data from two regional markets and the United States as a whole. Results reveal significant premiums attributable to cage-free (a 57% premium on average) and organic (an 85% premium on average). However, significant variation exists among geographic locations; price premiums for organic over conventional eggs in Dallas are almost twice as high as those in San Francisco. Estimates indicate that about 42% of the typically observed premium for cage-free eggs over conventional eggs (and 36% of the premium for organic eggs) can be attributed to egg color rather than differences in hens' living conditions. Despite the large implicit price premiums for cage-free and organic, our data reveal that most shoppers are not willing to pay such high prices for cage-free and organic attributes.

Key Words: animal welfare, cage-free, eggs, free-range, hedonic, organic

Introduction

The vast majority of commercial egg-producing hens in the United States live in battery cage systems. A typical egg farm contains anywhere from 100,000 to 1 million hens, with each hen housed in a metal wire cage with four or five other birds. These production systems have been criticized by animal advocacy groups for several reasons: the tight space requirements (about 67 square inches of space per hen) prohibit chickens from fully extending their wings, and hens are unable to exhibit natural behaviors such as dust bathing and laying eggs in nests. These concerns recently received widespread public attention when the Humane Society of the United States (HSUS), working with several other advocacy groups, introduced a ballot initiative to ban battery cage egg production in the state of California. The proposition, formally known as the Prevention of Farm Animal Cruelty Act, passed in November 2008, with 63.5% of Californians voting in favor. The effects of the ban in California have been intensely debated, and one of the key unanswered questions is the potential impact of the ban on egg prices.

In addition to policy initiatives, increasing consumer demand for animal welfare, human health, and variety has prompted producers to market a diversity of egg offerings. Demand for health attributes has resulted in the development of Omega-3 and vitamin-enriched eggs, and labeling programs facilitated by the U.S. Department of Agriculture, the United Egg Producers, and the Animal Welfare Institute have led to cage-free, organic, and free-range egg options. Although sales of generic eggs have decreased over the past decade, specialty egg sales have

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steadily increased, accounting for approximately 16% of total egg sales in 2005. Organic eggs represent one of the fastest growing segments in this market; sales grew at an average annual rate of 19% from 2000 to 2005, reaching $161 million in 2005 (Oberholtzer, Green, and Lopez, 2006). As a result, the egg market is now highly differentiated, and most grocery stores currently offer eggs differentiated by production method, color, size, brand, and packaging.

Despite these changes, there is presently little publicly available information on price differences between various types of eggs or on consumers' willingness to pay for animal welfare and health attributes. To address this issue, we carry out a hedonic analysis using retail scanner data for two regional markets and for the United States as a whole.

Background

Egg production is a large and highly concentrated business. Each year, more than 300 million laying hens produce over 90 billion eggs in the United States. In 2007, five states (Iowa, Ohio, Indiana, Pennsylvania, and Texas) produced 40% of eggs. The industry is moderately concentrated, with 205 egg-producing companies owning 95% of all layers in the United States (American Egg Board, 2009).

Egg consumption fell dramatically from the 1940s to the 1990s due to concerns about health and cholesterol; annual per capita egg consumption peaked at 403 in 1945, and reached a low of about 230 in the 1990s (Putnam and Allshouse, 1999). Per capita consumption of eggs has subsequently stabilized and was approximately 243 eggs per person per year in 2008 [USDA/Economic Research Service (ERS), 2009]. As consumer demand for eggs has changed and the market has become increasingly differentiated, several studies have investigated consumer preferences for egg characteristics. These studies relied on surveys to assess Canadian and UK consumer egg preferences. Fearne and Lavelle (1996) found that price and animal welfare were two key factors driving egg choice for consumers in the United Kingdom. Bennett (1997) used data collected from mail surveys to measure UK consumers' willingness to pay to support legislation to ban the use of battery cages in egg production; almost 80% of survey respondents supported the proposed legislation and were willing to pay, on average, £0.43 more per dozen given the ban. Asselin (2005) studied Canadian consumers' willingness to pay for Omega-3 and vitamin-enhanced eggs, and found people were willing to pay between $0 and $0.72 more per dozen for Omega-3 eggs, depending on their health consciousness.

A few studies have employed observed market data to evaluate consumer egg preferences. Baltzer (2004) used scanner data on weekly sales from a major retail chain in Denmark. He estimated an almost ideal demand system (AIDS) model to determine Danish consumers' marginal willingness to pay for five varieties of eggs—battery cage, barn, free-range, organic, and pasteurized eggs—and found consumers were willing to pay significant premiums for eggs that improved animal welfare and involved natural production methods. Karipidis et al. (2005) used data obtained from retail stores in two metropolitan areas in Greece during the summer of 2004. In their hedonic price modeling, 14 egg attributes were clustered into five groups: natural characteristics, poultry-feeding conditions, packaging, quality-control system, and vertical integration. The authors reported that eggs produced under organic and free-range feeding systems and Omega-3 enriched eggs have high hedonic prices, but other feeding conditions did not influence retail prices. Their study, however, included only 175 observations and a limited set of attribute types and levels.

Methods

Data

Our data consist of three sets of point-of-sale scanner data collected from a representative sample of retail outlets by Information Resources, Inc. (IRI).[1] Each set contains data on stock keeping units (SKUs), including information on size, color, package type, brand vs. private label, and the number of eggs per package. Moreover, the data set also indicates whether each SKU was advertised as cage-free, cage-free & Omega-3, cage-free & organic, fertile, free-range, free-range & organic, natural, Omega-3, organic, organic & Omega-3, pasteurized, vegan fed, or generic fresh eggs (i.e., battery cage eggs).[2] Color levels of eggs include white and brown, and size levels are small, medium, large, extra large, jumbo, and super jumbo. Packaging was categorized by IRI into eight types: carton, cardboard carton, plastic carton, styrofoam carton, paper carton, plastic wrapped carton, cardboard box, and other type.

The first data set consists of quarterly egg sales for over 1,985 SKUs across the entire United States over the 20 quarters from the beginning of 2004 to the end of 2008. In addition to the U.S. data, we also obtained weekly scanner data for two specific metropolitan areas: Dallas/Fort Worth, Texas, and San Francisco/Oakland, California. These data sets span from January 1, 2007 to January 25, 2009, and are in all respects identical to the overall U.S. data set except for data frequency (weekly rather than quarterly) and time period covered (two years starting in January 2007 vs. four years starting in January 2004). We chose these two specific locations for several reasons. First, we wanted a California location because of the debate over the recent California ballot initiative. Second, we wanted a location of a similar size that was some distance from California (and thus less likely to be susceptible to media exposure on the ballot initiative), and one that we perceived might be less interested in animal welfare issues.[3] In addition, Texas and California rank fifth and sixth among egg-producing states in number of eggs produced.

Table 1 reports the percentage of SKUs possessing the various attributes considered in this analysis. About 85% are generic fresh eggs (either conventional fresh or with no production method indicated), while the number of SKUs advertised as organic represents only 5.28% of the total. Another $1.22 + 0.05 + 0.58 = 1.85\%$ of SKUs advertised organic in addition to another attribute such as cage-free, free-range, or Omega-3. Approximately 70% of egg SKUs are white. Most SKUs are large-sized eggs (53%) and sold by the dozen (65%). A larger percentage of the SKUs in San Francisco are cage-free and organic than is the case in Dallas. Likewise, a larger percentage of SKUs are brown vs. white eggs in San Francisco as compared to Dallas. About 33% of the SKUs in Dallas are associated with package sizes including 13 or more eggs, but only about 20% of SKUs in San Francisco include this many eggs.

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[1] IRI records weekly data from 34,000 supermarkets, drug stores, mass merchandisers, and convenience channels across the United States. The U.S. data set contains information on approximately 108 billion egg sales from 2004 to 2008. USDA/ERS (2009) data indicate that about 258 billion shell eggs were produced during this time period. Therefore, our data set covers approximately 42% of all U.S. shell egg production from 2004 to 2008.

[2] The data set also included sales of cooked, cultured, hard-boiled, and homogenized eggs. We excluded these types of eggs in our analysis. We also removed SKUs from the data set in which package sizes were only one egg per package because the per egg price of such SKUs was often an order of magnitude higher than the mean.

[3] See Lusk (2010) for an analysis of how demand for cage-free and organic eggs differed and changed over time in these two locations. Note also that the Humane Society of the United States (2010) recently released a comprehensive report, "Humane State Ranking," rating all 50 states on a wide range of animal protection laws dealing with pets, animal cruelty and fighting, wildlife, animals in research, and farm animals. California is listed at the top and Texas comes in at 33rd place.

Table 1. Percentage of Fresh Egg SKUs Possessing Various Attributes by Market

	Percent of Total SKUs		
Attribute	United States	San Francisco / Oakland	Dallas / Ft. Worth
Production Method:			
Cage-Free	1.98	4.75	2.92
Cage-Free & Omega-3	0.11	0.60	—
Cage-Free & Organic	1.22	4.13	3.87
Fertile	0.22	2.39	—
Free-Range	0.45	—	—
Free-Range & Organic	0.05	—	—
Natural	1.25	1.19	0.97
Omega-3	1.99	1.09	3.85
Organic	5.28	10.02	2.93
Organic & Omega-3	0.58	1.31	0.02
Pasteurized	0.72	1.19	0.97
Vegan Fed	0.80	3.58	1.03
Conventional Fresh	74.42	61.48	72.46
None Indicated	10.92	8.26	10.98
Color:			
White	70.16	63.88	76.07
Brown	25.13	33.34	20.95
None Indicated	4.70	2.78	2.98
Size:			
Small	2.55	0.49	1.32
Medium	13.24	9.31	14.46
Large	52.92	59.74	60.38
Extra Large	17.61	22.38	14.85
Jumbo	12.11	8.09	8.00
Super Jumbo	0.47	—	—
None Indicated	1.09	—	0.97
Package:			
Carton	38.94	45.85	44.43
Cardboard Carton	23.07	38.08	13.69
Plastic Carton	5.65	3.41	6.70
Styrofoam Carton	23.72	9.42	25.43
Paper Carton	1.05	0.19	0.97
Plastic Wrapped Carton	1.08	1.19	1.64
Cardboard Box	1.10	0.80	0.65
Others	1.52	—	1.09
None Indicated	3.86	1.07	5.40
Brand Label:			
Private	18.57	31.30	56.29
Specific	81.43	68.70	42.71
Number of Eggs per Package:			
3–6	8.17	11.49	5.48
7–11	3.21	1.48	0.97
12	64.94	67.13	60.45
13–18	12.26	9.21	15.02
> 18	11.42	10.69	18.08
Number of Unique SKUs	1,985	122	150

Table 2. Percentage of Fresh Eggs Sold by Production Method and Market

	Percent of Total SKUs		
Attribute	United States	San Francisco / Oakland	Dallas / Ft. Worth
Production Method:			
Cage-Free	1.17	2.29	0.50
Cage-Free & Omega-3	0.04	0.07	—
Cage-Free & Organic	0.30	1.76	0.21
Fertile	0.06	2.70	—
Free-Range	0.04	—	—
Free-Range & Organic	0.00	—	—
Natural	0.49	0.45	0.06
Omega-3	0.52	0.36	0.54
Organic	1.02	4.43	0.41
Organic & Omega-3	0.13	0.12	0.00
Pasteurized	0.19	0.06	0.05
Vegan Fed	1.26	0.95	1.33
Conventional Fresh	87.35	84.47	79.40
None Indicated	7.43	2.34	17.50
Number of Eggs Sold (billion)	108.076 [a]	0.7256 [b]	0.9408 [b]

[a] Total eggs sold over the 20 quarters from 2004 to 2008.
[b] Total eggs sold over the 108-week time period from January 1, 2007 to January 25, 2009.

Although our hedonic analysis uses the price of an SKU as the unit of measure, it is also instructive to note the volume of eggs actually sold; this information is relevant to discussions about consumer demand for different types of eggs. To provide a feel for differences in sales volume across different production systems, we used the scanner data to calculate the quantity-share of eggs sold using each production method by location (table 2). In the United States, almost 95% of eggs sold are conventional fresh or generic eggs (eggs with "none indicated" for production method are almost certainly cage eggs). While about 5.28% of SKUs are organic, only about 1% of egg sales are organic.

Table 2 also reveals regional differences. Of all eggs sold in San Francisco, 4.43% and 2.29% are organic and cage-free, respectively. Dallas consumers bought fewer organic and cage-free eggs—only 0.41% and 0.50%, respectively. Overall, "specialty" eggs account for about 30% of total SKUs in San Francisco and 17% of SKUs in Dallas, but only about 13% and 3% of total eggs sold in San Francisco and Dallas. The small market shares do not necessarily imply a small volume of egg sales. The last row of table 2 shows that almost a billion eggs were sold in the Dallas/Ft. Worth stores over the two-year time period, and the average weekly volume of "specialty" egg sales was about 886,000 eggs per week in San Francisco and 270,000 eggs per week in Dallas.

For each SKU, we calculate the average price paid in each time period (each quarter for the U.S. data and each week for the regional data sets). Egg prices are deflated by the Consumer Price Index (2008 = 100). Because SKUs differ in the number of eggs per package, we calculate prices on a per egg basis. Figure 1 illustrates the trend in U.S. egg prices ($/egg) for three different production methods: conventional, cage-free, and organic. The price premium for organic over conventional fresh eggs ranged from $0.16/egg in the first quarter of 2008 to $0.21/egg during 2005. The average price premium for organic eggs over the entire period was about $0.20/egg. The average price premium for cage-free over conventional eggs was

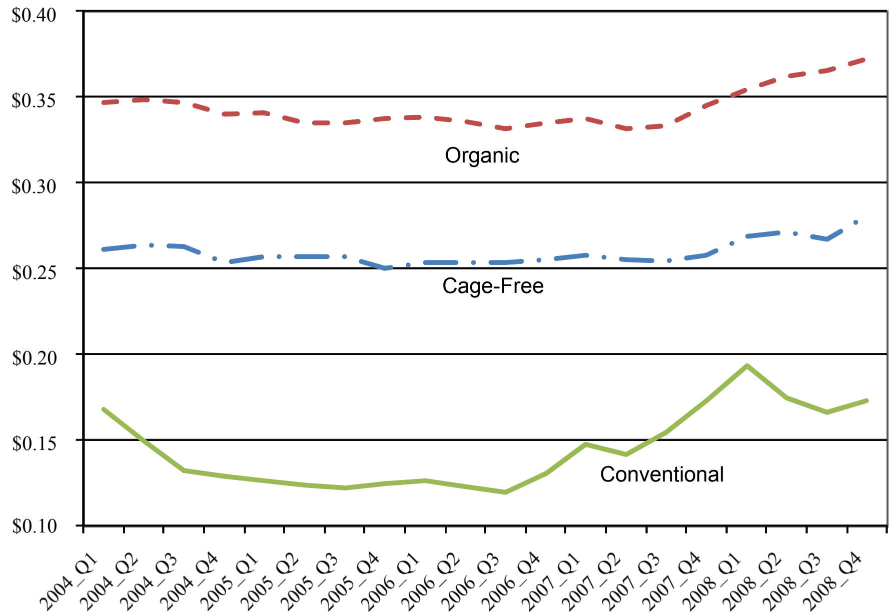

Figure 1. Average U.S. egg price ($/egg) over time by production method

about $0.12/egg over the time period and reached a minimum of $0.08/egg during early 2008, when conventional egg prices rose sharply. The price trends shown in figure 1 are calculated based on the raw data (adjusted for inflation) and do not account for differences that are often correlated with organic eggs. For example, organic eggs tend to be brown and tend to be sold in smaller package sizes (although this is not exclusively true), whereas conventional fresh eggs tend to be white and sold by the dozen. Thus, the raw price premia for organic vs. conventional ($0.20/egg) is attributable to a variety of factors other than "organic," a fact highlighting the need for hedonic regression analysis to calculate ceteris paribus effects.

Table 3 reports descriptive statistics for egg prices. The data reveal that prices tend to be higher in San Francisco as compared to Dallas or the rest of the country as a whole. For example, the average price of conventional fresh eggs was $0.26/egg in San Francisco but only $0.14/egg in Dallas. Many conditions contribute to the price difference between the two locations. In particular, the overall cost of living and average wage rates are higher in San Francisco than in Dallas. Differences in the costs of egg production and transportation are also relevant. Somewhat surprisingly, the premiums for organic and cage-free eggs over conventional eggs were lower in San Francisco ($0.13/egg and $0.06/egg, respectively) compared to Dallas ($0.20/egg and $0.12/egg, respectively) or the rest of the country ($0.20/egg and $0.12/egg, respectively).

The Hedonic Price Model

The primary objective of this paper is to estimate a descriptive model of egg prices to determine how egg prices differ by product characteristics such as organic and cage-free. We used the standard hedonic modeling approach to accomplish this task. The hedonic method relies on observing differences in market prices to infer the value or implicit price of underlying characteristics. The method has been used at least since Waugh (1928), and was

Table 3. Egg Price ($/egg) by Location and Production Method

	United States			San Francisco / Oakland			Dallas / Fort Worth		
Production Method	Mean (Std. Dev.)	Min.	Max.	Mean (Std. Dev.)	Min.	Max.	Mean (Std. Dev.)	Min.	Max.
Cage-Free	0.26 (0.05)	0.13	0.41	0.32 (0.04)	0.17	0.40	0.26 (0.04)	0.12	0.34
Cage-Free & Omega-3	0.22 (0.03)	0.18	0.27	0.36 (0.01)	0.34	0.38	—	—	—
Cage-Free & Organic	0.33 (0.10)	0.13	0.61	0.41 (0.07)	0.23	0.51	0.37 (0.05)	0.31	0.47
Fertile	0.28 (0.03)	0.22	0.35	0.29 (0.02)	0.21	0.32	—	—	—
Free-Range	0.43 (0.36)	0.16	1.23	—	—	—	—	—	—
Free-Range & Organic	0.30 (0.05)	0.18	0.35	—	—	—	—	—	—
Natural	0.20 (0.05)	0.07	0.35	0.26 (0.05)	0.17	0.33	0.16 (0.03)	0.13	0.21
Omega-3	0.27 (0.09)	0.07	0.61	0.32 (0.05)	0.17	0.40	0.22 (0.02)	0.08	0.27
Organic	0.34 (0.10)	0.03	0.72	0.39 (0.04)	0.08	0.51	0.34 (0.02)	0.26	0.57
Organic & Omega-3	0.38 (0.07)	0.18	0.53	0.38 (0.04)	0.23	0.49	0.47 (0.06)	0.43	0.51
Pasteurized	0.19 (0.34)	0.06	3.61	0.36 (0.02)	0.33	0.40	0.29 (0.01)	0.24	0.30
Vegan Fed	0.24 (0.03)	0.13	0.33	0.33 (0.02)	0.21	0.37	0.24 (0.01)	0.21	0.26
Conventional Fresh	0.14 (0.07)	0.01	2.09	0.26 (0.07)	0.08	0.68	0.14 (0.05)	0.03	0.45
None Indicated	0.15 (0.07)	0.02	0.88	0.23 (0.06)	0.08	0.33	0.16 (0.09)	0.07	1.29

Notes: Egg prices in the U.S. are from the first quarter of 2004 to the fourth quarter of 2008, and egg prices in the San Francisco / Oakland and Dallas / Fort Worth areas are from January 1, 2007 to January 25, 2009. Prices are deflated by the consumer price index (2008 = 100).

formalized in Rosen's (1974) seminal study showing how the "1st stage" hedonic price function could be derived via the interaction of consumer demand for and producer supply of product characteristics. The "1st stage" hedonic price functions we estimate show how egg prices in equilibrium vary with egg characteristics, which relate to a point on the marginal willingness-to-pay schedule. However, implicit prices do not reveal a full willingness-to-pay or demand schedule because the marginal implicit price is also determined by the producers' offer curve, which varies with the costs of providing different characteristics. Differences in cost across location or difference in demand can therefore explain differences in estimated implicit prices. Recent studies (e.g., Bajari and Benkard, 2005) have questioned the appropriateness of some of the assumptions of Rosen's model—such as the assumption of perfect competition, separability of attributes, and continuous product space—insofar as they allow the analyst to identify consumers' preferences for the underlying product characteristics.

If we make the standard assumption that any unobservables are uncorrelated with the observed product characteristics, the empirical model can be written as:

$$\text{(1)} \qquad \ln(Price_{it}) = \beta_0 + \sum_{j=1}^{13} \beta_1^j ProductionMethod_{ij} + \sum_{j=1}^{2} \beta_2^j Color_{ij} + \sum_{j=1}^{6} \beta_3^j Size_{ij}$$
$$+ \beta_4 PrivateLabel_i + \sum_{j=1}^{8} \beta_5^j Package_{ij} + \beta_6 (\#Eggs/Package)_i$$
$$+ \beta_7 (\#Eggs/Package)_i^2 + \sum_{j=1}^{11} \beta_8^j Month_{ij} + \varepsilon_{it},$$

where $Price_{it}$ is the average price ($/egg) for SKU i in time period t, the β's are parameters to be estimated, ε_{it} is a stochastic error term, and the remaining variables are dummy variables identifying the attributes shown in table 1, except for the variable *#Eggs/Package*, which is a continuous variable indicating the number of eggs per package. As previously mentioned, the U.S. data set consists of quarterly observations, and the two regional markets consist of weekly observations, so monthly dummy variables in equation (1) are replaced with three quarterly dummy variables when analyzing the national data set.

Potential options for functional forms are restricted given the large number of dummy variables in our model (McConnell and Strand, 2000; Oczkowski, 1994). As shown in equation (1), we chose the semi-log model over the linear model based on the results from Box-Cox specification tests and based on previous literature arguing that errors in the semi-log model are relatively more homoskedastic compared to errors in the linear model (Diewert, 2003). When dummy variables are included in a semi-log model, the resulting coefficients are not equal to percentage changes (Halvorsen and Palmquist, 1980). For the estimated coefficient corresponding to a dummy variable, such as β_1^1, the percentage effect on price is $100(e^{\beta_1^1} - 1)$. Moreover, given the natural log of the dependent variable, the predicted price is not a simple sum of the variables multiplied by the coefficients. Equation (1) can be rewritten succinctly as $\ln(Price_{it}) = \boldsymbol{\beta}\mathbf{X}_{it} + \varepsilon_{it}$, where $\boldsymbol{\beta}$ is a vector of coefficients and $\mathbf{X}_{it}$ is a conformable vector of explanatory variables. The expected price is $E[Price] = e^{\boldsymbol{\beta}\mathbf{X}_{it} + 0.5\sigma^2}$, where σ^2 is the variance of the error term. Thus, the predicted implicit price for a product with characteristics $\mathbf{X}_1$ rather than $\mathbf{X}_0$ is: $e^{\boldsymbol{\beta}\mathbf{X}_1 + 0.5\sigma^2} - e^{\boldsymbol{\beta}\mathbf{X}_0 + 0.5\sigma^2}$.

Results

Estimates of the semi-log hedonic price models are shown in table 4. Test results suggest the presence of heteroskedasticity; consequently, we report White's heteroskedasticity-consistent standard errors.[4] The models fit the data well, explaining 50%, 70%, and 66% of the egg price variation in the United States, San Francisco/Oakland, and Dallas/Fort Worth markets, respectively.

As a first step in the analysis, we sought to determine whether the implicit prices were identical across locations. To investigate this issue, a pooled model (or restricted model) was estimated; data from all locations were combined and parameters were constrained to

[4] Because of the nature of egg products, some variables are correlated. For example, production method and the color of eggs were highly collinear (but not perfectly so) due to the fact that different egg-laying breeds tend to be used for specialty egg production. To address this issue, we estimated the hedonic model sequentially, beginning with the simplest model with production method only, and then estimation of the more complicated model with additional attribute variables. *F*-tests were carried out to test for the significance of additional variables; results show all additional sets of variables are significant. Moreover, statistical tests do not support dropping the variables related to egg color from the regression, and the estimates related to production method are not particularly sensitive to inclusion of the color variables.

Table 4. Semi-Log Hedonic Model Estimates

Variable	United States	San Francisco / Oakland	Dallas / Ft. Worth
Constant	−2.043***	−0.095***	−1.939***
	(0.039)	(0.013)	(0.031)
Production Method:			
Conventional Fresh	Base	Base	Base
Cage-Free	0.449***	0.195***	0.407***
	(0.010)	(0.008)	(0.010)
Cage-Free & Omega-3	0.209***	0.572***	—
	(0.020)	(0.009)	
Cage-Free & Organic	0.572***	0.379***	0.606***
	(0.014)	(0.011)	(0.018)
Fertile	0.524***	−0.020**	—
	(0.015)	(0.006)	
Free-Range	0.629***	—	—
	(0.054)		
Free-Range & Organic	0.530***	—	—
	(0.044)		
Natural	0.206***	0.013	0.065***
	(0.014)	(0.018)	(0.011)
Omega-3	0.493***	0.261***	0.357***
	(0.013)	(0.016)	(0.011)
Organic	0.614***	0.260***	0.590***
	(0.009)	(0.006)	(0.019)
Organic & Omega-3	0.709***	0.255***	0.903***
	(0.016)	(0.012)	(0.011)
Pasteurized	0.183***	0.414***	0.986***
	(0.035)	(0.012)	(0.010)
Vegan Fed	0.428***	0.186***	0.522***
	(0.013)	(0.006)	(0.009)
None Indicated	−0.026***	0.025**	−0.030**
	(0.007)	(0.009)	(0.011)
Color:			
White	Base	Base	Base
Brown	0.233***	0.150***	0.227***
	(0.006)	(0.010)	(0.024)
None Indicated	0.033***	0.045**	0.024
	(0.011)	(0.014)	(0.023)
Size:			
Small	Base	Base	Base
Medium	0.167***	−0.976***	0.174***
	(0.019)	(0.014)	(0.027)
Large	0.413***	−0.838***	0.422***
	(0.018)	(0.015)	(0.011)
Extra Large	0.481***	−0.768***	0.466***
	(0.019)	(0.010)	(0.012)
Jumbo	0.530***	−0.679***	0.475***
	(0.019)	(0.010)	(0.012)
Super Jumbo	0.839***	—	—
	(0.026)		
None Indicated	0.488***	—	0.478***
	(0.031)		(0.019)

(continued . . .)

Table 4. Continued

Variable	United States	San Francisco / Oakland	Dallas / Ft. Worth
Package:			
Others	Base	Base	Base
Carton	−0.032***	−0.057	−0.037**
	(0.011)	(0.053)	(0.019)
Cardboard Carton	−0.017	−0.062**	0.008
	(0.012)	(0.021)	(0.016)
Plastic Carton	0.005	−0.072**	0.018
	(0.013)	(0.031)	(0.038)
Styrofoam Carton	−0.129***	0.044***	−0.134***
	(0.012)	(0.001)	(0.001)
Paper Carton	−0.052*	0.008***	−0.003***
	(0.027)	(0.001)	(0.000)
Plastic Wrapped Carton	0.017	0.028***	−0.055***
	(0.018)	(0.005)	(0.006)
Cardboard Box	−0.128***	−0.066***	0.169***
	(0.020)	(0.008)	(0.011)
None Indicated	−0.063***	—	0.614***
	(0.022)		(0.012)
Brand Label:			
Specific	Base	Base	Base
Private	−0.006	−0.103***	−0.072***
	(0.005)	(0.009)	(0.011)
#Eggs/Package	−0.030***	−0.035***	−0.024**
	(0.003)	(0.009)	(0.012)
$(\#Eggs/Package)^2$	0.0004***	0.0004	0.0003
	(0.0001)	(0.009)	(0.012)
Quarterly Dummy:			
October–December	Base	—	—
January–March	0.040***	—	—
	(0.006)		
April–June	−0.033***	—	—
	(0.006)		
July–September	−0.057***	—	—
	(0.006)		
Monthly Dummy:			
December	—	Base	Base
January	—	−0.019**	−0.073***
		(0.009)	(0.011)
February	—	−0.025**	−0.043***
		(0.008)	(0.011)
March	—	−0.016**	−0.062***
		(0.008)	(0.011)
April	—	−0.040***	−0.144***
		(0.008)	(0.011)
May	—	−0.041***	−0.153***
		(0.008)	(0.011)
June	—	−0.056***	−0.206***
		(0.008)	(0.011)

(continued . . .)

Table 4. Continued

Variable	United States	San Francisco / Oakland	Dallas / Ft. Worth
Monthly Dummy (cont'd.):			
July	—	−0.057***	−0.165***
		(0.001)	(0.001)
August	—	−0.052***	−0.152***
		(0.001)	(0.001)
September	—	−0.031***	−0.100***
		(0.001)	(0.001)
October	—	−0.036***	−0.087***
		(0.001)	(0.001)
November	—	−0.028***	−0.054***
		(0.001)	(0.001)
R^2	0.503	0.704	0.664
No. of Observations	28,701	9,053	11,158

Notes: Single, double, and triple asterisks (*,**,***) denote statistical significance at the 10%, 5%, and 1% levels, respectively. Numbers in parentheses are White's heteroskedastic-consistent standard errors.

equal.[5] The hypothesis of equality of coefficients on the three data sets is strongly rejected according to a Chow test ($p < 0.01$). There are many valid reasons to suspect the estimates may differ by location, and this intuition is borne out by statistical tests.

Given the rejection of the hypothesis that data from San Francisco and Dallas can be pooled into a single hedonic price function, one might question the validity of the hedonic model fit to the aggregate U.S. data (i.e., the first column of results in table 4). We report a hedonic price function for the entire U.S. market because it is of interest to policy makers and producers. The U.S. hedonic price function provides information on, for example, the difference in average price of cage-free vs. cage eggs in the United States, which is a statistic of interest to many individuals. We interpret the U.S. model estimates as providing descriptive statistics on the average prices of different types of eggs. It is important to note that the hedonic estimates from a U.S. model will not necessarily equal egg price difference in any particular location or market; moreover, the U.S. hedonic coefficients are not equal to the average hedonic coefficients across all locations.

Looking first at the U.S. market results (based on $N = 28{,}701$ quarterly price observations from 1,985 SKUs observed over five years), table 4 shows that most estimated parameters are statistically significant at the 0.05 level or lower. The coefficient corresponding to cage-free is 0.449, which implies that the U.S. average price premium for cage-free eggs is $100 * [\exp(0.449) - 1] = 56.7\%$ as compared to conventional egg prices. The U.S. average price premium for cage-free eggs (56.7%) over conventional eggs is less than that for free-range eggs (87.57%). Hens laying eggs labeled as both cage-free and free-range are kept uncaged in barns, but typically only free-range hens have access to the outdoors. It should be noted that federal standards for organic labeling require that hens be given outdoor access, and thus organic could also be considered free-range.

The Omega-3 coefficient for the overall U.S. model is 0.493, indicating an average price premium of 63.7% for eggs advertised to have this health benefit. In the U.S. market, organic

[5] The Dallas and San Francisco data represent such a small fraction of the overall U.S. data that any "double counting" in the pooled model is quite minimal. In the first quarter of 2007, less than 4% of all U.S. egg sales in our data set are in the Dallas and San Francisco markets.

eggs receive about an 85% premium over conventional eggs. Bundling the attributes of Omega-3 and organic generates a price premium of approximately 103%.

The average U.S. price premium for brown eggs is about 26% compared to white eggs. Differences in egg color stem from differences in breeds of hens laying the eggs. Although shell color is unrelated to quality, nutrition, or taste, some people may perceive brown eggs as healthier or of better quality than white ones. Because most cage-free and organic eggs are brown, this suggests a significant portion of the observed price premium for these production methods over conventional eggs in the market is likely attributable to color. One of the reasons brown hens (and thus brown eggs) are used in cage-free and organic production systems is that they are genetically predisposed to act more amicably toward other hens in the open barn environment than the traditional breeds of white hens used in the cage system. However, they also tend to be less productive. These productivity differences result in higher production costs for brown eggs, which might also explain the higher price premium for brown eggs over white.

Results in table 4 also show how egg prices vary with other egg attributes such as egg size, packaging material, branding, and package size. The results indicate that larger eggs generally receive price premiums relative to smaller eggs. Prices are also influenced by packaging material; eggs packaged in the most common types such as carton and styrofoam cartons tend to be lower priced than those in other package types. The lowest-priced packaging materials are the styrofoam carton and the cardboard box. Private-labeled eggs are priced about the same as brand-labeled eggs, holding constant other egg characteristics. As the number of eggs per package increases, the results show that the SKU price falls at a decreasing rate, perhaps suggesting volume discounting.

The last two columns in table 4 report the hedonic estimate models for the San Francisco and Dallas regional egg markets. Results reveal that most explanatory variables are statistically significant. The magnitudes of coefficients suggest Dallas is more similar to the United States than it is to San Francisco. Surprisingly, all parameter estimates associated with production method are larger in Dallas than in San Francisco. For example, the implied price premium for organic eggs is about 80% in Dallas but only 30% in San Francisco. Likewise, the price premium for cage-free eggs is about 50% in Dallas but only about 21% in San Francisco. The lower *percentage* premiums in San Francisco vs. Dallas could be explained by the fact that overall retail egg prices are higher in San Francisco than in Dallas. However, as can be observed in table 3 (and as we show later in table 5), cage-free and organic price premiums are higher in Dallas than in San Francisco, not only on a percentage basis but also on an absolute dollar basis as well.

Differences in price premiums across location may result from differences in demand. For example, Dallas consumers may be willing to pay more for cage-free and organic eggs than San Francisco consumers. However, supply differences could also be a factor. Specifically, although consumers in San Francisco may have a higher willingness to pay for cage-free and organic eggs than their Dallas counterparts, a potentially greater supply of these types of eggs in California may result in a relatively lower market price. While it is plausible that supply differences could explain the observed price premiums, it seems unlikely. Eggs can be transported between California and Texas [the shelf life of an egg is around 3–5 weeks (USDA/Food Safety and Inspection Service, 2010)], and California is a net importer of eggs (Sumner et al., 2008).

The highest priced egg in Dallas is the pasteurized egg—commanding a 168% premium over conventional eggs. The implicit price for vegan fed (68.5% premium) is higher in Dallas than in San Francisco (20% premium). Implicit prices for "natural" eggs are close to zero in Dallas and San Francisco. The effect of egg size is quite different between these two regional markets. Whereas larger eggs enjoy a price premium in Dallas and in the rest of the United States, small eggs command a price premium in San Francisco. It is unclear why this result was obtained in San Francisco, but it stems from the sale of a single SKU that only appeared in the last 44 weeks of the data set. As such, not much can (or should) be inferred from this particular finding.

At this point, it is worth asking whether the price premiums observed for cage-free and free-range eggs can be attributed to consumers' animal welfare concerns. First, the scientific evidence clearly favors the notion that hen well-being is higher in cage-free production systems than in the typical cage system [see the LayWel Research Project (2004) report, De Mol et al. (2006), or Norwood and Lusk (2011)]. Consequently, there is a clear link between these production systems and animal welfare. Still, it is possible that there are other unobserved factors correlated with cage-free production. Might people buy cage-free eggs for other reasons than production method used? Perhaps, but our regressions control for many of these factors (color, package size, type of packaging, etc.).

One obvious unobserved factor is brand name. We have information on individual brand names for each SKU, but there are too many individual brands in our sample to separately identify the effect of brand name from the individual product attributes and production methods. We partially controlled for such factors with the *Private* vs. *Specific* brand variables shown in table 4. However, even if we expand on this analysis by creating dummy variables for each brand name and then omit any categorical variables that are subsequently unidentified, we continue to find significant price premiums for cage-free eggs. For example, applying this approach to the data from Dallas, we find that the coefficient on cage-free was very similar to the result reported in table 4 (0.43 vs. 0.407), which does not control for each individual brand name. We interpret such findings to imply that the estimated premium for cage-free vs. cage eggs is unlikely to be caused by the presence of unmeasured brand-specific characteristics. Of course, the cage-free label might carry additional connotations other than improved animal well-being, such as perceptions of better taste. Accordingly, the observed price premiums for "cage-free" include animal welfare characteristics in addition to issues like taste and quality that consumers might infer from a cage-free label.

Table 5 reports predicted price premiums for several types of eggs as compared to conventional eggs on a dollar per dozen basis.[6] The expected price for conventional white eggs was about $1.77/dozen in the United States and $1.90/dozen in Dallas; the expected price in San Francisco ($3.03/dozen) was substantially higher. The estimated price for a dozen cage-free, brown eggs was about $3.50/dozen in the United States, $3.57/dozen in Dallas, and $4.28/dozen in San Francisco. Thus, the price premiums for cage-free, brown eggs over conventional, white eggs were about $1.70/dozen in the United States and Dallas but only $1.25/dozen in San Francisco.

Because cage-free and organic eggs are typically brown, whereas most conventional eggs are typically white, it is of interest to ask how much of the premium for cage-free and organic eggs typically observed is a result of egg color. To address this issue, table 5 compares the predicted prices for both brown and white cage-free (and organic) eggs to the predicted price for conventional, white eggs. For example, holding egg color constant at white, the U.S. data

[6] Due to the nonlinear transformation of the regression error, the calculated price premiums are consistent but biased estimates of the sample price premiums.

Table 5. Predicted Egg Prices and Premiums ($/dozen)

Egg Type	United States	San Francisco / Oakland	Dallas / Ft. Worth
Conventional, White	$1.77	$3.03	$1.90
Cage-Free, White	$2.77	$3.68	$2.85
Cage-Free, Brown	$3.50	$4.28	$3.57
Organic, White	$3.27	$3.93	$4.68
Organic, Brown	$4.12	$4.57	$5.87
Cage-Free, White Premium [a]	$1.00	$0.65	$0.95
Cage-Free, Brown Premium [a]	$1.73	$1.25	$1.68
% Premium Attributable to Color [b]	42.04%	47.73%	43.27%
Organic, White Premium [a]	$1.50	$0.90	$2.78
Organic, Brown Premium [a]	$2.36	$1.54	$3.97
% Premium Attributable to Color [b]	36.37%	41.41%	30.01%

Note: Estimated values are for one dozen large eggs in a carton container in the fourth quarter of 2008.
[a] Premium relative to conventional, white eggs.
[b] Calculated as: [1 − (*White Premium* / *Brown Premium*)] ∗ 100.

set indicates cage-free eggs are predicted to command a premium of $1.00/dozen over conventional eggs; however, because most cage-free eggs are brown, the price premium that will typically be observed is instead $1.73/dozen. Based on these calculations, $0.73 of the premium typically observed in a grocery store can be attributable to color, whereas the remaining $1.00 is a result of production practice (cage-free). Thus, 42% of the total premium typically observed for cage-free eggs is linked to egg color, not the fact that hens were housed in cage-free systems. Similarly, about 36.4% of the “typical” organic premium can be attributed to egg color rather than organic production per se.

On the Demand for Cage-Free and Organic Eggs

To this point, we have focused on the descriptive models explaining how egg prices vary with product characteristics. Table 4 provides estimates of the first-stage hedonic analysis and reports the implicit prices of several egg characteristics. While they relate to a point on the demand curve, they do not identify the demand curve as distinct from supply-side factors. Hence, it is worth asking whether and to what extent our data can be used to provide structural estimates of demand.

In classic demand theory, consumer utility is defined over the quantity of goods consumed. However, consumer utility can instead be written as a function of the characteristics or attributes of the goods (e.g., Lancaster, 1966; Rosen, 1974; Gorman, 1980). It is assumed a consumer will choose the good (which is defined by its underlying attributes or characteristics) that maximizes utility, given prices and a budget constraint. The first-order condition of this maximization problem indicates that the marginal price of an attribute (i.e., the derivative of the price of the composite good with respect to the underlying attribute of interest) will equal the consumer’s marginal rate of substitution between the attribute and a numeraire (see Rosen, 1974; Taylor, 2003). As demonstrated by Rosen, one can rewrite the optimization problem to derive an optimal bid or willingness-to-pay function. The result of this optimization problem shows that the consumer’s marginal willingness to pay for an attribute is equal to the marginal rate of substitution between the attribute and the numeraire. Thus, from these two equalities, we find that the marginal price of an attribute equals the consumer's marginal willingness to pay for the attribute (see Rosen). This insight is often used to link implicit prices from a hedonic model like that shown in table 4 to consumers' willingness to pay at a point on the demand curve.

For discrete characteristics, however, equality between the marginal implicit price and marginal rate of substitution breaks down because one cannot differentiate the utility function with respect to the discrete variable. The "1st stage" coefficients associated with discrete characteristics provide an estimate of implicit prices, but are not technically marginal rates of substitution (or willingness to pay). Yet, Bajari and Benkard (2005) argued that the coefficients associated with discrete attributes provide information or bounds on willingness to pay given the existence of a price function and an assumption about the functional form for utility (see also Bajari and Kahn, 2005). They went on to show that for discrete characteristics, such as cage-free or organic, the implicit hedonic prices from the first-stage regression can be coupled with data on the choices actually made by consumers to infer willingness to pay.

In particular, the regression coefficients imply that consumers in Dallas faced an expected implicit price premium of \$0.95/dozen for cage-free eggs, holding color constant at white (see table 5). It stands to reason that consumers who bought cage-free eggs in Dallas must have been willing to pay at least \$0.95/dozen for cage-free eggs, and consumers who chose not to buy cage-free eggs must have had a willingness to pay of something less than \$0.95/dozen for this characteristic. Despite this high implicit price (or perhaps because of it), just 0.50% of eggs purchased in Dallas were cage-free only (see table 2). A Turnbull lower-bound estimate on willingness to pay for cage-free eggs in Dallas is $0.005 * 0.95 = \$0.01$/dozen (see Haab and McConnell, 2002, p. 76). Similar reasoning suggests lower-bound estimates of about one to three cents on cage-free and organic eggs in Dallas and San Francisco.

One could take this line of reasoning further and actually estimate the mean willingness to pay in the population using the approach outlined in Bajari and Kahn (2005). The approach requires estimating the implicit price premium for cage-free or organic eggs at each data point, and calculating the probability of purchasing cage-free at each SKU using an assumed parametric function for the distribution of willingness to pay. Coupling this probability statement with the actual quantity of each SKU sold in a likelihood function, one can arrive at an estimate of the mean willingness to pay.

When we apply this approach to our data, we find the estimated mean willingness-to-pay values for cage-free and organic that rationalize the consumption data are very small.[7] This finding might seem counterintuitive initially, but it is perfectly consistent with the underlying data. Although the implicit prices for organic or cage-free are quite high, there are few people actually willing to pay the implicit price for cage-free and organic eggs, as evidenced by the small market shares for these products (see table 2). While *some* people are willing to pay the implicit price for cage-free or organic, most are not. Thus, in a population of shoppers, the mean willingness to pay for cage-free (or organic) eggs is substantially less than the estimated implicit price premium for cage-free (or organic) despite the existence of a few shoppers who are willing to pay significant premiums for these products.

[7]The unconstrained means are in fact negative. One could force the estimated willingness to pay for cage-free or organic to be positive by picking a particular distribution such as a lognormal distribution or a uniform with a limit at zero; but in such cases, we find that the likelihood function simply converges at the boundary, \$0.

Conclusions

The U.S. fresh egg market has recently witnessed an explosion in product differentiation. Using retail scanner data collected from a representative sample of grocery stores in the United States, this study investigated the value of several egg attributes using the hedonic method.

Specialty eggs commanded significant price premiums over conventional eggs. For example, the average U.S. percentage price premium for organic and Omega-3 eggs is over 100%. Other characteristics, such as egg color, package type, and egg size, were also significantly related to egg price. We also studied hedonic egg prices in two specific metropolitan areas—San Francisco/Oakland, California, and Dallas/Fort Worth, Texas—and found significant differences across locations. Somewhat surprisingly, estimated price premiums for cage-free and organic attributes appear lower in the state for which a ballot referendum to ban battery cage production recently passed than in a state many would think would be less open to animal welfare issues. Although egg prices were substantially higher in San Francisco, the price premiums for cage-free, organic, and other alternative production methods tended to be higher in Dallas.

Despite the high price premiums observed for cage-free and organic eggs, our data also reveal that the market shares for such products are very small. These data suggest average consumer willingness to pay in the population of egg shoppers is much less than the estimated price premiums. It should be noted that our data are not particularly informative in precisely articulating the average willingness-to-pay value, in part because cage-free and organic eggs are always so much higher priced than conventional eggs. One would need survey or experimental data to better project what choices people would make were prices more similar.

One interesting finding emerging from our analysis is that the retail price premiums observed for cage-free and free-range eggs appear much larger than the estimated cost differences at the farm level. For example, Sumner et al. (2008) estimate the costs of production to be about \$0.31/dozen higher in cage-free vs. cage production systems at the farm level, but our estimates suggest the U.S. average retail price premium for cage-free eggs is \$1.00/dozen. The data reported here are potentially revealing in what they have to say about retailers' pricing strategies. Although the market shares for cage-free and organic eggs are small, such products appear in almost every major grocery store chain, indicating the price premiums are probably not a result of the offerings of a particular kind of store. The price of any one egg characteristic is influenced by the cost and value of the good, but price could also be strategically set to encourage the patronage of certain consumers, allowing the food retailer to charge higher premiums on other goods. Whole turkeys at Thanksgiving are a prime example. Food retailers are suspected of selling turkeys at a loss on Thanksgiving, providing consumers with a large consumer surplus, which may increase the value of shopping at the store and increase consumers' willingness to pay for other items (DeGraba, 2006). It is possible that stores in some areas may sell cage-free eggs at lower prices than other areas as a strategy to influence store volume and price premiums for other goods. Just as turkey prices decline at precisely the same time demand rises, it is possible—though perhaps not probable—that higher demand for cage-free eggs in one location may translate into lower prices.

Also interesting is the mix of products offered in the market place. Apparently egg producers often bundle attributes and redundantly label attributes (e.g., an organic product is both cage-free and free-range, but some packages explicitly label all characteristics whereas others do not). Two often bundled characteristics (due to the particulars of egg production) are egg color and cage-free production. Because our data set contains a few "unusual" SKUs which are either brown and cage-raised or are white and cage-free, we can estimate the portion of the "typical" price premium witnessed on cage-free eggs that results solely due to color rather than a change in production practice. Based on our estimates, approximately 42% of the typical cage-free premium and about 36% of the organic premium can be attributed to the fact that these products are typically brown.

The hedonic approach employed in this paper is useful for identifying the implicit prices of egg characteristics. Such information is valuable for producers to know whether it is profitable to undertake costly investments to change production systems, and it is also beneficial in judging the potential impacts on market prices which may result from state-wide ballot initiatives that ban certain production practices. Future research will focus on exploring approaches for estimating consumer demand (rather than implicit prices) for egg production characteristics, identifying the determinants of demand for more "animal-friendly" products, and exploring retailer pricing strategies.

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