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Unscrambling U.S. egg supply chains amid COVID-19[☆]

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ABSTRACT

This article investigates how the shift from food-away-from-home and towards food-at-home at the onset of the COVID-19 pandemic affected the U.S. egg industry. We find that the pandemic increased retail and farm-gate prices for table eggs by approximately 141% and 182%, respectively. In contrast, prices for breaking stock eggs—which are primarily used in foodservice and restaurants—fell by 67%. On April 3, 2020, the FDA responded by issuing temporary exemptions from certain food safety standards for breaking stock egg producers seeking to sell into the retail table egg market. We find that this regulatory change rapidly pushed retail, farm-gate, and breaking stock prices towards their long-run pre-pandemic equilibrium dynamics. The pandemic reduced premiums for credence attributes, including cage-free, vegetarian-fed, and organic eggs, by as much as 34%. These premiums did not fully recover following the return to more "normal" price dynamics, possibly signaling that willingness-to-pay for animal welfare and environmental sustainability have fallen as consumers seek to meet basic needs during the pandemic. Finally, in spite of widespread claims of price gouging, we do not find that the pandemic (or the subsequent FDA regulatory changes) had a meaningful impact on the marketing margin for table eggs sold at grocery stores.

1. Introduction

From mid-March to April 2020, the U.S. public was largely caught off-guard by the sight of the empty grocery store shelves during the onset of the COVID-19 pandemic caused by a spike in grocery food demand and a collapse of cafeteria demand due to government shelter-in-place mandates, size limits on public gatherings, and widespread social distancing. Prior to the pandemic, consumers spent 54% of their food budget away from home (Elitzak and Okrent, 2018) or an estimated one-third of food quantity sales (Richards, 2020). Throughout March, U.S. eating-out expenditures were 51% below their March 2019 levels (USDA, 2020). By April, nearly three-quarters of food expenditures were for consumption at home. As demand moved from restaurants to grocery stores, one might conjecture that the food supply would easily transition. Given the overall economic contraction and likely aggregate hit to food demand, one might have also expected an overall reduction in food prices.

Instead, grocery store prices experienced their highest monthly increase since the 1970s (Gasparro and Kang, 2020). Retail food prices spiked as a result of significant frictions in the food supply chain that prevented the free flow of some commodity food products from foodservice and toward supermarkets and grocery stores. To quell spiking retail prices, regulatory agencies including the USDA JEL Codes:Agricultural Marketing Service (AMS), Food and Drug Administration (FDA), and Food Safety Inspection Service (FSIS) temporarily relaxed many labeling and food safety requirements to allow supply diversions towards grocery stores (FDA, 2020a; FSIS, 2020; USDA AMS, 2020a,b). The policy change serves as a natural experiment to determine the extent to which regulatory frictions contributed to the inflexibility in moving food between the bifurcated retail and foodservice supply chains.

In this paper, we investigate how the shift from food-away-from-home and towards food-at-home and the subsequent regulatory responses affected the U.S. egg industry. The U.S. egg market provides a useful setting to examine the effects of COVID-19 on food market. Food supply chains experienced well-documented shifts due to transportation issues, labor constraints, food security, consumer stigma, and trade restrictions, though a focus on egg prices allow us to focus on supply chain flexibility (Ellison et al., n.d; Gray, 2020; Hobbs, 2020; Malone et al., 2020; McFadden et al., n.d.). Most eggs in the United States are commodity products laid by hens that are of the same genetic stock,

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provided indistinguishable feed, and reared in comparable housing. However, egg production facilities are generally designed to deliver to one of two distinct markets: (1) the table egg market, which primarily focuses on selling whole, washed eggs to consumers grocery stores; and (2) the breaking stock (or "breaker") market, which sells pasteurized liquid and dried eggs primarily to restaurants, cafeteria, and food processors. In addition to "commodity" eggs, a segment of the table eggs market can also be characterized as "quality differentiated". Differentiated eggs—which include eggs certified as being "cage-free", as well as those using organic, vegetarian-only, or omega-3 enriched animal feeds—represent a growing share of the table egg market due to changing consumer preferences, private standards, and state-level animal welfare regulations.

The pandemic affected the markets for table eggs and breaking stock eggs in polar opposite ways. The table egg market experienced one of the most dramatic price increases of all food products, with wholesale egg prices tripling from February to March 2020 (BLS, 2020). The corresponding rise in retail table egg prices was so significant that claims of price gouging and lawsuits soon emerged (O'Brien, 2020). Breaking stock prices, on the other hand, dropped by almost 50% over the same period. On April 3, 2020, the FDA responded by issuing a temporary change to the policy regarding enforcement of the Egg Safety Rule (21 CFR Part 118) to allow producers who traditionally sell into the breaker market to sell to the table egg market (FDA, 2020b).

We seek to "unscramble" the apparent breakdown in equilibrium price relationships in the U.S. egg industry at the onset of the pandemic and to assess the subsequent impacts of the temporary suspension of FDA food safety standards. In doing so, we contribute to the literature in several ways. First, by exploring the rapid and acute changes in egg prices during the COVID-19 pandemic, this article relates to a broad literature on supply chain disruptions and the conditions under which the law of one price fails to hold. Examples in the literature include behavioral reasons (Lamont and Thaler, 2003), distance between markets (Lutz, 2004; Parsley and Wei, 1996), transactions costs (Baffes, 1991), and regulation (De Vany and Walls, 1996; Doane and Spulber, 1994; Fan and Wei, 2006).

We also contribute to the agricultural marketing literature as it relates to product differentiation. Agricultural marketing has relied heavily on product differentiation for the past few decades, leading to a proliferation of unique options at the grocery store. Some attributes such as product color, product grade, and product size can be visibly identified while other attributes can only be identified with a certification label. Consumer interest in socially desirable production practices has created niches in the protein marketplace for products that embody these unique "credence" attributes (Lusk, 2018). This has been especially true for shell eggs, creating premiums for "cage-free" and "organic" labels, as well as leading to regulatory changes targeted at promoting hen welfare (Allender and Richards, 2010; Lusk, 2019; Paul et al., 2019). We investigate how the COVID-19 pandemic affected price premiums for differentiated table egg products sold at retail stores. In this respect, this article relates to a recent series of articles on the impacts of animal welfare regulations on wholesale and retail egg prices (Allender and Richards, 2010; Carter et al., 2020; Malone and Lusk, 2016; Mullally and Lusk, 2017).

The remainder of this article is organized as follows. Section 2 provides an overview of the U.S. egg industry. Section 3 presents a stylized conceptual model of the impacts of COVID-19 and the subsequent FDA regulatory change on the U.S. egg industry. In Section 4, we construct a series of econometric models to test the hypotheses gleaned from our conceptual model. Estimation results are reported in Section 5. Section 6 formally derives producer and consumer welfare impacts, and Section 7 concludes with policy recommendations regarding the resiliency in food supply chains.

2. Background

In 2020, the U.S. egg layer flock consisted of 329.9 million layer hens (Ibarburu, 2020). Although layer genetics and animal feed are equivalent for the majority of these animals, production is segmented into two markets: (i) the table egg market and (ii) the breaker market. About 70% of U.S. layers ($\approx$ 230 million) yield eggs destined for the table egg market; the remaining 30% ($\approx$ 99 million) of layers historically produce for the breaker market (Ibarburu, 2020). As of July 2020, approximately 25% of table eggs are produced by layers housed in cage-free enclosures (*approx* 78 million). A small sub-set of cage-free production is additionally certified as using organic, vegetarian-only, or omega-3 enriched animal feeds.

Product packaging differs between the table egg market and breaker market. Shell eggs are packaged in Styrofoam or cardboard cartons by the dozen and are primarily sold to grocery stores and supermarkets for household consumption. Breaker eggs, on the other hand, are packaged in large containers, known as egg crates, that typically hold a hundred or more loose eggs. Breaker eggs are ultimately cracked and sold in liquid form for use in restaurants, cafeterias, or other foodservice locations. A smaller portion is, alternatively, dried and used in manufactured food.

Food safety regulations also differ between the table egg and breaker markets. The Egg Safety Rules (21 CFR Part 118)—administered by the FDA—require facilities that produce table eggs to implement a number of measures to reduce risks of *Salmonella Enteritidis* (SE) contamination during storage and transportation. The FDA rules mandate that producers must test facilities when laying hens are between 40–45 weeks of age (i.e., when SE is most likely to be detected if present). Further, producers are also required to register with the FDA and maintain records documenting compliance. Alternatively, facilities producing eggs destined for the breaker market are not required to comply with the Egg Safety rules because breaking stock eggs are pasteurized prior to preparation and consumption. Instead, these facilities are required only to maintain adequate refrigeration capacity.

In mid-to-late March 2020, retail egg prices hit record highs, while breaker egg prices hit record lows.[1] The U.S. egg industry petitioned the FDA to relax the Egg Safety Rules, stating that "absent additional flexibility to redirect eggs to the table egg market from poultry houses currently producing eggs for further processing, producers may have difficulty meeting the increased consumer demand for eggs in the table egg market" (FDA, 2020b). In response, on April 3, 2020, the FDA temporarily exempted breaker producers seeking to sell into the table market from SE testing, monitoring, and recordkeeping requirements under the Egg Safety Rules.

3. Conceptual model

Fig. 1 presents a conceptual model to understand the impacts of the COVID-19 pandemic and the subsequent FDA Egg Safety Rule exemptions on the market for commodity eggs. We show these impacts by deriving market equilibrium under three alternative scenarios: (i) a pre-pandemic *status quo* scenario, (ii) a COVID-19 scenario, and (iii) a COVID-19 scenario under which the FDA has issued the temporary Egg Safety Rule exemptions. The model suggests the shift from food-away-from-home to food-at-home resulting from the COVID-19 pandemic results in a large increase in short-run retail and farm-gate table egg prices and a drop in breaker prices. However, the FDA exemptions push short-run prices back towards their long-run equilibrium, in spite of the COVID-induced demand shifts. Drawing on these equilibrium outcomes for commodity eggs, we qualitatively discuss the impacts on retail prices for differentiated egg products below.

[1] The Egg Industry Center (EIC) notes that—at one point—the price-per-gallon for liquid eggs was lower than purified water sold at retail stores (EIC, 2020).

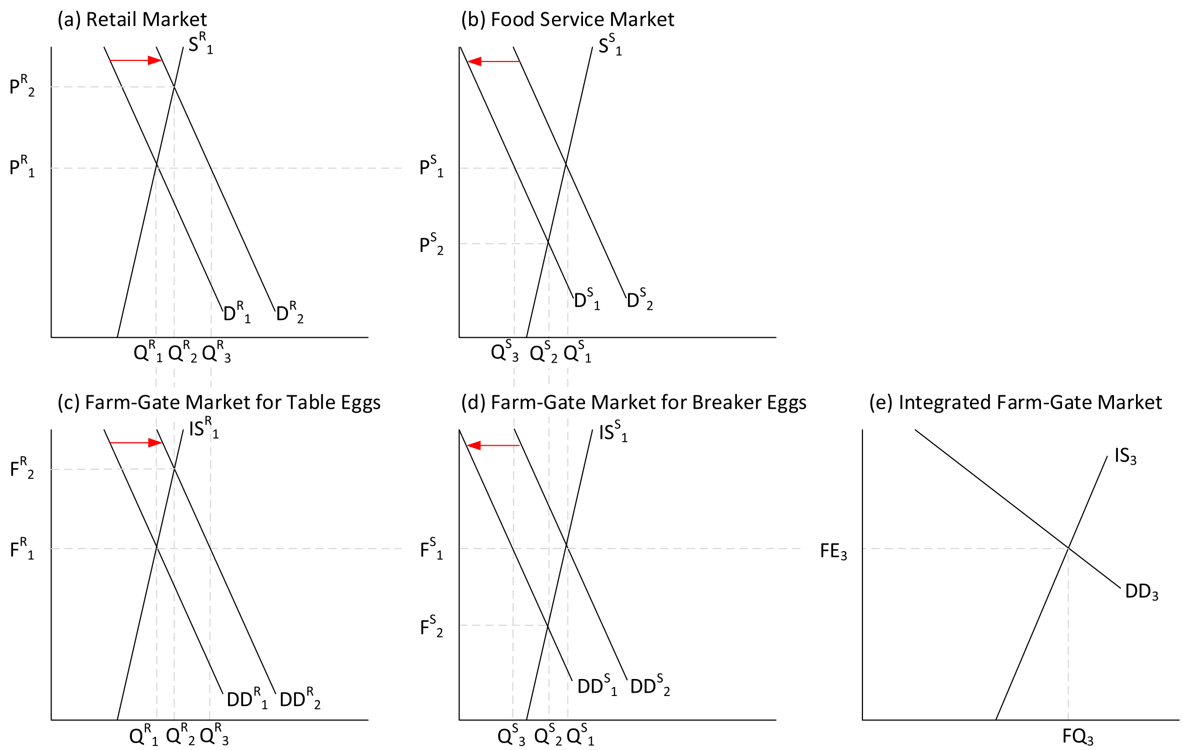


Fig. 1. Impacts of COVID-19 on Commodity Egg Markets. *Note:* This figure presents a conceptual model to understand the impacts of the COVID-19 pandemic and the subsequent FDA Egg Safety Rule exemptions on the market for commodity eggs. We show these impacts by deriving market equilibrium under three alternative scenarios: (i) a pre-pandemic *status quo* scenario, (ii) a COVID-19 scenario, and (iii) a COVID-19 scenario under which the FDA has issued the temporary Egg Safety Rule exemptions. The model suggests the shift from food-away-from-home to food-at-home resulting from the COVID-19 pandemic results in a large increase in short-run retail and farm-gate table egg prices and a drop in breaker prices. However, the FDA exemptions push short-run prices back towards their long-run equilibrium, in spite of the COVID-induced demand shifts.

Market Outcomes for Commodity Egg Products: To derive equilibrium outcomes in the commodity egg market in Fig. 1, we make two simplifying assumptions (in addition to the basic economic principles underlying the concepts of supply and demand). These assumptions are made for the purposes of model clarity and are without loss of generality. First, we assume that U.S. consumers can purchase eggs in two types of locations: (i) “retail” locations (denoted in Fig. 1 with superscript *R*) or (ii) “foodservice” locations (denoted in Fig. 1 with superscript *S*). A consumer who purchases eggs at a retail location prepares and consumes the eggs at home. Alternatively, when a consumer purchases eggs at a foodservice location, the eggs are prepared by foodservice workers and consumed onsite as part of a meal. Second, we assume that egg producers in the United States choose to produce one of two types of eggs: (i) table eggs or (ii) breaking stock eggs.

Scenario (i), pre-pandemic *status quo* market conditions are as follows. Segments D^R_1 in panel (a) and D^S_1 in panel (b), respectively, describe consumer demand for eggs at retail and foodservice locations. Because the cost of eggs is a small share of a household’s overall food expenditure, there is effectively zero cross-price elasticity of demand for eggs between the retail and foodservice locations. On the supply side, egg producers are segregated into table egg producers (described by short-run farm-gate supply curve IS^R_1 in panel (c) of Fig. 1) and and breaker egg producers (described by short-run farm-gate supply curve IS^S_1 in panel (d) of Fig. 1). Table egg producers must comply with FDA Egg Safety Rules and sell their products into the retail market. Producers of breaker eggs sell their products into the foodservice market, where they are pasteurized prior to preparation and consumption. Under pre-pandemic *status quo*, breaker egg producers are exempted from FDA Egg Safety Rules but are disallowed from selling into the retail market.

Retail and foodservice demand schedules D^R_1 in panel (a) and D^S_1 in panels (a) and (b) uniquely imply farm-gate derived demands DD^R_1 and DD^S_1 in panels (c) and (d), respectively. Thus, we derive pre-pandemic market equilibrium by setting retail derived demand (DD^R_1) equal to the farm-gate supply of table eggs (IS^R_1) and foodservice derived demand (DD^S_1) with the farm-gate supply of breaker eggs. In this equilibrium, Q^R_1 table eggs are produced and sold at retail stores and Q^S_1 breaker eggs are produced and used in meal preparations at foodservice locations. Farm-gate table eggs and breaker eggs are sold at price $F^R_1 = F^S_1$. Note that this is the long-run equilibrium relationship.[2] There is effectively zero short-run response of supply in one market to changes in prices in the other because breaker egg producers are prevented from cross-market arbitrage. However, in the long-run, breaker producers can arbitrage by converting facilities to comply with FDA Egg Safety regulations and selling into the table egg market.

In scenario (ii), we characterize market conditions during COVID-19 via two large demand shifts. Demand for eggs at retail locations in panel (a) shifts outward from D^R_1 to D^R_2. Simultaneously, demand for eggs at foodservice locations in panel (b) shifts inwards from D^S_1 to D^S_2. These demand shifts induce equivalent disruptions to derived demands DD^R_2 and DD^S_2 at the farm-gate. We derive scenario (ii) short-run equilibrium by equating the new derived demands with farm-gate supply curves IS^R and IS^S. As shown in Fig. 1, as a result of COVID-19, farm-gate and retail

[2] In reality, equilibrium breaker egg prices are lower than those for table eggs. If this was not true, there would be no incentive for egg producers to comply with Egg Safety Rules and sell into the table egg market. Notably, a condition of long-run market equilibrium is that—at the margin—there is no incentive for a breaker egg producer to obtain SE-compliance certification. Equally, there is sufficient incentive for a table egg producer to maintain SE-compliance certification. The reprenstation of equivalent pricing across the two egg production systems is a convenient way to reflect this fact.

prices for table eggs spike from F_1^R to F_2^R and from P_1^R to P_2^R. At the same time, breaker prices fall from F_1^S to F_2^S.

Scenario (iii) characterizes the COVID-19 scenario under which the FDA has issued the temporary Egg Safety Rule exemptions. As in scenario (ii), there is a large shift in demand away from foodservice locations and towards retail stores. Now, however, due to the FDA regulatory change, breaker producers are now able to arbitrage by selling into the table egg market. To characterize equilibrium in this scenario, we include in panel (e) aggregate derived demand curve DD_3, which is the horizontal sum of retail and foodservice derived demand, and aggregate farm supply curve IS_3, which is the horizontal sum of farm-gate table egg supply and breaker egg supply. Equilibrium outcomes are derived by equating DD_3 and IS_3. As shown in Fig. 1, the FDA regulatory change pushes farm-gate table egg and breaker egg prices to FE_3 and retail table egg prices to P_1^R—the initial long-run equilibrium prices.

Market Outcomes for Differentiated Egg Products: Although the conceptual model in Fig. 1 depicts the market for commodity eggs, it also sheds light on the likely impacts on retail pricing for differentiated table eggs. Standard models of vertical product differentiation suggest market demand for a product of higher quality (e.g., a carton of cage-free table eggs) versus that of lower quality (e.g., a carton of conventional table eggs) is a function of (a) the degree of quality differentiation between the two products (i.e., how much "higher" the quality of the one versus the other), (b) the prices of the two products, and (c) the importance of quality to consumers (Saitone and Sexton, 2010).

As shown in Fig. 1, the pandemic and the regulatory change affect point (b). In scenario (ii) of Fig. 1, as the retail price of commodity table eggs increases, this would cause the *absolute* price of the higher quality product to increase, but would cause the *relative* price of the higher quality product (i.e., the price premium) to fall. In scenario iii, as the FDA regulatory suspension pushes commodity egg prices back towards their long-run equilibrium, both absolute and relative prices for differentiated products would return to their pre-pandemic levels.

Additionally or alternatively, we postulate that the pandemic may also affect point (c). That is, one could imagine that the economic (and existential) uncertainty created by the pandemic may cause consumers to lower their individual preferences for quality as they focus on ensuring their basic needs are met. As with point (b), this would lower the relative price of the higher quality product in scenario ii. However, to the extent the pandemic has affected point (c), relative prices would not return to pre-pandemic levels following the FDA regulatory change in scenario iii. We empirically test these hypotheses in the sections that follow.

4. Methodology

In this section, we use econometric modeling to measure the impacts of the consumer shift away from foodservice and towards retail food purchasing on prices across the U.S. egg supply chain. We then assess the extent to which temporary suspension of Egg Safety Rules for breaker producers have returned prices to their long-run equilibrium dynamics. In answering these questions, we distinguish between commodity and differentiated egg products. Section 4.1 explains our analytical procedure for commodity egg products, including retail table eggs, farm-gate table eggs, and breaker egg prices. Section 4.2 explains the analysis for retail prices for differentiated egg products.

All data used for the analysis are obtained from USDA Agricultural Marketing Service (AMS) *Market News*. All prices are observed on a weekly time step from January 2016 through May 2020. Start and ends are chosen purposefully. We begin the analysis in calendar year 2016 to avoid price aberrations associated with the outbreak of highly pathogenic avian influenza (HPAI) in 2015 (Dobrowolska and Brown, 2016) and the impacts of short-term bottlenecks associated with the imposition of California animal welfare standards (Sumner, 2017). We limit the analysis to prices observed through May 2020 to ensure the observed price responses to the COVID demand shocks and regulatory changes, as opposed longer-run supply adjustments, such as increases (or reductions) in the layer flock size.

4.1. Commodity egg products

To assess price impacts for commodity egg products, we obtain farm-gate and retail (store door) prices for large-sized, grade A white eggs produced in conventional cages (i.e., undifferentiated commodity table eggs) from USDA AMS. Farm-gate prices are producer averages for Iowa, Minnesota, and Wisconsin (three of the largest egg-producing states). Retail prices are observed in Chicago—the nearest major metro area. We match these data with weekly average breaker egg prices in the Central U.S. states. Fig. 2 displays retail, farm-gate, and breaking stock egg prices expressed in natural logarithmic form, as well as the log relative prices for farm-gate table eggs versus retail table eggs and breaker eggs.

Visual inspection of Fig. 2 shows that commodity egg prices moved together prior to the pandemic (panel a) and relative price relationships were stable (panel b). Consistent with anecdotal evidence, at the onset of

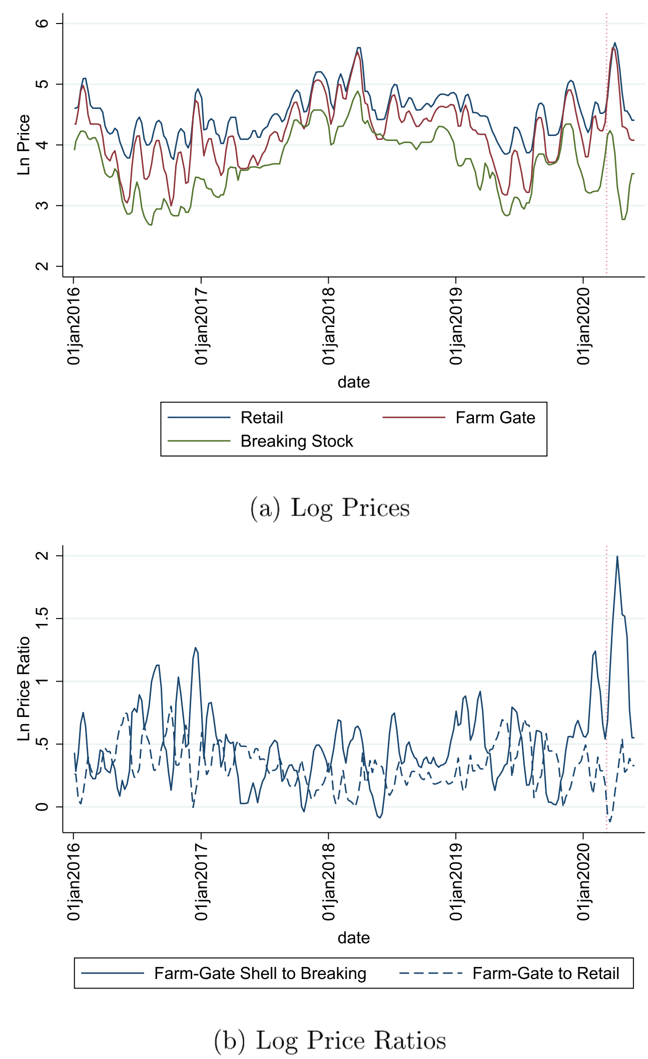


Fig. 2. Egg Prices and Prices Relatives. *Note:* Farm-gate and retail (store door) prices are for large-sized, grade A white eggs produced in conventional cages (i.e., undifferentiated commodity table eggs). Farm-gate prices are producer averages for Iowa, Minnesota, and Wisconsin (three of the largest egg-producing states). Retail prices are observed in Chicago—the nearest major metro area. We match these data with weekly average breaker egg prices in the Central U.S. states. *Source:* USDA Agricultural Marketing Service.

the pandemic, farm-gate and retail table egg prices increased drastically, while breaker prices plummeted. Table 1 provides the results for augmented Dickey-Fuller test for non-stationarity in the commodity egg price data, where the optimal lag specification is determined according to the Hannan-Quinn Information Criterion (HQIC) (Hannan and Quinn, 1979). We conduct this test for prices observed prior to the pandemic (i.e., before March 4, 2020). As shown in the Table, we fail to reject a unit root in the three commodity egg price data. Below we discuss the implications of this for informing our empirical model.

Using these data, we employ a three-step empirical procedure to estimate the impacts of the consumer shift and FDA regulatory change on commodity egg prices. First, we construct a vector autoregressive (VAR) model to estimate the dynamic equilibrium relationship between retail table egg prices, farm-gate table egg prices, and breaker egg prices prior to the pandemic.[3] Second, we forecast this pre-COVID dynamic price relationship forward through the early weeks of the pandemic to construct a series counterfactual prices against which to measure the impacts of the pandemic. Finally, we deduce the impacts of the FDA regulatory change by comparing the rate at which prices converged to counterfactual levels following the regulatory change with the rate implied by the orthogonal impulse response estimates associated with the VAR model.

We specify the vector autoregressive (VAR) dynamic pre-pandemic equilibrium relationship for commodity egg prices as follows:

$$R_t = \alpha^R + \sum_{i=1}^{j} \left(\gamma_i^R R_{t-i} + \lambda_i^R F_{t-i} + \delta_i^R B_{t-i}\right) + \mathbf{X_t}'\Omega^R + e_t^R \quad (1)$$

$$F_t = \alpha^F + \sum_{i=1}^{j} \left(\gamma_i^F R_{t-i} + \lambda_i^F F_{t-i} + \delta_i^F B_{t-i}\right) + \mathbf{X_t}'\Omega^F + e_t^F \quad (2)$$

$$B_t = \alpha^B + \sum_{i=1}^{j} \left(\gamma_i^B R_{t-i} + \lambda_i^B F_{t-i} + \delta_i^B B_{t-i}\right) + \mathbf{X_t}'\Omega^B + e_t^B \quad (3)$$

where R_t,F_t, and B_t, respectively, are the retail table egg price, farm-gate table egg price, and the breaker egg price (all specified in natural logarithmic form) observed in time t. Our VAR specification allows prices to move together according to a long-term equilibrium. However, in each week, each market experiences an exogenous shock. The other markets adjust to this exogenous shock over the following j weeks, where lag length is specified as 2 weeks as prescribed by the Hannan-Quinn Information Criterion (HQIC) (Hannan and Quinn, 1979) Vector X is set of exogenous controls, consisting of 51 indicators for the year-week (with baseline month January) to account for seasonality and a series of year indicators (with baseline year 2016) that allow to prices to rise over time due to inflationary pressures and changes in the technical efficiency of egg producers over time.

We improve on the efficiency of the VAR model by imposing the following constraints (summarized in Appendix Table A1) on the first-lag adjustment in Eqs. (1)–(3). Because our price variables each exhibit unit root processes, we constrain the coefficient on the own-price first-week lag to equal one for each price (i.e., $\gamma_1^R = \lambda_1^F = \delta_1^B = 0$). Additionally, we constrain the coefficients on the cross-price coefficients so that prices adjust only to the closest link in the supply chain in the first-week following an innovation (i.e., $\delta_1^R = \gamma_1^B = 0$). All own-price and cross-price coefficients are unconstrained for the second-period lag. After estimation, we conduct a Wald test to assess the validity of the cross-price exclusion constraints. We further test the parameter stability in our VAR representation (Hamilton, 1994; Lütkepohl, 2005). This ensures that the VAR parameters are stable, and, thus, inference using orthogonalized impulse-response functions is valid.

We estimate the model for the period January 1, 2016 through March 4, 2020 (i.e., the pre-pandemic period). We then forecast this pre-COVID dynamic price relationship forward through May 2020 to construct a series of counterfactual prices against which to measure the impacts of the pandemic. We further measure the impacts of the FDA rule change by comparing observed egg prices in light of the FDA rule change versus counterfactual egg prices for a scenario in which COVID-19 occurred, but the FDA requirements were not relaxed. We note that, even in the absence of the FDA rule change, farmers licensed to sell into the retail market would have responded by increasing production. However, the speed of that response is constrained by the biological realities of egg production. In most cases, table egg producers responded by increasing the number of layer hens. One of the desirable components of our price model is that the speed at which prices adjust to unexpected shocks is implicitly baked into our VAR adjustment parameters. Thus, we can simulate the prices that would have occurred in the absence of the regulatory change by comparing observed prices following the rule change with the counterfactual prices that our impulse response functions in light of an unexpected shock of the magnitude experienced at the onset of the pandemic. We deduce the impacts of the FDA regulatory change by comparing the rate at which prices converged to counterfactual levels following the regulatory change (i.e., after April 3, 2020) with the rate implied by the orthogonal impulse response estimates associated with the retail price shock (for retail and farm-gate table egg prices) and the breaker price shock (for breaker prices).

Table 1
Augmented Dickey-Fuller Tests for Stationarity.

Price Series	Obs	Lag Spec	Test Stat	p Value	Conclusion
Ln Breaking	214	3	−2.588	0.0955	*Fail to reject*
Ln Farm-Gate	214	3	−3.239	0.0178	*Fail to reject*
Ln Retail	214	3	−3.176	0.0214	*Fail to reject*

Note: This table provides the results for augmented Dickey-Fuller test for non-stationarity in the commodity egg price data, where the optimal lag specification is determined according to the HQIC. We conduct this test for prices observed prior to the pandemic (i.e., before March 4, 2020). We fail to reject a unit root in the three commodity egg price data.

4.2. Differentiated egg products

To estimate price impacts for differentiated egg products, we obtain weekly retail consumer prices for a wide variety of commodity and differentiated egg products across eight U.S. regions (Alaska, Hawaii, Midwest, Northeast, Northwest, South Central, Southeast, and Southwest). These data are collected by USDA AMS via survey of 29,200 store locations across the U.S. In each region, weekly prices are disaggregated by several traits, including product size (medium, large, and extra

[3] We note that—as shown in Table 1—our commodity egg prices exhibit unit processes. In the event of non-stationarity, error correction modeling (as opposed to VAR modeling) is required to formally test the long-run co-integration of time series variables. Although the error correction representation, in which short-term equilibrium dynamics are estimated via first-differences, does allow formal testing of co-integration, it comes at the substantial cost of estimation efficiency by excluding information concerning comovements in the data. Following Sims (1980) and Sims et al. (113–144), we elect to proceed with the VAR representation. Our goal is to determine the inter-relationships among the variables rather than obtaining specific parameter estimates. Further, we know from economic theory that egg prices at different points in the supply chain are co-integrated. We note that, when we test for co-integration via an error correction specification (Johansen, 1995), our results indicate the series are co-integrated with 99% confidence.

large), product color (white and brown), product grade (A and AA),[4] and products labeled assertions about credence attributes (cage-free, organic, vegetarian-fed, and omega-3). Because we estimate retail price impacts for commodity table eggs via Eq. (1), to assess the retail price impacts for differentiated egg products, we need only measure the observed premiums (or discounts) for these products relative to conventional eggs prior to and in the midst of the pandemic.

To do so, we regress observed retail prices R (expressed in natural logarithmic form) for product j in market i at time t against three different sets of indicators. The first set of indicators is a series of time dummies (denoted τ_t) for each week observed over the sample from 2016w1 ($t = 1$) through the end of the sample in 2020w22 ($t = T$). The second set of indicators is a series of dummies for each of the observed product size, color, grade, credence attributes traits. The indicators take value one for observed prices associated with the relevant product categories and take value zero otherwise.[5] In defining these indicators, we exclude categories "product size large", "product grade A", "product color white", and "conventionally produced" (i.e., commodity eggs) as the baseline. Product size indicators medium$_j$ and X-large$_j$ are concatenated into vector $\mathbf{SIZE}_j$. We use similar script for vectors $\mathbf{COLOR}_j$, $\mathbf{GRADE}_j$, and $\mathbf{CREDENCE}_j$. The third set of indicators is a series of dummies for each of the eight U.S. regions (collectively denoted by vector $\mathbf{REGION}_i$). Summary statistics for the differentiated products analysis are reported in Table 2. Correlations among the product attribute indicators are reported in Appendix Table A2.

Using the three sets of indicators defined above, we estimate the following regime-switching hedonic price model:

$$R_{ijt} = \sum_{l=1}^{T} \lambda_l \tau_t + \begin{bmatrix} \mathbf{SIZE_j} \\ \mathbf{COLOR_j} \\ \mathbf{GRADE_j} \\ \mathbf{CREDENCE_j} \\ \mathbf{REGION_i} \end{bmatrix}' \left[\beta_0 \quad c_t\beta^C \quad p_t\beta^P\right] + e_{ijt} \tag{4}$$

Coefficients λ_t on the time indicators in Eq. (4) measure the national average weekly price of commodity table eggs. Coefficients on indicators $\mathbf{REGION}_i$ allow for a wedge between regional prices and the national average prices, resultng from regional regulatory differences, regional differences in transportation costs, and regional preferences. Coefficients on product trait indicators measure the premiums (discounts) for the various product attributes.

To investigate the extent to which COVID-19 and the FDA regulatory suspension have affected prices, we allow coefficients β, which measure premiums for differentiated products and regional price wedges, to vary across three temporal regimes: (1) a pre-pandemic regime, (2) a COVID regime, and (3) a post-FDA-change regime. To do so, in addition to β_0, which is estimated over the entire sample period, we interact two additional model parameters to be estimated—β^C and β^P—with regime indicators c_t and p_t, respectively. Indicator c_t takes value one for all periods after the beginning of the pandemic (i.e., after March 4, 2020). Indicator p_t takes value one for all periods after the FDA regulatory change (i.e., after April 3, 2020). The coefficients are interpreted additively, meaning the premium in the COVID-19 regime is calculated as $\beta_0 + \beta^C$. The premium after suspension of the Egg Safety Rule is calculated as $\beta_0 + \beta^C + \beta^P$. We test whether the FDA regulatory suspension has returned price premiums to their pre-pandemic levels by the hypothesis test(s) $\beta^C + \beta^P = 0$.

5. Results

Results for the commodity egg impact analysis are reported in Section 5.1. Differentiated product results are presented in Section 5.2.

5.1. Commodity egg results

The parameter estimates in Table 3 describe the pre-pandemic dynamic equilibrium relationship for the commodity egg price system, obtained by estimating Eqs. (1)-(3) from January 1, 2016 through March 4, 2020. As discussed in Section 4, these parameters jointly describe the inter-relationships among variables rather than allowing for specifically

Table 2
Differentiated Product Analysis—Summary Statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Ln Price	10,496	0.73	0.56	−2.41	2.64
Credence Attribute Indicators					
Cage-Free	10,496	0.23	0.42	0	1
Vegetarian-Fed	10,496	0.06	0.24	0	1
Omega-3	10,496	0.20	0.40	0	1
Organic	10,496	0.16	0.37	0	1
Product Color Indicator					
Brown	10,496	0.40	0.49	0	1
Product Grade Indicator					
AA	10,496	0.13	0.34	0	1
Product Size Indicators					
Medium	10,496	0.08	0.27	0	1
X-large	10,496	0.16	0.36	0	1

Note: This table provides summary statistics for the differentiated product analysis. Data are weekly retail consumer prices for a wide variety of commodity and differentiated egg products across eight U.S. regions (Alaska, Hawaii, Midwest, Northeast, Northwest, South Central, Southeast, and Southwest), collected by USDA AMS via survey of 29,200 store locations across the U.S.

Table 3
Pre-COVID VAR Mechanism Estimates.

Variables	(1) Ln Retail	(2) Ln Farm Gate	(3) Ln Breaking
Ln Retail			
Lag 1	1.00	1.07***	0.00
		(0.10)	
Lag 2	0.21***	0.24**	0.15
	(0.06)	(0.12)	(0.11)
Ln Farm Gate			
Lag 1	0.60***	1.00	0.28***
	(0.02)		(0.049)
Lag 2	−0.88***	−1.36***	−0.39***
	(0.05)	(0.13)	(0.11)
Ln Breaking			
Lag 1	0.00	0.06	1.00
		(0.05)	
Lag 2	0.08***	0.18***	−0.07**
	(0.02)	(0.06)	(0.03)
Constant	−0.09	−1.25***	−0.12
	(0.11)	(0.30)	(0.21)
Week Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	216	216	216
	χ^2	df	p Value
Wald test for cross-price exclusions	4.55	2	0.1030

Parameter estimates describe the pre-pandemic dynamic equilibrium relationship for the commodity egg price system, obtained by estimating Eqs. (1)–(3) from January 1, 2016 through March 4, 2020.
Standard errors in parentheses.
** $p<0.05$
*** $p<0.01$

[4] The distinction between Grade AA and Grade A eggs is that Grade AA eggs have whites that are thick and firm, whereas Grade A eggs have whites that are only reasonably firm.

[5] For example, for transactions involving extra-large, grade A, brown cage-free eggs, indicators "X-large", "Brown", and "Cage-free" would take value one. All other indicators would take value zero.

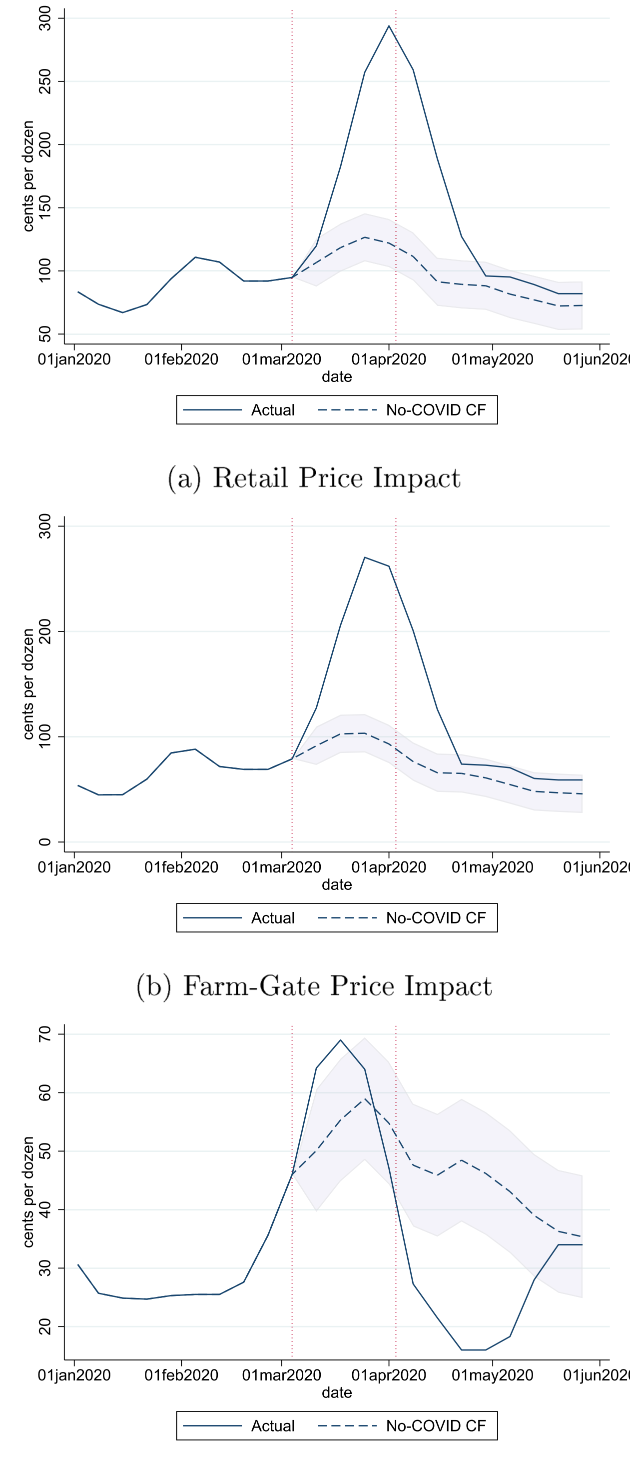
causal interpretation (Sims, 1980; Sims et al., 113–144). Nevertheless, at face value, most of the estimates appear reasonable.

For the retail price equation, shown in Column (1) of Table 3, we see that the single-period lag on the farm-gate price is 0.60 (significant 99%), suggesting a shock at the farm-gate is partially passed through to the retail price the following week. Similarly, the coefficients on the second-period lags for all explanatory prices are statistically significant at 99%. The second-period own-price lag is diminishing in magnitude, supporting the notion that shocks are transitory in nature. Turning to the farm-gate equation in Column (2) of Table 3, the parameter estimate on the single-lag retail price is statistically indistinguishable from one (and significant at 99%), suggesting a shock to the retail price is fully passed through to the farm-gate the following week. The first-period lag on the breaking price is statistically indistinguishable from zero. This is consistent with the idea that diversion of substantial numbers of breaking stock eggs into the table egg market was infeasible prior to suspension of the Egg Safety Rule requirements for table eggs. Similar to Column (1), the second-period lags for all explanatory prices are statistically significant at 95%, although the second-period own-price response is implausibly large in magnitude for direct causal interpretation. Finally, parameters in the breaker equation in Column (3) of Table 3 are consistent with those in Columns (1) and (2). First- and second-period lags on the farm-gate price are small in magnitude and statistically significant at 99%. The second-period lag on the retail price is positive, but statistically indistinguishable from zero.

Post-estimation tests for cross-price exclusion constraints and parameter stability confirm that the parameter estimates in Table 3 are a reliable representation of the pre-pandemic dynamic equilibrium relationship among commodity egg prices. As shown at the bottom of Table 3, we fail to reject the null hypotheses that prices adjust only to the closest link in the supply chain in the first-week following an innovation (i.e., $\delta_1^R = \gamma_1^B = 0$). Additionally, estimates in Table 3 satisfy tests for parameter stability and covariance stationarity (Lütkepohl, 2005; Hamilton, 1994),[6] ensuring that inference using orthogonalized impulse-response functions is valid.

Accordingly, we proceed with the impact analysis by forecasting through the end of May 2020 the dynamic equilibrium price relationships implied by our parameter estimates. Panels (a), (b), and (c) of Fig. 3 plot these counterfactual price estimates for retail table eggs, farm-gate table eggs, and breaker eggs, respectively, against actual prices experienced at the onset of the pandemic.[7] In each of these panels, the first dashed vertical line represents the onset of the pandemic, and the second dashed vertical line shows the date on which the FDA suspended Egg Safety Rule requirements for breaker producers seeking to sell into the table eggs market.

Turn first to retail price impacts for commodity table eggs in panel (a) of Fig. 3. As shown in the Figure, actual retail prices for commodity table eggs increased from 95¢per dozen in the week of March 4, 2020 to $2.94 per dozen as of April 1, 2020. In contrast, our retail price forecast is $1.22 per dozen as of April 1, 2020—the onset of the pandemic increased retail prices for commodity table eggs by approximately 141%. Following this spike, retail prices returned to 82¢per dozen by the end of May, about 13% above our forecasted retail price of 72¢per dozen. The farm-gate commodity table egg prices in panel (b) of Fig. 3 tell a similar story. As of March 4, 2020, farm-gate prices were 79¢per dozen. These prices increased to $2.62 per dozen as of April 1, 2020. On that date, our counterfactual price estimate is 93¢. This suggests the onset of the pandemic increased farm-gate prices by 182%. By the end of May, farm-gate prices fell to 59¢per dozen—26% above counterfactual



(a) Retail Price Impact

(b) Farm-Gate Price Impact

(c) Breaking Price Impact

Fig. 3. Impacts of COVID-19 Pandemic on Commodity Egg Prices. *Note:* Panels (a), (b), and (c) plot counterfactual price estimates for retail table eggs, farm-gate table eggs, and breaker eggs, respectively, against actual prices experienced at the onset of the pandemic. In each of these panels, the first dashed vertical line represents the onset of the pandemic, and the second dashed vertical line shows the date on which the FDA suspended Egg Safety Rule requirements for breaker producers seeking to sell into the table eggs market.

[6] In other words, estimated Eqs. (1)–(3) satisfy the condition that the modulus of each eigenvalue in the companion matrix is less than one (see Appendix Fig. A1).

[7] Note that for the purposes of Fig. 3, prices are expressed in levels rather than natural logs.

estimate of 46¢.

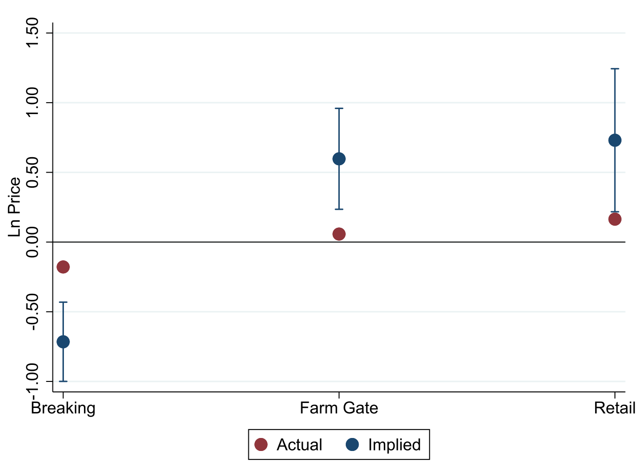
Combining the results for the retail and farm-gate prices, we do not observe a significant impact of the pandemic on the marketing margin. As of April 1, 2020, the actual implied marketing margin was 32¢($2.94 - $2.62) per dozen. Our estimated counterfactual implied marketing margin on that date is 29¢($1.22 - $0.93) per dozen. Similarly, at the end of May, the actual implied marketing margin was lower than the counterfactual marketing margin—23¢(82¢- 59¢) per dozen versus 27¢ (73¢- 46¢)

Breaking stock prices, shown in panel (c) of Fig. 3, initially rose the above counterfactual price estimate following the onset of the pandemic, before falling to 47¢per dozen as of April 1, 2020 versus the counterfactual estimate of 55¢per dozen (14.5% drop). Breaking prices ultimately fell 67% below counterfactual prices in mid-April, before returning to just 6% below counterfactual prices (34¢versus 36¢) by the end of May.

As explained in Section 4, we deduce the impacts of the FDA regulatory change by comparing the rate at which actual prices converged to counterfactual levels following the regulatory change (i.e., after April 3, 2020) with the rate implied by the orthogonal impulse response estimates associated with the retail price shock (for retail and farm-gate table egg prices) and the breaker price shock (for breaker prices). Comparisons for the final week of May are summarized in Fig. 4. The entire evolution of responses is shown in Appendix Fig. A2. These results suggest that—had the FDA not suspended Egg Safety Rules for breaker producers seeking to sell into the table eggs market—farm-gate and retail table egg prices would have been approximately 53% and 56% higher than those observed in the last week of May. On the other hand, breaking prices in the same week would have been about 50% lower.

5.2. *Differentiated egg results*

Table 4 reports the results of the retail price impact analysis for differentiated eggs. Columns (1) and (2) of the Table report the coefficients and corresponding standard errors obtained from estimating Eq. (4). Columns (3) and (4) report results of the post-estimation tests that price premiums returned to their pre-pandemic levels following the FDA regulatory suspension (i.e., the hypothesis tests $\beta^C + \beta^P = 0$). We first discuss premiums (or discounts)—relative to retail commodity egg



(a) Impact of Relaxed Regulation

Fig. 4. Impacts of FDA Regulatory Change on Commodity Egg Prices. *Note:* This figure shows the impacts of the FDA regulatory change by comparing the rate at which actual prices converged to counterfactual levels following the regulatory change (i.e., after April 3, 2020) with the rate implied by the orthogonal impulse response estimates associated with the retail price shock (for retail and farm-gate table egg prices) and the breaker price shock (for breaker prices).

Table 4
Impacts on Retail Price Premiums for Differentiated Eggs.

	(1) Regression Results	(2)	(3) Post-Estimation Tests	(4)
Variables	Coefficient	Std. Err.	Coefficient	Std. Err.
Credence Attributes				
Cage-Free	0.74***	(0.06)		
COVID Interaction	−0.34***	(0.06)		
Policy Interaction	0.14***	(0.00)	−0.20**	(0.06)
Vegetarian-Fed	0.67***	(0.05)		
COVID Interaction	−0.28***	(0.05)		
Policy Interaction	0.18***	(0.00)	−0.11*	(0.05)
Omega-3	0.72***	(0.05)		
COVID Interaction	−0.15**	(0.05)		
Policy Interaction	0.26***	(0.00)	0.10*	(0.05)
Organic	1.06***	(0.06)		
COVID Interaction	−0.16*	(0.06)		
Policy Interaction	−0.22***	(0.00)	−0.38***	(0.06)
Product Color				
Brown	0.14***	(0.02)		
COVID Interaction	0.13***	(0.02)		
Policy Interaction	0.08***	(0.00)	0.21***	(0.02)
Product Grade				
AA	−0.00	(0.02)		
COVID Interaction	−0.16***	(0.02)		
Policy Interaction	0.36***	(0.00)	0.20***	(0.02)
Size Traits				
Medium	−0.18***	(0.02)		
COVID Interaction	0.09***	(0.02)		
Policy Interaction	−0.06***	(0.00)	0.02	(0.02)
X-large	0.13**	(0.03)		
COVID Interaction	0.06	(0.03)		
Policy Interaction	0.01***	(0.00)	0.07	(0.03)
Constant	0.14***	(0.03)		
Year-Week Fixed Effects	Yes			
Regional Fixed Effects	Yes			
COVID*Region Fixed Effects	Yes			
Policy*Regional Fixed Effects	Yes			
Observations	10,378			
R-squared	0.76			

Robust standard errors in parentheses.
* $p<0.1$
** $p<0.05$
*** $p<0.01$

prices—for differentiated products prior to the COVID-19 pandemic. We then discuss the impacts of the pandemic and subsequent regulatory change on these relative prices.

Referring to the pre-pandemic premiums reported in Column (1) of Table 4, among eggs labeled with credence attributes, organic eggs have traditionally traded with the highest premium with a 106% premium (statistically significant at 99%) relative to conventional eggs. Cage-free table eggs have traded at 74% premium (significant at 99%) relative to conventional eggs. Similarly, vegetarian-fed and omega-3-enriched eggs traded at 67% and 72% (statistically significant at 99%) above conventional eggs.[8] Turning to the coefficients on COVID interactions in Column (1) of Table 4, the onset of the pandemic reduced premiums among all egg products differentiated by credence attributes. The premium for cage-free eggs fell by approximately 34% (significant at 99%). The premiums for vegetarian-fed, organic, and omega-3-enriched eggs fell by 28% (significant at 99%), 16% (significant at 90%), and 15% (significant at 95%), respectively.

Recall that in the Conceptual Framework in Section 3, we posit that the pandemic can affect prices for vertically differentiated products in two ways (Saitone and Sexton, 2010). First, assuming consumer preferences are unchanged by the pandemic, an increase in the price of a product perceived as being of lower quality will naturally lower the *relative* price (i.e., the price premium) of a higher quality product. Additionally or alternatively, if the pandemic forces consumers to shift towards basic needs, it could cause a segment of consumers to lower their willingness-to-pay for (vertically differentiated) quality attributes. Further recall that in Section 5.1, we found that the onset of the pandemic increased retail prices for commodity eggs by as much as 141% above counterfactual levels. Accordingly, we are unable to conclusively say whether the reduction in price premiums for credence attributes is a result of changing preferences for quality or an increase in the absolute price for conventional eggs (i.e., the "low quality" product as referenced in the Conceptual Framework in Section 3).

Estimates on the post-FDA policy change interaction are more compelling with respect to the preferences versus prices question. Following the FDA exemptions from FDA Egg Safety Rules from breaking stock producers seeking to sell into the table egg market, premiums for cage-free eggs (relative to conventional) rose by 14%. Combining this point estimate with the COVID interaction suggests a 20% net reduction (-34% + 14%) in the premium for cage-free eggs, relative to the pre-pandemic baseline. The post-estimation test of the linear hypothesis tests $\beta^C + \beta^P = 0$ in Columns (3) suggests this result is statistically different from zero at 95% confidence. Results are similar for vegetarian-fed eggs. Premiums rose by 18% after the FDA policy, but the net impact (relative to the pre-pandemic baseline) was an 11% reduction in the price premium (significant at 90%). Note that premiums for organic eggs continued to fall even following the FDA change, such that the net impact was a 38% reduction in the price premium (significant at 99%).

Of particular interest is the fact that the omega-3 is the only credence attribute for which premiums *rose* relative to their pre-pandemic baseline. This is meaningful, considering that—among the observed credence attributes—omega-3 enrichment is the sole attribute that implies health benefits to the consumer (as opposed to animal welfare or environmental benefits). In light of the fact that retail prices for commodity eggs traded at approximately 14% above counterfactual levels following the FDA change, we find it unlikely that the changes in premiums for animal welfare and environmental credence attributes (which ranged from −11% to −38%) can be explained by changes in absolute prices. Rather, we believe these results constitute strong (though not fully conclusive) evidence that the falling premiums are the result of a change in preferences for credence attributes rather than arising solely in response to rising commodity egg prices.

[8] In addition to the premiums (and corresponding impacts of the pandemic) for credence attributes, coefficient estimates in Table 4 for other product attributes also appear reasonable. Prior to the pandemic, brown colored eggs experienced a 14% premium (significant at 99%) relative to white eggs. Medium eggs received a 18% discount (significant at 99%) relative to large-sized eggs, whereas extra-large eggs received a 13% premium (significant at 95%). As shown in Table 4, prior to the pandemic, there was no statistically distinguishable difference between Grade AA and Grade A egg prices.

6. Welfare impacts

In this section, we formally assess the welfare implications of the price impacts discussed in Section 5. We consider outcomes for table egg consumers, intermediaries, and producers and breaker egg producers (evaluated as revenue changes on a per week basis). These results are presented in Table 5. To derive these impacts, we assume for simplicity that the short-run farm-gate supply curves for table and breaker eggs (IS_1^R and IS_1^S from Fig. 1) are perfectly inelastic. Thus, we can derive revenue changes by multiplying actual and counterfactual prices by observed quantities.

Data on the volumes of breaker eggs and retail tables sold are obtained from USDA AMS. Based on Ibarburu (2020), we assume 25% of table eggs are produced in cage-free enclosures. We do not capture effects for other differentiated products, which represent a smaller share of the table eggs market.

Table 5 presents welfare outcomes under two scenarios. In this first scenario, we derive the impacts of the onset of the COVID-19 pandemic, where actual prices are those observed as of April 1, 2020 and counterfactual outcomes are for the alternate reality where the pandemic did not occur. For retail commodity table egg prices, farm-gate table egg prices, and breaker egg prices, these outcomes correspond to actual and No-COVID counterfactual prices from panels (a)–(c) of Fig. 3. For cage-free retail table egg prices, we multiply the retail commodity egg prices by the COVID-adjusted premium in the "actual" scenario and the pre-pandemic premium in the counterfactual scenario measured in Table 4. In the second scenario, we derive the impacts of the FDA

Table 5
Weekly Impacts of COVID-19 and FDA Regulatory Response on Welfare Outcomes.

Variable	Units	COVID Impacts		Regulatory Impacts	
		Actual	CF	Actual	CF
Estimated Price Impacts					
Conventional Eggs					
Retail	*$ per dozen*	2.94	1.22	0.82	1.25
Farm-Gate	*$ per dozen*	2.62	0.93	0.59	0.92
Breaking Stock	*$ per dozen*	0.47	0.55	0.34	0.26
Cage-Free Retail	*$ per dozen*	4.12	2.12	1.26	1.93
Retail-to-Farm Margin	*$ per dozen*	0.32	0.29	0.23	0.33
Table-to-Breaker Margin	*$ per dozen*	2.15	0.38	0.25	0.67
Quantity Parameterization					
Table Eggs	*million dzn*		7.2		7.0
Share Cage-Free	*% of table*		25%		25%
Breaking Stock	*million dzn*		1.3		1.2
Welfare Impacts per week					
Consumers:	*$ Million*		−12.9		3.4
Intermediaries:	*$ Million*		0.2		−0.7
Producers:					
Table Eggs	*$ Million*		12.2		−2.3
Breaker Eggs	*$ Million*		−0.1		0.1
Total (per week)	**$ Million**		**−0.6**		**0.5**

Note: This table presents welfare outcomes under two scenarios. In this first scenario, we derive the impacts of the onset of the COVID-19 pandemic. In the second scenario, we derive the impacts of the FDA regulatory change, where actual prices are those observed as of May 31, 2020 and counterfactual outcomes are for the alternate reality where the pandemic occurred, but the regulations were not relaxed.

regulatory change, where actual prices are those observed as of May 31, 2020 and counterfactual outcomes are for the alternate reality where the pandemic occurred, but the regulations were not relaxed. To derive these counterfactuals, commodity egg prices are adjusted as depicted in panel (d) of Fig. 3. "Actual" and counterfactual retail cage-free egg prices are equal to the retail commodity table egg price multiplied by the post-policy-change premium measured in Table 4.

Referring to the welfare impacts in Table 5, we see that the onset of COVID-19 cost retail table egg consumers approximately $12.9 million per week. A large share of this surplus was transferred to table egg producers. On net, the pandemic cost $0.6 million per week. The FDA regulatory change offset the costs of the pandemic to retail table egg consumer by about $3.4. Approximately 68% of this welfare was transferred to consumers from table egg producers. In total, the FDA regulatory suspension increased market welfare by about $0.5 million per week.

7. Policy implications and conclusion

This article investigates how the shift from food-away-from-home and towards food-at-home at the onset of the COVID-19 pandemic affected the U.S. food supply chain. We find that the pandemic increased retail and farm-gate prices for table eggs by approximately 141% and 182%, respectively. In contrast, prices for breaking stock eggs—which are primarily used in foodservice and restaurants—fell by 67%. On April 3, 2020, the FDA responded by issuing temporary exemptions from certain food safety standards for breaking stock egg producers seeking to sell into the retail table egg market. We find that this regulatory change rapidly pushed retail, farm-gate, and breaking stock prices towards their long-run pre-pandemic equilibrium dynamics. The pandemic reduced premiums for credence attributes, including cage-free, vegetarian-fed, and organic eggs, by as much as 34%. These premiums did not fully recover following the return to more "normal" price dynamics, possibly signaling that willingness-to-pay for animal welfare and environmental sustainability have fallen as consumers seek to meet basic needs during the pandemic.[9] Finally, in spite of widespread claims of price gouging, we do not find that the pandemic (or the subsequent FDA regulatory changes) had a meaningful impact on the marketing margin for table eggs sold at grocery stores.

Policy implications are self-evident. The success of ongoing efforts to create a food supply chain more resilient to future disruptions hinges on an understanding of the barriers that prevented the flow of goods between foodservice and retail industries at the onset of the COVID-19 pandemic. While some barriers, such as the fixed costs of infrastructure technology, are difficult to quickly remove, we show that temporary suspension of regulatory constraints can have a substantial impact at allowing arbitrage across markets.[10]

Of course, the wisdom of relaxing any given regulation is context specific. We emphasize that the impacts we measure are only a subset of the full impacts of the policy. The policymaker must weigh the benefits of deregulation against the costs of the market failures the regulation was designed to address. The Egg Safety Rules studied here were developed by the FDA as a means of reducing the risks of *Salmonella Enteritidis* (SE), which is among the leading bacterial causes of foodborne illness in the United States. Still to be quantified is the impact of suspending the Egg Safety Rules on the burden of food-borne disease—table eggs are a primary source of human SE infections. We leave it to future researchers to unscramble this quandary.

[9] Recent research suggests that some consumers exhibit concern regarding the environmental consequences of regulatory changes (Kecinski et al., 2020).

[10] Suspension of Egg Safety Rules was among many regulatory responses across the food supply chain. For example, state governments permitted distillers to produce hand sanitizer to fill short-run shortages of the product. Some policymakers also allowed craft breweries to more easily sell their beers for off-premises consumption.

CRediT authorship contribution statement

Trey Malone: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **K. Aleks Schaefer:** Conceptualization, Data curation, Formal analysis, Methodology, Writing - original draft, Writing - review & editing. **Jayson L. Lusk:** Methodology, Writing - original draft, Writing - review & editing.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.foodpol.2021.102046.

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