Economic and market issues on the sustainability of egg production in the United States: Analysis of alternative production systems[1]

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ABSTRACT Conventional cage housing for laying hens evolved as a cost-effective egg production system. Complying with mandated hen housing alternatives would raise marginal production costs and require sizable capital investment. California data indicate that shifts from conventional cages to barn housing would likely cause farm-level cost increases of about 40% per dozen. The US data on production costs of such alternatives as furnished cages are not readily available and European data are not applicable to the US industry structure. Economic analysis relies on key facts about production and marketing of conventional and noncage eggs. Even if mandated by government or buyers, shifts to alternative housing would likely occur with lead times of at least 5 yr. Therefore, egg producers and input suppliers would have considerable time to plan new systems and build new facilities. Relatively few US consumers now pay the high retail premiums required for nonconventional eggs from hens housed in alternative systems. However, data from consumer experiments indicate that additional consumers would also be willing to pay some premium. Nonetheless, current data do not allow easy extrapolation to understand the willingness to pay for such eggs by the vast majority of conventional egg consumers. Egg consumption in the United States tends to be relatively unresponsive to price changes, such that sustained farm price increases of 40% would likely reduce consumption by less than 10%. This combination of facts and relationships suggests that, unless low-cost imports grew rapidly, requirements for higher cost hen housing systems would raise US egg prices considerably while reducing egg consumption marginally. Eggs are a low-cost source of animal protein and low-income consumers would be hardest hit. However, because egg expenditures are a very small share of the consumer budget, real income loss for consumers would be small in percentage terms. Finally, the high egg prices imposed by alternative hen housing systems raise complex issues about linking public policy costs to policy beneficiaries.

Key words: economics of hen housing, hen welfare, economics of animal welfare, hen housing regulation

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INTRODUCTION

Agricultural sustainability encompasses positive contributions to the environment, to healthful food, and to community welfare. Applied to the egg industry, sustainability also refers to the treatment of laying hens and especially the systems used for hen housing. Although recognizing that issues such as environmental consequences, food safety, and humane treatment of hens are also important, this article focuses on the relationships between hen housing and economic and market conditions.

From the basic definition of the word, sustainability applied to an industry must imply that the industry continues to operate for a prolonged period. In a dynamic economy, the economic viability that is required for sustainability implies adaptation to changing market conditions, including those that encompass broad consumer and social demands. Without economic viability, firms in an industry cannot continue to operate. Practices that do not allow economic viability in some fashion cannot be considered sustainable. Furthermore,

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the economic and market implications of different production practices affect the egg industry's contribution to employment, nutrition, and consumer satisfaction. For these reasons, economic and market issues are central to any notion of sustainability of an industry.

Policies and other drivers that encourage the adoption of practices that contribute to meeting environmental, social, or other sustainability criteria often have implications for economic and market outcomes. And economic relationships affect the actual outcomes of measures motivated by sustainability objectives. Therefore, as one considers alternative production systems that may address some sustainability criteria, the effect on the market position of an industry must be included in the analysis. Changing production systems may have implications for input usage, output per unit of input, costs of production, product characteristics, consumer response, overall output, firm size, marketing and distribution relationships, and market prices among other economic and market variables.

Besides affecting costs and relationships in egg markets, hen housing and other conditions affecting the flock may be of direct interest to members of society whether they consume eggs or not. Some members of society would likely be willing to pay for humane hen treatment or environmental sustainability if a market for these services could be established. Such public goods and services have special characteristics, however, that make establishing markets difficult.

This article focuses primarily on direct consequences of hen housing regulations for costs, prices, and quantities. Eggs from noncage systems are generally more costly to produce than conventional eggs and must command significant market premiums to be competitive when buyers have a choice (Patterson et al., 2001; Sumner et al., 2008). Due to the high initial investment required for aviaries and furnished cages and the low stocking density of free-range systems, most noncage eggs are produced in floor systems in the United States. Therefore, for commercial purposes and for most of the available data, conventional cages and noncage floor systems are the dominant forms. We will use the terms cage and noncage below to refer to conventional cages and noncage floor systems unless more specific reference is made to an alternative system.

SUPPLY AND THE EGG INDUSTRY

This brief summary article reviews the likely economic and market implications of shifting egg production from the current system, which relies primarily on caged housing for hens, to alternative noncage systems. We use this case to consider social sustainability because it has been of considerable current interest and because some data and analysis are available for these alternatives. The analysis could be extended to deal with additional alternatives such as free-range, furnished cages, and pasture-based production systems. Some such data are discussed later in this article, but developing further data for these alternatives would be a useful extension to the analysis discussed here. In this article, we will not detail all of the economic issues related to all potential hen housing systems or other hen treatment issues.

In 2008, about 76.7 billion table eggs were produced in the United States. As Figure 1 shows, most of these eggs were sold through retail channels. Almost one-third went on for further processing to be used in food products, whereas a smaller share was sold to institutions and a very small share was exported. Egg production is not evenly distributed throughout the United States. Table 1 shows the top 10 egg-producing states by the number of table egg-laying hens in 2009. As shown in the table, the US table egg-laying flock numbered about 276 million laying hens in 2009. Iowa had more than 19% of table egg-laying hens in the country, followed by Ohio with 9.6% and Indiana with 8.3%. As Table 2 shows, egg production is relatively concentrated, with 10 firms supplying almost half of the entire table egg market in 2008.

Changes in hen housing could be imposed by governments or by industry-set standards, say as required by major buyers. However, we note that many specialty eggs, differentiated by the housing system and other standards, are already available in the US market. Specialty eggs provide alternatives to consumers, and responses of consumers to these alternatives can provide information useful in assessing effects of government or industry mandates or standards. Discussions with egg producers in the United States confirmed that the large egg-producing companies participated in the organic market and the noncage, nonorganic market (Sumner et al., 2008). Nonetheless, informal evidence suggests that very small and more specialized firms have larger market shares in the markets for eggs from free-range or pasture-raised hens than they do for conventionally produced eggs. The overall market for eggs from free-range and pasture-raised hens is itself very small, and no systematic large-scale data are available. Furthermore, a high share of these particular specialty eggs are likely marketed through alternative channels and are generally not available in the conventional supermarkets or larger outlets that often do carry organic eggs and eggs from other noncage systems.

Available information shows that the sale of organic eggs grew steadily in recent years. From 2000 to 2005, organic egg sales grew by an average annual rate of 19% (NBJ, 2006). Using ACNielsen Homescan data, the USDA-Economic Research Service estimated that organic eggs accounted for 1% of the fresh egg market in 2004 (Oberholtzer et al., 2006). The USDA-Economic Research Service has determined that growth in the specialty egg market is rapid and that organic eggs represent the fastest growing item in this category (Oberholtzer et al., 2006). Figure 2 confirms that although organic eggs are a growing part of the egg industry, the share remained small as of 2007, the last year for which such national data were available.

Figure 1. Distribution of US egg production through alternative supply channels, 1998 to 2008. Source: AEB (2008). Amounts for 2008 are estimated.

A SIMPLE FRAMEWORK FOR CONSIDERING ALTERNATIVE LAYER HOUSING SYSTEMS

A natural approach to considering the economic and market effects of a mandated change in industry-wide housing systems (or other such production or product modification) is to model the effects on the supply and cost of production on one side of the equation and the effects on the demand and consumer behavior on the other side. Such an approach uses available data and parameter estimates and allows the approximation of market outcomes as a consequence of many different potential changes to housing systems. Dealing with the public good aspects of hen housing and related issues is more demanding, mostly because it is difficult to assess consumer and other public preferences for goods not sold directly or widely in a market.

Four parameters (or sets of parameters in a more complex model) are required to assess the effect of restrictions on hen housing or other sustainability regulations on the egg market. The first 2 of these parameters reflect the demand side of the market, and the last 2 reflect the supply side of the market. The relationship between these parameters is described algebraically in the appendix.

The first demand-side parameter represents the response of the quantity of eggs demanded to the market price and is used to characterize the degree to which buyers reduce egg purchases as prices increase due to higher production costs. Economists often measure this demand response to price as the price elasticity of demand, which is the percentage change in quantity purchased resulting from a percentage change in price. The value of the demand elasticity relates directly to the degree of substitutability of other goods for eggs. A lower value (closer to zero) indicates less substitutability, such that a price increase causes a smaller decrease in quantity purchased because consumer options for substitutes are limited. With a very elastic demand, if the price increases, the quantity decreases dramatically. Thus, for example, if eggs from Iowa that were close substitutes for Ohio-produced eggs could be readily available in the Ohio market, then an increase solely in the cost of Ohio-produced eggs could drastically cut the size of the industry in Ohio. The elasticity is

Table 1. Top 10 egg-producing states by number of table egg-laying hens for 2009

State	Average number of table egg-laying hens in 2009[1] (thousands)	Share of US table egg-laying hens in 2009[1] (%)
Iowa	52,901	19.1
Ohio	26,604	9.6
Indiana	22,899	8.3
Pennsylvania	21,494	7.8
California	19,348	7.0
Texas	14,116	5.1
Nebraska	9,570	3.5
Minnesota	9,689	3.5
Michigan	9,682	3.5
Florida	9,493	3.4
Other states	80,637	29.2
US total	276,433	100.0

[1]Includes only hens for table egg production from flocks of 30,000 hens or more. Annual estimates based on monthly averages covering the period December 1 previous year through November 30. Source: USDA (2010).

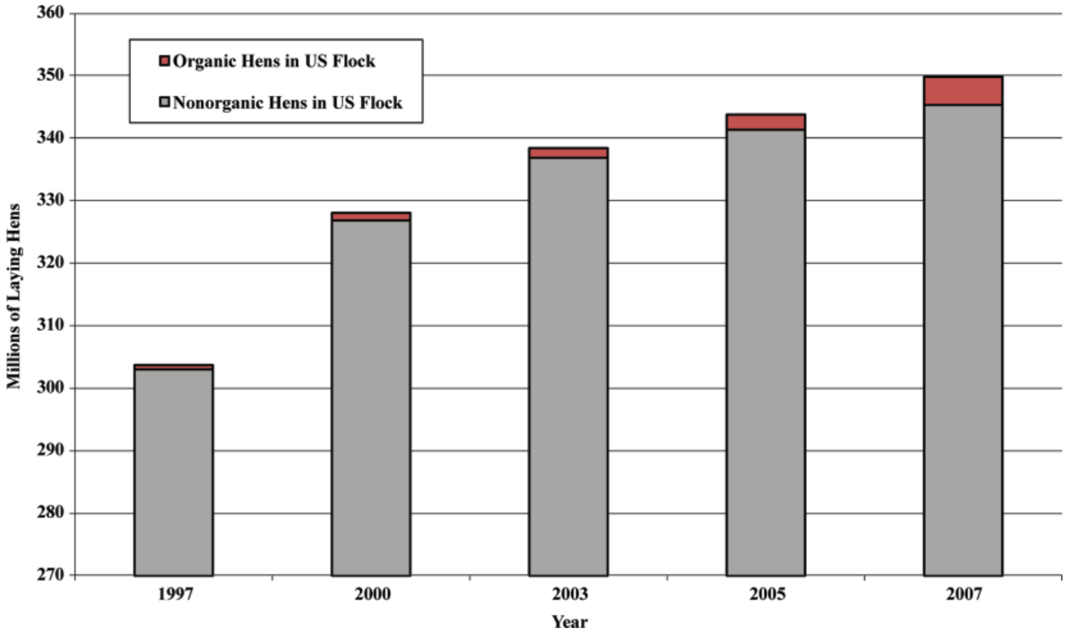

Figure 2. Organic and total laying hens in US flock, 1997 to 2007. Note: Estimates of hen flock size include laying hens for hatching purposes. Source: USDA-ERS (2009); USDA (2010) for numbers on all laying hens. Source for 2007 data: USDA (2009). Color version available in the online PDF.

also influenced by the share of eggs in the purchasers' total expenditures. For example, for food processors, the smaller the share of eggs in production costs of their final product, the less effort these buyers devote to finding potential substitutes and the less elastic is their demand.

The second demand-side parameter is the degree to which potential buyers value eggs produced using the alternative housing system relative to eggs produced using the conventional cage system. A positive value for this shift in demand implies that, in aggregate and at the relevant market prices, buyers would purchase more eggs, for a given price, produced under the alternative system. One can think of this parameter as the increase in price buyers would be willing to pay for eggs produced under a certain alternative system, relative to eggs produced conventionally. The value of a demand shift need not be positive for all consumers or even on average. For example, the demand shift would be negative if buyers preferred eggs from the conventional cage system, say, because they particularly valued less contact of the eggs with feces. The degree of this demand shift depends on buyers' perceptions about production systems and may change when different information becomes available.

The 2 parameters on the supply side are analogous to those just discussed. The price elasticity of supply measures the percentage change in the quantity of eggs marketed for each percentage change in price expected by producers. The elasticity of supply also indicates

Table 2. Top egg-producing companies for 2008 by number of layers owned[1]

Item	Company	Number of laying hens owned (thousands)	Percentage of US table egg-laying hen population
Rank			
1	Cal-Maine Foods Inc. (Jackson, MS)	28,600	10
2	Rose Acre Farms (Seymour, IN)	21,600	8
3	Sparboe Summit Farms Inc. (Litchfield, MN)	12,000	4
4	Decoster Egg Farms (Clarion, IA)	11,800	4
5	Moark LLC (Norco, CA)	11,600	4
6	Michael Foods (Minnetonka, MN)	11,200	4
7	Daybreak Foods (Lake Mills, WI)	9,200	3
8	Ohio Fresh Eggs (Croton, OH)	7,200	3
9	Fort Recovery Equity (Fort Recovery, OH)	6,200	2
10	Midwest Poultry Services (Mentone, IN)	6,000	2
Total of top 10 firms		125,400	44
US table egg-laying hen population[2]		284,003	

[1]Number of laying hens per firm is an estimated flock size on December 31, 2008.

[2]US table egg-laying hen population for 2008 is the estimated table egg-laying hen population for January 2009. Source: Company rank data comes from Watt Poultry (2009). US table egg-laying hen population data comes from USDA-NASS (2009).

the amount, in percentage terms, by which marginal per-unit costs of production change for each percentage change in output. The supply function is less elastic when there are tighter limits on industry expansion overall or if unit costs increase rapidly as industry output expands. Such rising costs may be caused by increased input prices as more feed, labor, or capital is demanded by the industry or regulations limit expansion of the industry. As discussed later in the paper, the egg industry generally uses a small share of the available supply of most important inputs, and given a few years for adjustment, inputs such as labor, feed, and other materials are readily available at little if any additional per-unit costs. The second supply-side parameter is the degree to which shifting to the alternative housing system raises the marginal per unit cost of production. The cost increase may be different for different producers because of their location or the nature of their operations, but for aggregate industry-wide analysis, the relevant increase in costs is that which applies to farms that remain in production.

EVIDENCE ABOUT THE PARAMETERS USED IN THE SIMPLE ECONOMIC MODEL

The standard model described previously and the algebraic representation in the appendix show how the 4 key parameters determine the price and quantity outcomes of a shift to alternative production systems. These parameters are the magnitude of the additional costs from producing under an alternative system, the increased willingness to pay for eggs under an alternative system, the elasticity of demand for eggs, and the elasticity of supply of eggs. In this section, we discuss each of these factors, with respect to parameters for noncage systems versus conventional cages.

Additional Costs of Production Associated with Noncage Housing Systems

Several studies have examined costs associated with alternative production systems. Sumner et al. (2008) reviewed several data sources and many of the issues and reported on data from California producers. Their basic finding is that farm-level costs are 40 to 70% higher for the noncage system than for conventional cages. Table 3 summarizes cost data by specific item and indicates the additional costs from using a noncage system (Sumner et al., 2008, 2010). These data are from a small sample of farms that produce under both systems and use a standardized accounting method across the systems. Feed costs are the most important cost item (Bell, 2002). Cost of feed as well as other items such as labor, pullets, and housing are higher per dozen eggs for the noncage system. A range of estimates is provided for each cost item in Table 3.

Table 3 also shows the sum of the cost items for the low cost and median cost for each category. These different ways of viewing the data are useful to illustrate the state of knowledge about cost differentials. There is no right way of displaying or calculating these cost differences. For example, using medians of the range reflects a central tendency across all firms in the industry. However, using the low cost for each item applies

Table 3. Comparison of production costs between cage production system and noncage production system in cost per dozen[1]

Item	Cage production system range and median ($ per dozen)	Noncage production system range and median ($ per dozen)	Cost differential noncage minus cage system using midpoints	Cost differential noncage minus cage system using low costs
Pullets[2]	0.09 to 0.11 0.10	0.14 to 0.17 0.155	0.55	0.05
Feed	0.28 to 0.45 0.365	0.35 to 0.50 0.425	0.06	0.07
Housing[3]	0.05 to 0.14 0.095	0.09 to 0.37 0.23	0.135	0.04
Labor[4]	0.03 to 0.04 0.035	0.07 to 0.19 0.13	0.095	0.04
Sum of the itemized costs and difference at the midpoints	0.595	0.94	0.345	
Sum of the itemized costs and differences at the low costs	0.45	0.65		0.20
Percentage cost difference based on the sum of items			0.345/0.595 = 58%	0.20/0.45 = 44%
Total cost[5]	0.57 to 0.92 0.745	0.97 to 1.13 1.05	0.305	0.40
Percentage cost difference			0.305/0.745 = 41%	0.40/0.57 = 70%

[1]Source: Sumner et al. (2008).

[2]Pullet cost is the original cost of the hen averaged over the hen's lifetime egg production.

[3]Housing cost aggregates the cost of the housing structure, housing equipment, maintenance, service, supplies, and utilities.

[4]Labor cost represents only labor allocated to the layer house.

[5]Total cost constitutes a sum of the 4 cost categories plus additional costs such as overhead, taxes, and miscellaneous costs, which are not listed separately.

Table 4. European Union comparison of cage production systems and noncage production systems, 2003[1]

Cost factor	Conventional cage system	Noncage system	Percentage difference between noncage and cage system
Laying cycle (d)	388	382	−1.55
Annual egg yield per hen	280	269	−3.93
Pullet cost[2] (€) ($)	3.17 (4.28)	3.63 (4.90)	14.51
Average pullet cost per egg produced (€) ($)	0.0113 (0.0152)	0.0135 (0.0182)	19.47
Annual feed consumed per hen[2] (kg)	38.82	41.84	7.78
Average annual feed consumed per egg produced (kg)	0.139	0.156	11.90
Workers per 100,000 hens	2.72	5.74	110.76
Workers per million eggs	0.097	0.213	119.19

[1]Source: Based on data from Agra CEAS Consulting (2004).

[2]Value in US dollars (in parentheses) calculated at December 24, 2004, exchange rate, publication date of the source.

if over time we expect firms that remain competitive to adopt practices that result in the lower costs for each item. Thus, to provide the most inclusive range of estimates, we report on the data in several ways. Table 3 also shows the differences in percentage terms. For the median of the overall costs, the differential between systems is 41%. The differential between the low-cost values for conventional and noncage systems is 70%. Using the sum of the medians for each cost item, the percentage differential is 58%, and using the sum of the low costs for each item, the differential is 44%. These ranges provide a reasonable assessment of the range of additional costs of shifting from the conventional cage system to the noncage system.

Some European data on costs and input use under alternative systems are found in Table 4. These data do not supply overall cost estimates for the 2 systems but do indicate that each component of production would have higher costs for the noncage system. In particular, feed per egg is about 12% higher for noncage systems in Europe, and labor use per hen is almost double in the noncage system (Agra CEAS Consulting, 2004). Both of these findings are consistent with the California data reported in Sumner et al. (2008).

Additional Willingness to Pay for Eggs Produced in Noncage Systems

Figure 3 shows recent national market average prices of eggs sold as conventional eggs, noncage eggs, and organic eggs (which by law must also be produced using noncage systems). Figure 3 shows that prices of conventional eggs have ranged from a little below $1.00 per dozen up to about $1.65 per dozen at the peak in February and March of 2008. Prices for noncage and organic eggs were much higher throughout the period. Noncage eggs ranged from a low of about $2.15 per dozen in May 2007 to more than $3.00 per dozen during April 2008, May 2009, and February 2010. Organic eggs ranged from a low of about $3.00 in June 2007 to about $4.00 in May and August 2008, September 2009, and February 2010. The percentage differentials at retail between the conventional and noncage eggs ranged from about 60% in the winter of 2007 to 2008 to more than 200% in the summer of 2009. These large retail price differences, which exceed the difference of farm production costs, suggest that either there are higher marketing costs per dozen for the higher priced eggs or that marketers earn a higher margin on these products and take advantage of the insensitivity to prices of the small share of buyers who purchase these nonconventional eggs.

More than 95% of egg buyers are unwilling to pay the added costs of noncage eggs, given the information available to them and the alternatives presented in the market. No market data are available as to whether average or median consumers would be willing to pay more or less for eggs produced in noncage or other nonconventional systems relative to eggs produced by hens in traditional cages. Assessing the potential purchasing behavior of buyers not currently in the market is challenging and requires much additional research. In surveys, European and US consumers report that they are concerned about hen welfare (European Commission, 2005). Information about the distribution of preferences would be useful in specifying how much potential buyers would be willing to pay for noncage eggs.

In one of the earliest systematic studies devoted to finding consumer willingness to pay for eggs from alternative systems, Bennett and Larson (1996) used a survey-based contingent valuation method to find consumers' expressed values. Contingent valuation models use survey techniques to attempt to assign economic values to nonmarket goods. Using this method, the authors find an average additional willingness to pay among US consumers of about 18%, or an additional $0.35 at 1996 prices, for free-range eggs, much less than the current retail price differential.

Economists have more recently turned to experimental approaches that face buyers with real purchase options, albeit usually in artificial settings. Norwood and Lusk (Oklahoma State University, unpublished data) used an auction procedure to estimate the willingness to pay among US consumers for eggs from a variety of production systems. When offered eggs from a barn system with little enrichment, the median consumer was indifferent between eggs from the conventional cage and the noncage system. If relatively little floor space was available in a barn system, eggs from the cage system were slightly preferred by the median buyer. In these systems, buyers were told there would be more than 3,000 birds per barn. The predominant noncage system used in the United States has up to 30,000 birds per barn. In the Norwood and Lusk experiment, the barn systems enriched with individual nests, bedding, and free-range access yielded a median additional willingness to pay of \$0.56 per dozen eggs. The results show that informed subjects were willing to pay more if there is generous space per hen, some scratching room, some type of nest, and safe outdoor access, at least under these experimental conditions. This study does not predict how typical consumers would behave in a grocery store because participants were provided in-depth information about housing systems before registering their bids.

Consumers in the market tend to be relatively uninformed about the different production systems. For example, Norwood and Lusk (Oklahoma State University, unpublished data), found that consumers believe that only 37% of eggs (rather than 95%) are currently produced in conventional cages. Further research on the distribution of preferences would be useful for clarifying this discrepancy and specifying how much potential buyers would be willing to pay for noncage eggs.

Experimental research on consumer egg preferences has also been conducted in Europe (Bennett and Blaney, 2003; Carlsson et al., 2007), but there is no published study using a nonstudent sample that measures preferences across a broad range of consumers for eggs produced in a noncage system versus those produced in cage systems.

The Elasticity of Demand

Several studies have attempted to measure statistically how the quantity of eggs purchased responds to the market price. In all cases, the percentage change in eggs purchased decreases relatively little when the price increases. When considering a permanent change in housing systems over a significant adjustment period, the relevant measure is the long-run elasticity that applies when anticipated price changes are expected to be long-lasting. The retail demand elasticities in the literature generally range from about −0.15 to −0.3. Representative studies, which vary in relevance of the data and statistical analysis, include the following: Kastens and Brester (1996), You et al. (1996), Huang and Lin (2000), and Yen et al. (2003). None of the econometric estimates use data from the last 15 yr. There is a need for more research to confirm the small elasticity of demand in the current market.

Published econometric studies have concentrated on the final buyer response to changes in retail prices. The response of quantity demanded to changes in farm costs and farm prices depends on the linkage between farm prices and retail prices in the marketing chain. Using a retail demand elasticity of −0.2, the farm-level elasticity should be about −0.1 if one uses a fixed markup

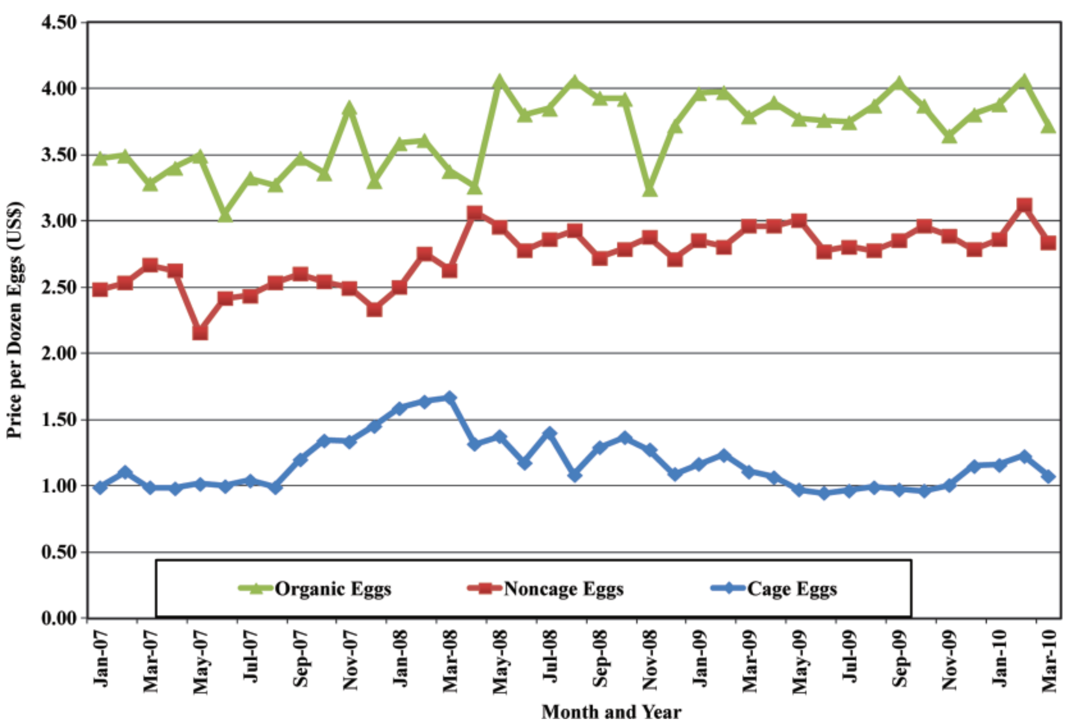

Figure 3. Monthly retail price (US\$) of 1 dozen large shell eggs by type, January 2007 to March 2010. Source: USDA-AMS (2010). Color version available in the online PDF.

equal initially to about half the retail price. This means that a sustained 40% increase in the price of eggs would cause only a 4% reduction in the quantity of eggs consumed (with a proportional markup, the farm and retail elasticities are equal).

These elasticity estimates would apply to eggs consumed in the United States and are generally also applied to eggs produced in the United States because imports and exports are very small. The export demand for eggs produced in the United States is very elastic because of competition from eggs produced in other countries and because the US share of the international market is very small. Imports could be considered a very close substitute for domestically produced eggs, however, so that if imports became a significant part of the market, raising the cost of domestically produced eggs would cause a dramatic decrease in quantity of domestic eggs and little change in price.

If imports were important, the effects would be much like those developed in Sumner et al. (2008) for California, where, because of free trade among states and the flexibility of shipments of eggs into California, the California price change from a shift to higher cost noncage systems would be very small but the quantity of eggs produced in California would decrease dramatically.

Marginal Cost and the Elasticity of Supply

The econometric literature is not helpful for assessing by how much marginal cost of production of eggs would decline with reduced output, given time for the industry to build new housing and adjust to new regulations. There are no recent studies of the long-run supply elasticity of eggs and no studies that estimate the long-run supply using appropriate econometric techniques. The marginal cost parameter is the inverse of the degree to which quantity would decline with a reduction in market price, that is, the long-run supply elasticity. If we envision the sorts of policies that would lead to a large shift in laying hen housing systems, they are most likely to be implemented after considerable lead time, as is underway in Europe and California. That means producers would have time to make the appropriate adjustments, including changing technologies, making new investments, or leaving the industry.

The likely supply response over this horizon can be explored by considering the underlying marginal cost conditions (i.e., by considering factors that limit the expansion of egg output or lower per-unit costs substantially if aggregate industry output were to decline). Major inputs to egg production are housing, labor, pullets, feed, health services, and general materials and services. For most of these inputs, the egg industry uses a small share of the total quantity available on the market, and reduced demand would not reduce the costs of these items, given several years for adjustment to new market conditions. For purposes of illustration, we consider a supply elasticity of about 10. This means that a 20% reduction in the quantity of eggs produced (allowing time to adjust fully) would lower the marginal per-unit cost of production by about 2%.

ILLUSTRATION OF THE MARKET EFFECTS OF A NONCAGE HOUSING MANDATE ON THE PRICE AND QUANTITY OF EGGS IN THE UNITED STATES

We can apply the parameter values discussed in "Evidence About the Parameters Used in the Simple Economic Model" to the model discussed in "A Simple Framework for Considering Alternative Layer Housing Systems." The equations used for the calculations appear in the appendix as equations [4] and [5]. For illustration, we set the increase in the proportional marginal cost (shift up in marginal cost) to 0.4. We set the increase in proportional willingness to pay (shift up in willingness to pay) to 0.1. Elasticity of demand (long run, farm level) was set to −0.1 and the elasticity of supply (long run, farm level) was set to 10.

Using these values applied to equation [4] in the appendix yields a change in the price of eggs of 39.7%. That is, a shift to a noncage system that raised costs of production by 40% and willingness to pay by 10% would raise the farm price by 39.7%. This occurs because the long-run supply function is elastic and the demand function is inelastic. In addition, the magnitude of the added willingness to pay for eggs is only moderate. But note that the increase in willingness to pay has limited overall effect because of the inelastic demand for eggs.

Next, consider the effect on the quantity of eggs produced and consumed. The effect can be calculated directly from equation [5] in the appendix. The percentage change in the quantity of eggs is −3%. That is, a shift to a noncage system that raised costs of production by 40% would lower the output of eggs by about 3%. The effect on quantity is small because the quantity demanded responds little to price and because some of the negative demand response to price is offset by an increase in willingness to pay for eggs perceived to be produced using a more desired housing system.

The effects on such downstream and upstream aggregates as employment, farm revenue, and consumer well-being may be calculated directly from these price and quantity effects. For example, given that quantity decreases little and noncage systems use much more labor per unit of output, our results suggest a large increase in egg industry employment.

The effects on industry total gross revenue are also strongly positive, but this is because costs increase substantially. The approximate percentage change in gross revenue is the sum of the change in price and quantity; therefore, total revenue would be expected to increase by about 37%, due to the approximately 40% increase in market price. However, because the price increase was due fully to an increase in costs and quantity decreases, the net revenue for egg producers decreases.

PUBLIC GOOD ISSUES RELATED TO PERCEPTIONS ABOUT TREATMENT OF ANIMALS

The previous analysis attempts to capture the effects on the egg market of a change in housing systems for laying hens. However, as noted in the introduction, in addition to consumer willingness to pay more for eggs from noncage systems, citizens and other taxpayers may be willing to pay to have eggs produced in preferred housing systems even if they do not consume eggs or even if those values are not reflected in their own consumption. For example, vegans may urge improved layer housing, but because they do not consume eggs, they have no way to express such preferences in the market for eggs. Treating the housing of hens as an economic good separate from the eggs produced allows the analysis to separate the demand for changes in layer housing itself and assess that good separately.

One way to approximate consumers' willingness to pay for alternative housing for laying hens is through auction experiments. Norwood and Lusk (Oklahoma State University, unpublished data) conducted an experiment in which participants were auctioned the opportunity to ensure better conditions for 1,000 laying hens. About 29% of the bids were zero, and the median bid was \$2.00. The average bid, which reflected some very high bids by a few individuals, was \$57.18. (We note that 1,000 hens produce more than 21,000 dozen eggs per year, and \$2.00 per 1,000 hens is approximately \$0.00009 per dozen eggs. For perspective, we note that the price premium for noncage eggs has been more than \$1.50 per dozen for most of the 2007 to 2009 period, as shown in Figure 3.) Even the high bids in this experiment represented only a small share of the value attributable to 1,000 laying hens.

Typically, public goods are provided through collective action because buyers acting in their own self-interest in the market will cause these goods to be undersupplied. The typical mechanism for supplying a public good that benefits the whole society, such as national defense or air quality improvement, is through general taxation or regulation. Societal welfare is improved when policies align the distribution of costs for providing the public good (say, improved treatment of hens) to those who benefit most. If benefits from better housing for hens are distributed roughly in proportion to egg consumption, then a regulation that raised the price of eggs satisfies this standard economic criterion. However, if many of those who prefer alternative hen housing systems consume relatively few eggs, then some other policy mechanism may be more appropriate.

CONCLUSIONS

This summary article lays out a framework for considering basic economic and market consequences of shifting to alternative housing systems for egg-laying hens. To highlight the importance of the analysis, we show some illustrative calculations with example parameter values. In that illustration, we find that the primary effect would be on the price of eggs with relatively small effects on the quantity of eggs produced or consumed in the United States. As noted above, in the case of a large increase in imported eggs, the market price change would be small and quantity produced in the United States would decrease dramatically.

The analysis presented here could be extended to deal with additional alternatives such as free-range, furnished cages, and pasture-based production systems, although data on such alternatives is limited. With the recent trend in retail egg sales toward more eggs being marketed as specialty eggs, large-scale systematic data may eventually become more available, allowing more in-depth analysis of the effects of government or industry mandates or standards. Such analysis should acknowledge the public good aspects of alternative animal treatment regimens and recognize that these aspects should be considered outside of the market for eggs. Indeed, the high egg prices implied by alternative hen housing systems raise complex issues about the linking of policy costs to policy beneficiaries.

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APPENDIX

An Example Algebraic Model of the Egg Market Response to National Layer Housing Restrictions

This appendix develops a standard economic model of US egg supply and demand. [See also Sumner et al. (2008, 2010) for an application to the California hen housing regulations.] Consider first the specification of a demand function that depends on price and consumer preferences or willingness to pay for eggs produced using an alternative housing system. For simplicity, consider a demand function for eggs of log differential form so that the percentage or proportional change in the US demand for eggs is given by

$$\mathrm{dln}Q^d = \eta(\mathrm{dln}P - \mathrm{dln}B), \qquad [1]$$

where Q^d is the quantity of US eggs demanded; P is price; η is the price elasticity of demand for eggs in the United States, which is negative; and B represents the additional willingness to pay for eggs produced using a particular noncage housing system. The term dlnB represents a percentage or proportional increase in the willingness to pay or demand price that would be experienced in the market. Notice that as willingness to pay under the alternative increases, the quantity demanded increases.

Analogously, consider a simple supply function where the percentage or proportional change in the quantity of eggs supplied to the US market takes the form

$$\mathrm{dln}Q^s = \varepsilon(\mathrm{dln}P - \mathrm{dln}C), \qquad [2]$$

where Q^s is the quantity of eggs supplied to the US market and dlnC is a vertical cost shifter reflecting the added marginal cost of producing eggs using the noncage alternative to the conventional cage environment. The elasticity of supply, ε, is positive because the higher the price, the more eggs will be supplied to the market. Notice that as costs increase, the quantity of eggs supplied decreases.

To determine the effects of the shift to the alternative system, we use the equilibrium condition

$$\mathrm{dln}Q^d = \mathrm{dln}Q^s = \mathrm{dln}Q, \text{ and insert equations [1] and [2].} \qquad [3]$$

Solving this equation for the proportional change in price as a function of the US egg market elasticities of demand and supply and the 2 shifters yields

$$\mathrm{dln}P = [-\varepsilon/(\eta - \varepsilon)](\mathrm{dln}C) + [-\eta/(\eta - \varepsilon)]\mathrm{dln}B. \qquad [4]$$

This expression shows that the more that costs increase with the increase in the cost of production due to the alternative housing system, the more the price of eggs in the United States increases. This term is positive because the elasticity of supply is positive and the elasticity of demand is negative so the denominator is negative.

Finally, using the expression for dlnP in equation [4] to insert into either equation [1] or equation [2] yields the following equation for the effects of the change in housing system on the new quantity of eggs:

$$\mathrm{dln}Q = [-\eta\varepsilon/(\eta - \varepsilon)](\mathrm{dln}C - \mathrm{dln}B). \qquad [5]$$

In equation [5], we see that the larger the cost increase from the new housing system, the fewer eggs will be sold ($[-\eta\varepsilon/(\eta - \varepsilon)]$ is negative). However, the larger the increase in the willingness to pay for eggs produced under the alternative system, the more eggs will be sold. Overall, the quantity effect will be negative not as a matter of the algebra but because the eggs produced under the alternative system are available currently and command a very small share of the market. That means the additional willingness to pay by consumers must be small relative to the additional cost of production for the eggs under the alternative housing system.