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Consumer confidence in Food Safety and the 2010 egg recall*

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Abstract

Iowa egg producers recalled nearly 500 million eggs in August 2010. The typical effect of a recall is to cause a decline in the demand for the affected product, yielding a decrease in the price. In the case of August 2010 egg recall, the price of eggs increased in the following weeks. This essay investigates the market effects of the egg recall. I estimate a system of simultaneous equations that includes supply and demand equations for the two main segments of the US industry. This essay offers preliminary evidence of the market effects of the August 2010 egg recall and describes the methodology to estimate the shift in consumers' willingness to pay for eggs accounting for the diversion of eggs in the other segment of the industry.

Key words: Egg, food safety, simultaneous equations.

JEL classification: D21, M31, Q10, Q18.

Introduction

The egg industry came under the spotlight in the summer and fall of 2010 following the discovery of a *Salmonella* outbreak in shell eggs. On August 13, 2010, Wright County Egg of Galt, Iowa, announced the recall of its production from May 16 to August 13, 2010 (CDC 2010). A few days later, on August 20, 2010, Hillandale Farms of Iowa recalled part of its production from April 9 to August 17, 2010 (CDC 2010). In total, the egg producers recalled nearly 500 million eggs. Most of those eggs were however already consumed and the quantity effectively recovered was much smaller. CDC (2010) report nearly 2,000 confirmed cases of illnesses from the outbreak of *Salmonella* in eggs. The actual number of illnesses is likely many times larger as not all affected consumers consulted a physician and only a small share of illnesses were linked to the outbreak in eggs.

Food safety incidents that require recalls are frequent but most do not receive much public attention. For large incidents that receive widespread media coverage, however, the short term reaction of consumers is often to radically reduce their consumption. This is for example what happened in the 2006 *E. coli* incident in spinach (Arnade, Calvin and Kuchler 2009). In the longer run, provided that no other incident occurs and that corrective actions are taken,

consumers regain confidence in the safety of the affected product and consumption returns to the level before the incident.

Given the typical reaction of consumers and that the quantity of eggs recalled was a small share of the total egg production, the August 2010 recall should have caused an immediate decrease in the consumption of eggs and a decrease in the price. This is not what happened. In the days after the announcement of the recall, the price of eggs increased by more than 40% and then steeply declined. The effect of the recall had seemingly vanished by November.

A shift in the demand for shell eggs alone cannot explain the movements in the price of eggs in the weeks that followed the recall. An explanation of the market effects of the August 2010 egg recalls must include both shifts in the demand and the supply. First, as consumers lose confidence in the safety of eggs, the demand for eggs should shift to the left. On the supply side, the egg industry has the peculiarity that shell eggs, even those tainted with *Salmonella* can be diverted toward breaking eggs. It is however more difficult to divert breakers toward shell eggs segment of the industry. Even though shell eggs are perfect substitutes for breaking eggs, the supply of shell eggs should still be quite inelastic as the total quantity of eggs depends on production decisions taken months before. The supply shifts to the left because of the recall, which removed eggs from the market. That shift of the supply of eggs should be small given that the recall involved only a small share of the total quantity available on the market and that tainted fresh eggs can be redirected toward breaking eggs.

This essay offers preliminary evidence of the market effects of the August 2010 egg recall and describes the methodology to estimate the shift in consumers' willingness to pay for eggs. My approach accounts for the simultaneity of demand and supply curves as I estimate simultaneous equations for the demands and the supplies of fresh and processed (breaking) eggs. I then use my estimates to predict quantities and prices for fresh and processed eggs as if the recall had never happened. This approach allows me to isolate the effect of the recall on the supply from the removal of eggs and the effect of the shift down in consumer willingness to pay.

I begin by providing background information about the egg industry and the events surrounding the 2010 recall. I then review literature on the estimation of the effects of food recalls on consumers' willingness to pay. The section that follows describes my empirical approach and the data. I then present my preliminary empirical results and discuss their implications. The last section concludes.

Literature on food recalls

The objective of food recalls is to remove a food product from circulation because it poses a threat to consumers' health. This differs from recalls for durable products such as cars for which the objective is often to implement corrective measures. In food, recalls differ in their intensities in function of the health risk to consumers. For food safety incidents involving contamination by a potentially deadly pathogen, firms must go into great length to stop the distribution of the contaminated product. Some perceive recalls as an effective tool to prevent foodborne illnesses and informing consumers about the risk of foodborne illnesses. Recall may however be ineffective in removing a contaminated food product because of lags between marketing and detection of contamination and difficulties in tracing products. In addition, recalls may play a greater role in preventing illnesses by providing incentives to food makers and distributors to produce safe food.

The market effects of a recall manifest in various ways. For instance, a recall may affect return to shareholders (Jarrel and Peltzman 1985, Hoffer, Pruitt and Reilly 1988) or affect the resale value of a durable good (Hartman 1987). As a food recall provides new negative information regarding the quality of a product, consumers revise their beliefs about food safety in a manner such that a typical outcome of a food recalls is a decline in the willingness to pay for the affected product (Boecker and Hanf 2000). The reaction of consumers, however, depends in the severity of the contaminant and media coverage (Piggott and Marsh 2004). In food scares, foodborne illness risk can dominate all other considerations until buyers consider food safe again (Grunert, 2005) although consumers may only gradually integrate that new information (Liu, Huang and Brown 1998). However, most food safety incidents go unnoticed and do not result in any significant reaction from consumers. This contrasts with high-profile incidents such as *E. coli* in spinach in 2006, consumers react strongly to the announcement of contamination (Calvin 2007).

Recalls are an inherent risk of producing and selling food that investors incorporate in their expectation of return for a food company. As such, it is not surprising that Salin and Hooker (2001) find mixed results for the effect of recall on stock market. Only for recalls that exceed in size market expectations that stock market should be significantly affected. For market prices, the story is different as a recall provides information about the current quality of a product. As

Pouliot and Sumner (2012) show, if a recall removes a large quantity of food and consumer confidence is little shaken, then the recall may cause an increase in the price of the product that is being recalled. For most recalls, however, the shift in demand should dominate the shift in supply. In US meat, Schroeder and Lusk (2002) find that recalls have marginal impacts on daily futures market prices. Marsh, Schroeder and Mintert (2004) focus on consumer willingness to pay. The authors find that on average recalls have small but significant impacts on demand for beef, pork and poultry.

In studies of the *E. coli* incident in bagged spinach in 2006, Arnade, Calvin and Kuchler (2009) and Arnade, Calvin and Kuchler (2010) find that the recall had a significant and long lasting effect on the demand for bagged spinach. On the short-run, consumers shied from consuming any leafy-green. In the longer-run, the consumption of leafy-green was back to its level prior to the incident but consumption patterns changed as consumers substituted for other leafy-green and increased their consumption of bulk leafy-green while limiting their of bulk leafy-green.

Industry background and the 2010 recall

The US egg industry has faced several challenges in the last decade including avian flu, new animal welfare requirements and food safety concerns. All of these challenges contributed to shape the US egg industry into many segments that specialize in the production of various types of eggs and the geographical location of egg production. This section briefly describes the production of eggs and offers a short profile of the US egg industry. In addition, I describe the events surrounding the recall in the summer of 2010.

Egg production in the United States

The production of eggs in the United States takes place mostly in large integrated farms. Most eggs are produced for consumption with the remainder going into hatching. In 2010, the total number of eggs sold for consumption was 78.2 billion (Laux 2011). Iowa, Ohio, Pennsylvania, Indiana and California are in decreasing order the five largest producing States, accounting for approximately 45% of the production (Laux 2011). The production of eggs is largely concentrated in the mid-west because of lower feeding cost. Mid-west States produce mostly processed eggs, which can be transported at low cost to food production facilities across the

country. The share of processed eggs in total egg consumption grew from 11% in 1975 to nearly 32% in 2007.

A simple way to characterize the structure of the egg industry is by dividing it into two branches: shell eggs and processed eggs. Figure 1 illustrates the basic structure of the egg supply chain. Shell egg producers target consumers and food services. Shell eggs are graded according to their weight (e.g. extra-large, large, medium and small) and the quality of the yolk and the white (e.g. AA, A and B) and packaged in protective crates of various sizes. The production of shell eggs also includes specialty eggs such as organic and free range. Processed eggs are broken, pasteurized and sold mostly to food processing plants as liquid, dried or frozen eggs. In their various states, processed are either sold as whole, white only or yolk only with sometimes added flavor. Producers of shell eggs sell a share of their production as breakers because not all eggs meet quality standard for sale as shell eggs (e.g. exempt of cracks). Eggs produced with the intent of sale as shell eggs but do not meet quality standards are referred to as checks and undergrades. Animal welfare standards differ for shell eggs and processed eggs, with stricter standards covering the production of shell eggs.[1] Thus, producers of shell eggs can sell all their production to processing but do not because the price for processed eggs is lower. Producers of processed eggs cannot in general sell their eggs to the shell eggs marketing chain because animal welfare requirements are looser for processed eggs.

[1] See issue 90 of Poultry Science for discussion on issues regarding animal welfare in the egg industry (e.g. Lay et al. 2011, Mench et al. 2011, Sumner et al. 2011, and Thompson et al. 2011)

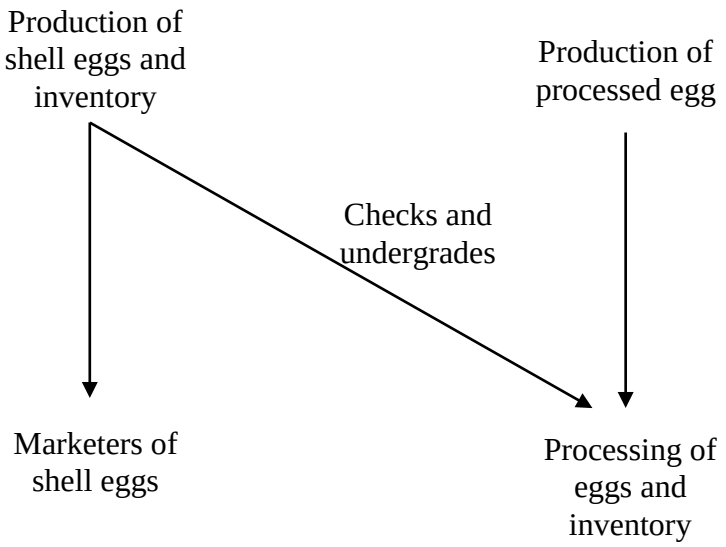

Figure 1: Schema of egg production and consumption

Figure 1 shows only one stage of the supply chain for eggs. In figure 1, producers sit at the top. Marketers buy shell eggs from producers and sell the eggs to consumers. Plants buy the processed eggs and transform them into dried liquid or frozen eggs. Then, a variety of plants use these eggs as ingredients. Eggs are storable. Observe in figure 1 that I show that inventory of shell eggs is done by producers and that inventory of processed eggs is done by the egg processing plants. This corresponds most closely to the method of collection of the data that I will use in the empirical analysis. Figure 1 is also consistent with the storage of processed eggs after breaking.

The empirical model later in the text is based on figure 1. Although it does not explicitly include consumers, the demand by marketers and food plants depends on variables that affect consumption down in the supply chain as shocks are distributed according to the elasticities of demand and supply.

Quality control and transfer of information have motivated vertical integration in the US egg industry (Martinez 2002). Most eggs are produced under contractual arrangement. A production cycle takes nearly two years as it requires the production of hens that will produce the eggs that yield egg producing hens. A pullet takes about 21 weeks to mature into an egg producing hen and then produces eggs at a cost effective rate for about one year. Changes in

lightings and feedings can stimulate production and increase the length of the cost effective rate of production (FAO 2003).[2] Adjustments in supplies are not symmetric as it is more difficult to increase than to decrease production. A long-run increase in production requires augmenting the number of layers that producers the hens that produce eggs. In the short-run, producers can increase production by adjusting lights and feeds. In the short-run, producers can reduce production rapidly by culling hens that produce consumption eggs. In the long-run, producers can reduce production by culling hens that produce eggs for reproduction.

The 2010 recall

Salmonella contamination has been a recurrent problem for the US egg industry. Contamination occurs either by fecal contamination when a hen lays an eggs, by dirt and dust from the environment or by bacteria in the ovary or oviduct of a laying hen (Egg Safety Center 2010). Farms wash eggs to reduce the risk of contamination from *Salmonella* on the egg shell but the risk of contamination from *Salmonella* within the egg remains especially to consumers that do not fully cook their eggs. Vaccination of hens, a practice not commonly used in the United States, may contribute to reduce the risk of contamination within the egg. Processed eggs are pasteurized which virtually eliminate the risk of *Salmonella* contamination.

Wright County Egg of Galt, Iowa announced on August 13, 2010 the recall of its production from May 16 to August 13, 2010 (CDC 2010). A week later, on August 20, 2010, Hillandale Farms of Iowa recalled part of its production from April 9 to August 17, 2010 (CDC 2010). In total, the recall amounted to nearly 500 million eggs.[3] CDC (2010) reported nearly 2,000 confirmed cases of illnesses from the outbreak of *Salmonella* in eggs but the number of illnesses is likely many times larger. After investigation, the FDA found several violations of the Egg Safety Rule at both companies. The FDA authorized, after corrective actions, the two farms to resume shipment of shell eggs: on October 15, 2010 for Hillandale Farms and on November 20, 2010 for Wright County Egg (FDA 2010). After the recall, the DeCoster family, owner of the Wright County Egg farms, faced multiple lawsuits, loss business with large retail chains and then the family gave up control of their egg operations (Foley 2011).

[2] For instance, force molting increases production by starving chicken resulting in loss of feather which then stimulates production.

[3] Although the number of eggs recall is very large, it represents less than one percent of the annual production of eggs in the United States.

Although only two farms were source of the Salmonella contamination, the recall likely affected the whole US egg industry. The quantity recalled was a small share of the total production, but extensive media coverage of the incident may have contributed to consumers losing confidence in the safety of eggs in the United States. Figure 2 shows the price of Midwest large eggs between 2007 and 2011. The price for 2010 is in black and the vertical dash line is August 13. There is no apparent seasonality in the price of eggs. In the days after the announcement of the recall, the price of eggs increased by more than 40% and then steeply declined. The effect of the recall had seemingly vanished by November. The price of processed eggs followed a similar pattern although the peak and the dip in the price were less accentuated.

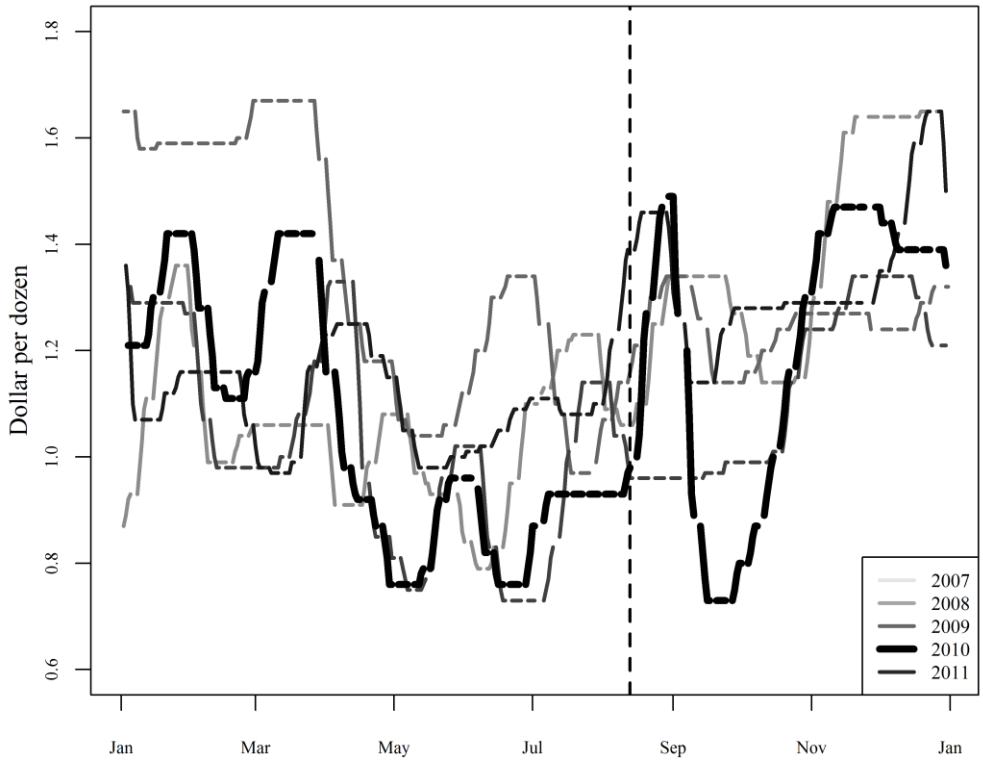

Figure 2: Daily Mid-West price for large fresh eggs between 2007 and 2011 in dollar per dozen (AMS 2012)

Figure 2 offers an incomplete picture of the market effects of the recall. The eggs produced by the two farms source of the *Salmonella* outbreak were diverted toward the eggs breaking segment of the industry. Thus, the second branch helped to absorb the market effect of

the recall. A more complete description must then include the price of breaking eggs and the quantities of shell eggs and breaking eggs.

Empirical model

Previous empirical studies of the impact of food safety scare focus on the demand (e.g. Arnade, Calvin and Kuchler 2009, and Arnade, Calvin and Kuchler 2010). Consistent estimates of demand equations require that either quantities or prices are exogenous. Common arguments include that quantities are predetermined from biological lags such that the quantity are predetermined or that prices are predetermined because of short-run fixity (Thurman 1986, 1987). A demand system yield consistent estimates of the effects of a food recall if the quantity recalled is predetermined by past production and if the recall does not induce a response in the supply. That is, if the recall causes the supply to shift, then quantities are no longer predetermined and demand estimates are inconsistent.

The structure of the egg industry in figure 1 suggests a strong relationship between the shell and the processed eggs sectors. In addition, anecdotal evidence shows that shell eggs were diverted toward the processed egg sector in response to the recall. Thus, consistent with the structure of the egg industry and the response of the industry to the recall, the empirical model features four simultaneous expressions that analytically describe the four parts in figure 1.

Let me begin with the expression for the supply of shell eggs at time t:

(1) $$\beta_s^s(L)q_{st} = \alpha_s^s + \delta_{st-k}^s p_{st} + \gamma_{s-m}^s p_{ct} + \omega_{s-m}^s p_{pt} + \boldsymbol{\lambda}_s^s \mathbf{w}_{st} + \rho_s^s I_{st-1} + \boldsymbol{\varphi}_s^s \mathbf{x}_{st} + \tau_s^s T_t + \varepsilon_{st},$$

where the coefficients and variables in bold are vectors. The variable q_{st} is the weekly quantity of shell eggs sold which is different than the quantity produced as shell eggs can be stored. I account for the time-series properties of the data using an autoregressive lag-dependant variable and by adding a time trend T_t. I define the polynomial lag operator for the dependent variable as $\beta_s^s(L) = 1 - \beta_s^s L - \left(\beta_s^s L\right)^2 - \ldots$ The supply is a function of the price of shell eggs, p_{st}, the price of checks and undergrades in the previous period, p_{ct-1}, the price of processed eggs, p_{pt}, and the price of inputs, w_{st}, such as feed prices. The other variables that affect the supply of shell eggs are the inventory of shell eggs in the previous period, I_{st-1}, and a vector of other control

variables, $\mathbf{x}_{st}$, possibly including seasonal dummies. Note that I use one lag on the price of checks and undergrades and the inventory to avoid potential endogeneity problems.

Current market conditions and expectations regarding market conditions as far back as two years earlier determine the production of shell eggs. Producing eggs first require contracting for hens. About two years lapse between the signature of a contract for hens and the actual production of eggs. Thus, current production depends on output and input prices expectations from two years earlier. Short term changes in prices also affect supply as producers have a certain control on yield through lighting and feeding. For the empirical model, I simplify by assuming right expectations. That is, when making their production decision, I assume that producers know the price they will receive or pay. The practical implication is that I use current prices in the model in (1).

The inverse demand for shell eggs is given by

(2) $$\beta_s^d(L)\,p_{st} = \alpha_s^d + \delta_s^d q_{st} + \boldsymbol{\lambda}_s^d \mathbf{v}_{st} + \tau_s^d T_t + \omega_s R_{st} + \upsilon_{st}\,.$$

The expression for the inverse demand uses the same empirical specification to account for time series properties of the data as it includes an autoregressive lag-dependant variable and a time trend. The inverse demand depends on the quantity of shell eggs, q_{st}, on a vector of demand shifters, $\mathbf{v}_{st}$, which includes, for example, seasonality variables and prices for substitutes for eggs such as meat products. The variable R_{st} is dummy variable that equals one between November 2005 and May 2007 because of apparent, non-explained, problem in the data. More detail on this in the next section.

Note that I use the inverse demand rather than the demand for shell eggs. In a model with simultaneous equations, the two specifications for demand are equivalent (Thurman 1986). I chose to estimate the inverse demand as it is easier to interpret a shift in the demand in the price space.

The supply of processed eggs is

(3) $$\beta_p^s(L)\,q_{pt} = \alpha_p^s + \delta_{pt-k}^s p_{pt} + \omega_{pt}^s p_{st} + \boldsymbol{\lambda}_p^s \mathbf{w}_{pt} + \boldsymbol{\varphi}_p^s \mathbf{x}_{pt} + \tau_p^s T_t + \varepsilon_{pt}\,.$$

As in previous models, the expression for supply of processed eggs includes an autoregressive lad-dependent variable and a time trend to account for time-series properties of the data. The supply of processed eggs is a function of the price of processed eggs, p_{pt}, the price of shell eggs,

p_{st}, and the price of inputs, w_{pt}, and a vector of supply shifters, $\mathbf{x}_{pt}$. Note that the dynamics in the production of processed eggs is the same as in the production of shell eggs. In expression (3), I assume right expectations for the price of output and inputs as I do in expression (1).

Finally, the expression for the demand for processed eggs is

(4) $$\beta_p^s(L)\,p_{pt} = \alpha_p^d + \beta_p^d p_{pt-l} + \delta_p^d q_{pt} + \boldsymbol{\lambda}_p^d \mathbf{v}_{pt} + \rho_p^s I_{pt} + \tau_p^d T_t + \upsilon_{pt}.$$

Like previous models, the empirical model for the inverse demand for processed eggs controls for time-series properties of the data using an autoregressive-lag dependant variable and a time trend. The inverse demand for processed eggs is a function of the quantity of processed eggs, q_{pt}, and a vector of demand shifters, $\mathbf{v}_{pt}$. Observe that the inventory of processed eggs, I_{pt}, appears in the demand for processed eggs rather than in the supply for processed eggs. This is because, given when quantities and prices are measure in the data for processed eggs, the buyers of processed eggs are those that hold most of the inventory.

The system of equations in (1)-(4) is overidentified as it contains four endogenous variables $\left(q_{st}, p_{st}, q_{pt}, p_{pt}\right)$ and more than four exogenous variables. There are several estimations techniques to incorporate all the instruments in the system of equations. In what follows, I will use three-stage least squares and explore different specifications to examine the sensitivity of estimates to the choice of instruments.

Data

Most of the data come from the Agricultural Marketing Service (USDA/AMS 2012), a branch of the United States Department of Agricultural. Data for the price of corn and the price of soybean meal are from the Feedstuffs.com(2012), which collects various price series for use by agribusinesses. Monthly data for the price of beef, chicken and cheese are from Bureau of Labor Statistics (2012). I changed the units of some variables from their source for measurement consistency across variables. Table 1 describes the data, identifying each variable following the notation in expressions (1)-(4) and with the units used in the estimations.

I calculated the consumption of shell eggs as the sum of the change in the stock of shell eggs and the production of shell eggs. The monthly data are from the Egg Industry Center at Iowa State University. Data from USDA/AMS (2012) for retail purchase of shell eggs seem erroneous, notably because of a sharp incline in production between November 2005 and May

2007. In addition, I am unable to determine the unit of measurements as they appear inconsistent with their descriptions and the units of measurements for other variables. Thus, I resort on calculating consumption from the monthly data. The price of shell eggs also follows an unexplained pattern between November 2005 and May 2007. As I do not have a substitute variable for the price of shell eggs, I control for the discrepancy in the price using a dummy variable in the expression for the demand for shell eggs.[4]

Table 1: Data description

Variables	**Description**
q_{st}	Weekly estimated shell egg consumption.
q_{pt}	Weekly quantity of processed eggs in thousand dozen (Wednesday).
p_{st}	Weekly price of AA, large eggs in dollar per dozen.
p_{pt}	Weekly price of breaking eggs in the eastern region in dollar per dozen, calculated as the mean of the low and the high (Tuesday/Friday).
p_{ct}	Weekly price of checks and undergrades in dollar per dozen, calculated as the mean of the low and the high (Tuesday/Friday).
I_{st}	Weekly inventory of shell eggs in thousand dozen (Monday).
I_{pt}	Weekly inventory of processed eggs in thousand dozen equivalent (Monday).
$Corn_t$	Weekly price corn in dollar per ton.
Soy_t	Weekly price of soybean meal in dollar per ton.
$Beef_t$	Monthly US city average price of ground beef in dollar per pound.
$Chicken_t$	Monthly US city average price for chicken, fresh, whole in dollar per pound.
$Cheese_t$	Monthly US city average price for American processed cheese in dollar per pound.

Consumption data are not available at a weekly frequency and it was therefore difficult to find instruments for the demand equations. One solution is to run a regression on monthly

[4] Update of this essay will attempt to better explain what happens between November 2005 and May 2007 and explain the unit of measurement for the price of shell provided by USDA/AMS (2012). In the estimation, the dummy variable does not significantly affect coefficient values but helps ensuring that the residuals are normally distributed.

consumption data and then predict these variables in a weekly frequency. Thus, for the prices for beef, chicken and cheese, I divided each variable by four, ran a loess regression on the monthly variables and the used the prediction to make the variables weekly. The advantage of this approach is, of course, to make more data available. However, it is not possible to capture weekly noise that in practice affect weekly values as the prediction is based on nearby monthly values.

The price of breakers from the Agricultural Marketing Service is only available starting on September 13, 2006. As such, the dataset starts on September 13, 2006 and ends on December 28, 2011. Table A1 summarizes the data by providing the mean, standard deviation, minimum and maximum for each variable.

Table 2 shows p-values for augmented Dickey-Fuller and Phillips-Perron tests for unit-root on the log of the variables that will enter the econometric model. I perform the unit-root tests only in the period before the *Salmonella* incident as the estimations will use that set of data. There is no evidence of unit-root on the variables for the quantities of shell and processed eggs, the price of shell eggs and for the inventories of shell and processed eggs. I find weak evidence of unit-root in the variables for the price of processed eggs and the price of checks and undergrades. There is significant evidence of unit-roots in the variables for the prices for corn, soybean meal and the weekly predictions for the price of beef, chicken and cheese.

The unit-root tests show that the dataset comprises a mix of stationary and non-stationary variables. One possible solution is to re-write the model in first-difference which rids of the problem unit-root if all variables are first difference stationary. However, first-difference implies a loss of information and the estimation of a different model. In the estimations that follow, I will mostly ignore the problem with unit-root. Model 1 will not include any of the variables for which unit-root tests find significant evidence of non-stationarity. Estimation results show that there is little difference in the outcome of the models when including variables with unit-roots, suggesting that variables with a unit-root have small effects on coefficients estimates and their standard-errors. In addition, post-estimation tests do not find evidence of unit-root in the residuals.

Table 2: P-values for unit root tests on log of variables – September 13, 2006 to August 12 2010

Variables	Aug. Dickey-Fuller	Phillips-Perron
q_{st}	0.0000	0.0000
q_{pt}	0.0000	0.0000
p_{st}	0.0006	0.0000
p_{pt}	0.1082	0.1333
p_{ct}	0.0809	0.1337
I_{st}	0.0000	0.0000
I_{pt}	0.0000	0.0000
$Corn_t$	0.3087	0.0582
$Soybean_t$	0.4431	0.1562
$wBeef_t$	0.1966	0.8450
$wChicken_t$	0.3342	0.2065
$wCheese_t$	0.6803	0.3149

Note: The null hypothesis of the unit root test is that variable is not stationary (contains a unit root). The Augmented Dickey-Fuller tests are specified with one lag and the Phillips-Perron tests use the default lag in Stata.

Preliminary results

I present in this section results from estimating the system of supply and demand equations and results from the market effect of the recall. I estimate the model from data between September 13, 2006 and August 12, 2010. This allows me to describe the egg market in the absence of food safety incident. Then, from these econometric estimates, I forecast the egg market after the recall in the months after the recall on August 13, 2010. By looking the difference between the forecast and the market data, I can then obtain an estimate of the market effects of the recall.

Estimation results

I estimate the model for four sets of control variables. Model 1 is the simplest specification and excludes prices for checks and undergrades, corn and soybean in the supply equations, excludes prices for beef, chicken and cheese in the demand equations and excludes the variables for inventories. Model 2 adds the variables for inventories and the prices of corn and soybean. In model 3, I add the price of checks and undergrades in the equation for the supply of shell eggs. Finally, model 4 includes all the variables.

I estimates the models by iterated three-stage least squares, which yields consistent estimates of demand supply parameters. In each model and each equation, I used three lags on the dependent variables to make the residuals white noise according to portmanteau tests. For all models and equations, Dickey-Fuller and Phillips-Perron do not show evidence of unit-root in the residuals.

Table A2 in appendix provides the complete estimation results. Results differ slight across models. In each model, the supply equations slope up with respect to the price and the inverse demand equations slope down with respect to the quantity. Almost all coefficients have the expected sign. One notable discrepancy in sign is for the coefficients for the prices of corn and soybean in the supply equation for processed eggs. However, these coefficients are not significant.

The coefficients in table A2 reveal how variables affect equilibrium in the short-term. Thus, although the coefficients for prices and quantities are elasticities as I estimate log-log models, they capture the responsiveness of prices and quantities for only a one week period. I report in table 3 price elasticities that acknowledge the dynamic nature of the model from the autoregressive lag dependent variable. I refer to these as the long-run elasticities as they account for a full movement along supply and demand curves.

Results for the long-run elasticities are consistent across models for the supplies but display more variability for the demands. All elasticities have reasonable values given specifities for the production and demand of eggs. As expected, the elasticity of supply for shell eggs is low with an average value of about 0.16. The demand elasticity for shell eggs shows the most variation across model. Estimates yield on average an elasticity of demand for shell eggs of -1.5. The supply of processed eggs is very inelastic with an average value of about 0.05. Finally, the demand for processed eggs is very inelastic with an average value of about -0.12.

Table 3: Long-run price elasticities

Model 1	Model 2	Model 3	Model 4
Supply of shell eggs			
0.137	0.165	0.171	0.178
Demand for shell eggs			
-2.455	-0.915	-0.944	-1.543
Supply of processed eggs			
0.052	0.047	0.046	0.053
Demand for processed eggs			
-0.292	-0.034	-0.035	-0.121

The supply and demand for shell eggs are more responsive than the supply and demand for processed eggs. This reflects differences in the marketing channels and differences in use of various egg products. The production of processed eggs is, in a significant part, a residual of the production of shell eggs. Thus, even though the price of processed eggs varies, quantities may not respond because of the shell egg producers ship their residual production into the processed eggs segment of the industry. Shell eggs are sold as a food product while processed eggs mostly enter food products as an ingredient. The consumption of shell eggs is done mostly by consumers and restaurants. As many other protein sources can substitute for eggs, the demand for shell eggs responds more than proportionally to changes in the price. Processed eggs in contrast tend to enter into food products as ingredients. As recipes require fixed proportion of ingredients and that it is difficult to find substitutes for eggs, the demand for processed eggs is not responsive to price.

Market effects of the egg recall

This section presents partial and preliminary results for the estimation of the effects the recall on the market for shell eggs and processed eggs. I also describe the methodology to estimate the impact of the recall on consumer confidence.

Estimates of the equations for supply and demand in table A2 describe the market for shell eggs and processed eggs in the absence of shocks such as a recall. Thus I can use these estimates to forecast the market for eggs as if the August 2010 recall had never happened. Figure 2 shows the percentage deviation between the market data and forecasts from my models between August 13, 2010 and December 29, 2010. Note that the scales are different in each panel of figure 2.

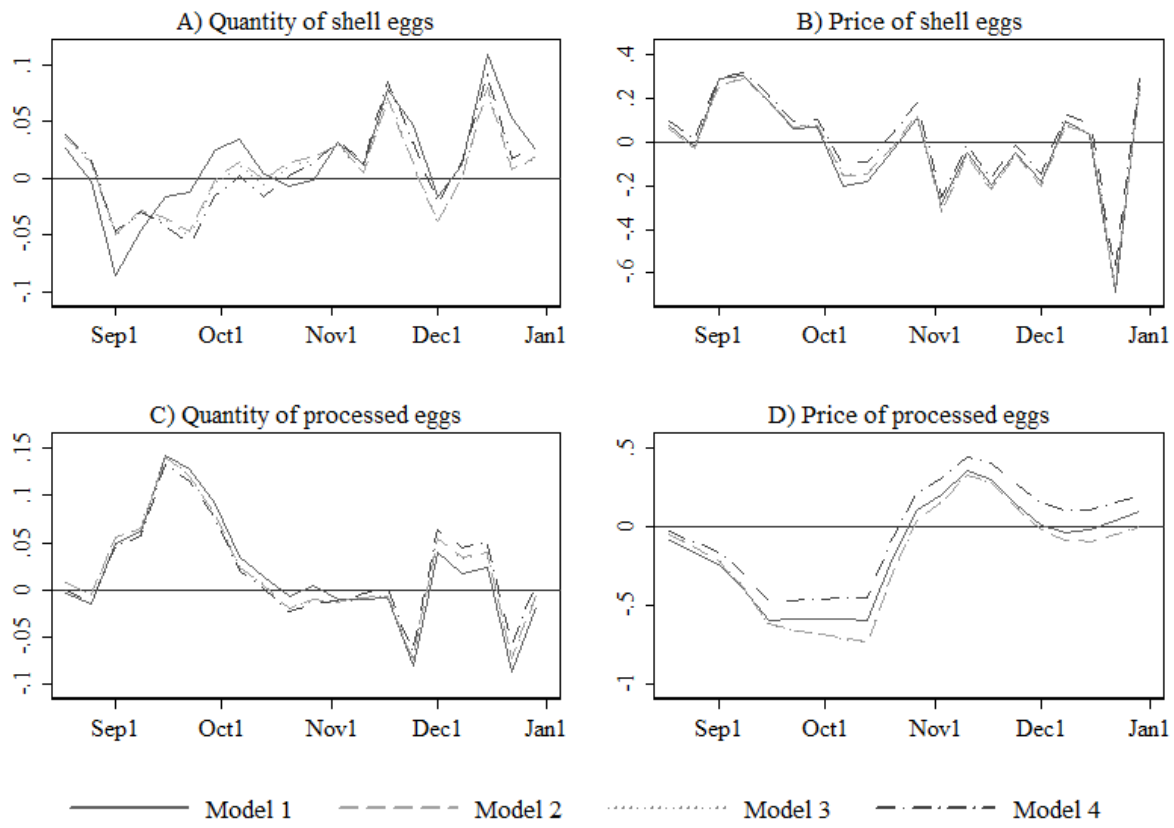

Figure 2: Percentage deviation between observed and predicted values between August 18, 2010 and December 29, 2010

The quantity of shell eggs dropped in the weeks following the recall by nearly 10 percent and then by October had recovered to a level similar to what the model forecasts. During the same period, the price of shell egg increased by almost 30% to return to its normal level in October. Notice in panel A) and B) the pikes at the end of November and the end of December. These shocks arise because of Thanksgiving and Christmas. Future estimations will better account for these holidays. Panel C) and D) show that the effects of the recall occurred with a delay for the processed egg segment of the industry. The quantity of processed eggs increased by almost 15% in the middle of September. At the same time, the price of processed eggs was down by about 5%.

Figure 2 illustrates the market effects of the recall but does not quantify the change in willingness to pay by consumers. The recall was a shock on the production of shell eggs. From press release, it is possible to calculate the quantity of eggs destroyed and the quantity of eggs that was explicitly redirected toward the processed eggs segment of the industry. The recall potentially had an effect on consumer willingness to pay for shell eggs, which estimation is the end objective of this study. The recall did not directly affect the processed egg segment of the industry as processed eggs were not involved and because processed eggs are pasteurized and therefore exempt from *Salmonella* contamination.

I will use simulations to find the shock on the demand for shell eggs, given the quantity of eggs that was recalled, that yields deviations consistent with those in figure 2. These simulations will not only yield a one-time snapshot of the shock on consumers' confidence from the recall but how consumer confidence evolved in the weeks following the recall.

Conclusion

Although specific to a single event, my work helps understand the reaction of consumers to information regarding the safety of food products. I provide new evidence to help guide food safety policies and recall procedures. The results are also useful to food producers who seek to regain the confidence of consumers after a recall. The estimation method provides robust results and a methodology that can be applied to study other incidents.

The empirical model consists of four equations: 1) supply of shell eggs, 2) demand for shell eggs, 3) supply for processed eggs and 4) demand for processed. I estimate the model using three-stage least square and to assess the robustness of my estimates, I estimate four models that include difference sets of variables. Future work will explore other specifications for supply and demand equations and investigate which of the model yields the best prediction and therefore determine which model to use in estimating the effects of the recall on the egg market. The regressions in this essay use storage in the previous week to instrument current storage. Although this is a valid approach to estimate unbiased supply and demand parameters, using storage in previous period yields biased prediction of the effects of the recall. The predictions in this essay consider lag storage for shells eggs and processed eggs as exogenous variables and therefore the predictions use a biased variable. Storage likely played a crucial role in absorbing the effects of

the recall. Future econometric work will specify explicitly storage in two additional equations in the system of supply and demand equations in this essay.

This essay offers preliminary results of the effect of 2010 egg recall on consumer confidence. Much remains to be done to find estimates of the change on consumers' confidence through simulations. The essay currently offers estimates of demand and supply equations and provides preliminary representations of the market effects of the recall on the egg market.

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Appendix

Table A1: Summary of weekly data – September 13, 2006 to December 28 2011

Variables	Units	Mean	Std. Dev.	Min	Max
q_{st}	Thousand dozen	5,978	1,764	3,292	12.135
q_{pt}	Thousand dozen	1,029	61	786	1,232
p_{st}	Dollar per dozen	1.28	0.27	0.60	2.38
p_{pt}	Dollar per dozen	0.59	0.20	0.26	1.15
p_{ct}	Dollar per dozen	0.46	0.20	0.16	1.00
I_{st}	Thousand dozen	29,590	3,066	23,016	39,918
I_{pt}	Thousand dozen	7,392	895	5022	11,166
$Corn_t$	Dollar per ton	185.86	51.55	97.6	304.7
$Soybean_t$	Dollar per ton	326.89	64.71	177.0	463.3
$wBeef_t$	Dollar per pound	2.40	0.21	2.12	2.94
$wChicken_t$	Dollar per pound	1.22	0.08	1.04	1.34
$wCheese_t$	Dollar per pound	3.94	0.16	3.67	4.36

Table A2: Regression results – September 13, 2006 to August 12 2010

	Model 1	**Model 2**	**Model 3**	**Model 4**
Supply of shell eggs				
Intercept	1.771	0.827	0.837	0.832
	(0.316)	(0.416)	(0.418)	(0.413)
q_{st-1}	0.701	0.260	0.257	0.254
	(0.069)	(0.073)	(0.080)	(0.078)
q_{st-2}	-0.348	-0.128	-0.127	-0.129
	(0.085)	(0.077)	(0.079)	(0.077)
q_{st-3}	0.273	0.263	0.261	0.257
	(0.068)	(0.062)	(0.062)	(0.061)
p_{st}	0.051	0.100	0.104	0.110
	(0.026)	(0.028)	(0.030)	(0.028)
p_{pt}	-0.000	-0.010	-0.006	0.018
	(0.000)	(0.012)	(0.032)	(0.036)
p_{ct-1}			-0.005	-0.023
			(0.032)	(0.032)
I_{st}		0.202	0.203	0.203
		(0.023)	(0.026)	(0.025)
$Corn_t$		-0.013	-0.012	-0.003
		(0.020)	(0.020)	(0.020)
$Soybean_t$		-0.061	-0.062	-0.069
		(0.021)	(0.020)	(0.021)
T_t	-0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Demand for shell eggs				
Intercept	3.507	5.830	5.740	5.511
	(3.307)	(2.562)	(2.564)	(2.625)
p_{st-1}	-0.017	-0.025	-0.024	-0.009
	(0.070)	(0.064)	(0.064)	(0.062)
p_{st-2}	0.094	0.071	0.069	0.065
	(0.063)	(0.062)	(0.062)	(0.059)
p_{st-3}	0.216	0.208	0.207	0.194
	(0.063)	(0.059)	(0.059)	(0.056)
q_{pt}	-0.288	-0.814	-0.792	-0.486
	(0.728)	(0.557)	(0.558)	(0.533)
$wBeef_t$				-0.234
				(0.322)
$wChicken_t$				0.510
				(0.396)
R_{st}	-0.278	-0.275	-0.276	-0.245
	(0.057)	(0.055)	(0.055)	(0.058)
T_t	0.001	-0.001	-0.001	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)

Table A2: Regression results – September 13, 2006 to August 12 2010 - continued

	Model 1	**Model 2**	**Model 3**	**Model 4**
Supply of processed eggs				
Intercept	1.961	2.801	2.770	2.991
	(0.071)	(0.500)	(0.498)	(0.508)
q_{pt-1}	0.658	0.498	0.502	0.494
	(0.075)	(0.073)	(0.073)	(0.074)
q_{pt-2}	0.038	0.049	0.050	0.049
	(0.088)	(0.083)	(0.083)	(0.084)
q_{pt-3}	-0.008	0.002	0.003	-0.014
	(0.080)	(0.077)	(0.077)	(0.077)
p_{pt}	0.016	0.021	0.021	0.025
	(0.017)	(0.017)	(0.017)	(0.017)
p_{st}		-0.115	-0.112	-0.139
		(0.040)	(0.039)	(0.037)
$Corn_t$		0.015	0.015	0.004
		(0.028)	(0.027)	(0.028)
$Soybean_t$		0.046	0.046	0.062
		(0.028)	(0.028)	(0.029)
T_t	0.000	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Demand of processed eggs				
Intercept	1.209	4.769	4.691	2.706
	(1.502)	(1.382)	(1.380)	(1.299)
p_{pt-1}	1.148	1.133	1.134	1.132
	(0.071)	(0.072)	(0.071)	(0.071)
p_{pt-2}	-0.199	-0.203	-0.202	-0.197
	(0.105)	(0.109)	(0.109)	(0.107)
p_{pt-3}	0.015	0.044	0.042	0.014
	(0.068)	(0.074)	(0.074)	(0.074)
q_{pt}	-0.120	-0.752	-0.742	-0.425
	(0.223)	(0.203)	(0.202)	(0.188)
I_{pt}		0.074	0.074	0.033
		(0.061)	0.202	(0.290)
$wCheese_t$				0.322
				(0.290)
T_t	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)

Note: Standard errors are in parentheses.