Higher Minimum Quality Standards and Redistributive Effects on Consumer Welfare

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Abstract

This paper estimates an individual level demand model for animal welfare differentiated eggs with German household data. We evaluate the effect on consumer surplus of a higher minimum quality standard for eggs in terms of animal welfare. Our results show that, on average, households with higher income are willing to pay more for eggs that provide higher animal welfare. While poorer consumers are forced to buy a higher priced alternative or opt out of the market, prices for the remaining higher quality eggs typically fall after increasing the minimum quality standard. As a result consumer welfare is redistributed from low-income to high-income households. This provides evidence for a regressive impact of higher minimum quality standards. In counter-factual scenarios, we estimate the required cost reduction due to efficiency gains or, equivalently, a tailored subsidy in order to offset the regressive effect. As market power increases, the cost reduction must be higher. Finally, we examine hypothetical future scenarios by successively increasing the minimum quality standard until only the highest quality egg alternative remains on the market.

Keywords: Minimum quality standard, Product differentiation, Regulation, Consumer harm, Bayesian estimation, Heterogeneity

JEL classification: L11, L13, L50, H23

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1 Introduction

Product quality regulations in the form of minimum quality standards and product bans are a ubiquitous aspect of our everyday lives, but not much is known about their economic impact. While higher minimum quality standards are usually non-controversial from an ethical or ecological viewpoint, they might have unintended consequences for consumers. We empirically study the impact of a higher minimum quality standard on consumer welfare, taking into account how firms optimally adjust prices for those product variants that are still available. Our counter-factual experiments offer guidance to policy makers on how potentially regressive effects of a higher minimum quality standard, through which notably lower-income households are particularly affected, can be mitigated.

Ours is a timely topic as policy makers and regulators take an increasingly paternalistic stance with regards to consumer health and safety, but also in relation to environmental and ethical standards that firms and consumers should adhere to. Higher minimum quality standards and product bans, as we analyze, have been introduced and discussed in various areas and for various reasons, ranging from environmental protection[1], consumer health and safety[2] to broader ethical standards, including animal welfare[3].

Faced with a restricted set of products, consumers will adjust their individual consumption. But also firms, notably retailers, will optimally adjust their pricing of the still available products and product variants. Understanding these adjustments is key both to assess the overall impact of any given policy and to correctly anticipate the impact of any planned policy. We conduct such an analysis for the case of a ban on the sale of battery eggs in Germany where animal welfare is one dimension of product quality. In the EU, fresh eggs are grouped into four categories that provide different levels of hen welfare. The ban deprived consumers of their lowest-quality and lowest-price alternative.

We argue in this paper that possible equilibrium effects on prices should be considered in order to assess the likely impact on consumers when minimum quality standards are increased. In equilibrium, one should expect a drop in prices for close substitutes. If firms have some degree of market power, they will aim to attract former low-quality product buyers and decrease their margin for upper quality products. While former low-quality product buyers are then typically still negatively affected by the ban, a higher minimum quality standard benefits consumers who

[1]For instance, the EU banned conventional light bulbs and nickel-cadmium batteries in 2009.

[2]For instance, the New York City Health Department banned large-sized soft drinks sold in restaurants, sports arenas and movie theaters in 2012.

[3]For instance, the EU banned battery hen's eggs in 2012 and cosmetic tested on animals in 2013.

buy upper quality products anyway. Hence, there are losers and winners, but the impact on total consumer surplus is ambiguous.

The theoretical literature on minimum quality standards has not made clear-cut predictions about their effect on social welfare in the absence of strict assumptions about market structure, cost functions, and consumer preferences. Even if we focus exclusively on changes in aggregate consumer welfare, the theoretical literature has been ambiguous regarding the impact of minimum quality standards.[4] Nor are we aware of any empirical study that explicitly addresses the effects of higher minimum quality standards on prices and consumer welfare in vertically differentiated product markets.

Technically, we use an empirical framework that is particularly well-suited to analyze heterogeneous consumer preferences in markets with vertical product differentiation. In our main analysis, we estimate a hierarchical Bayesian multinomial logit model with a flexible mixture of normals first-stage prior to estimate non-normal consumer heterogeneity. We rely on a modified version of the standard Markov Chain Monte Carlo (MCMC) algorithm in Rossi, Allenby, and McCulloch (2005) that is described in Pachali, Kurz, and Otter (2017) and implement order constraints for the egg label intercepts to explicitly model vertical product differentiation in our demand framework.

The results show substantial heterogeneity in preferences for animal welfare differentiated eggs. Higher-income households are willing to pay, on average, more for eggs that provide better animal welfare. As prices for the majority of higher quality eggs fall after the increase in the minimum quality standard, this means that consumer welfare is essentially redistributed from low-income to high-income households. Our findings suggest that equilibrium price reactions on the supply side are a major driver for the regressive impact of higher minimum quality standards. In contrast to other regulatory questions, such as merger approvals by competition authorities, equilibrium price effects and the resulting (possibly asymmetric) changes in consumer welfare do not seem to be considered ex ante by policy makers in product regulation cases.

Using counter-factual experiments, we show how consumer protection agencies can estimate the necessary reduction in costs of the new minimum quality standard in order to offset the regressive effect. This cost reduction can be achieved, for instance, by economics of scale. If the expected reduction in costs is close to the necessary cost reduction, the policy of increasing the minimum quality standard is less problematic in terms of harming low-income households. Otherwise a tailored subsidy scheme can be proposed as another way to soften the regressive effect.

[4] See for instance, Besanko, Donnenfeld, and White (1987); Besanko, Donnenfeld, and White (1988); Crampes and Hollander (1995); Buehler and Schuett (2014).

We identify the role of market power as an essential determinant for the level of the cost reduction required to protect consumers who would otherwise be harmed by the higher minimum quality standard. Finally, we examine hypothetical future scenarios in which the minimum quality standard is increased until only organic eggs remain on the market. We find that the necessary cost reduction to compensate poorer consumers would have to increase if the policy maker further raises the minimum quality standard.

The rest of this paper is organized as follows. The related literature is discussed in Section 2. Section 3 provides details on the German egg market and describes the data used in the analysis. The empirical model and estimation techniques are introduced in Section 4. The demand estimation results are discussed in Section 5. Section 6 discusses redistributive effects of increased minimum quality standards, the role of market power and policy implications. Finally, Section 7 draws conclusions from our findings.

2 Related literature

As our analysis shows, taking into account firms' optimal (price) responses to policies, such as the considered ban, is essential to analyze both the overall (welfare) impact and notably its distributional consequences on households with different socio-demographic characteristics. This requires to set up a structural model of the supply side. The respective empirical literature, to which this paper contributes, is sparse.

In a recent study, Dubois, Griffith, and O'Connell (2017) evaluate the effect of banning advertising in junk food markets. The authors estimate the impact of household demand for potato chips if advertisers persuade consumers to place less value on product healthiness. In a simulation they show that potential health benefits of an advertising ban for potato chips would be partially offset by lower equilibrium prices and switching behavior to other junk food products. Ryan (2012) analyzes higher environmental standards in the cement industry, showing how this can discourage entry and, by softening competition and thereby increasing prices, reduces social welfare. In a study similar to ours, Allender and Richards (2010) look at the consumer impact of hen welfare regulation. With data on the Californian egg market they examine the hypothetical impact on consumers of a cage-free egg production mandate. In their analysis, however, there is only a distinction between regular cage eggs (circa 95% market share) and cage-free eggs (5 % market share).[5] Likely equilibrium price effects are not taken into account

[5]The authors explain that in contrast to the European Union, there is no clear labeling practice for eggs in California.

and the authors assume constant prices after the regulation. Our study incorporates the impact of equilibrium price adjustments following the adoption of a higher minimum quality standard in a fully developed structural model, including both demand and supply.

Assessing individual consumer welfare changes is a crucial part in our policy analysis as it allows us to identify the redistributive effects of higher minimum quality standards. We apply a hierarchical Bayesian approach in this paper that is especially well suited to infer the prevalent degree of consumer heterogeneity. To our knowledge, only a small body of literature has considered the distributional effects of changes in market structure and regulation. West (2004), for instance, examines the distributional impact of alternative vehicle pollution control policies finding that low-income households demonstrate a greater price responsiveness to pollution control measures. This suggests greater progressivity of gas or miles taxes across lower-income households. Allen, Clark, and Houde (2014) extend the merger analysis literature by explicitly estimating distributional effects of a merger in the Canadian mortgage market, an aspect of merger evaluation that had been previously ignored.

3 Market details and data

The market for fresh hen's eggs

The German market for fresh eggs is suitable to study the effect of higher minimum quality standards on consumer welfare in markets with vertical product differentiation for two reasons: first, there is an EU-wide requirement to state the breeding category on egg packages and to additionally print a code on each single egg indicating origin and breeding category since 2004. Thus, consumers typically associate the four breeding categories with different quality levels: battery eggs $\precsim$ barn eggs $\precsim$ free-range eggs, and $\precsim$ organic eggs. These perceived quality differences can be motivated by consumers seeking a "warm glow" for knowing that animals have better living conditions and/or a belief that eggs from those "happier" hens do indeed taste better. Table 1 depicts the differences in living conditions for hens between the different egg categories. The price differences across categories are substantial and partly driven by differences in production costs. The fact that there is sufficient demand for each category suggests that consumers are heterogeneous in their willingness-to-pay (WTP) for different levels of animal welfare/quality. Second, in 1999 the EU decided that all member states had to ban the production of battery eggs by 2012. Germany already implemented the ban in 2010.[6] Nevertheless, battery eggs could still be imported from other EU countries until 2012 and an updated version

[6]Note that even after 2012 not all member states of the EU, especially among the new eastern member states, have implemented this ban. The EU commission plans to sue these countries for breaching the directive.

Table 1: Main differences between egg breeding categories

Egg label	Hens per m^2	Surface per hen in cm^2	Outdoor area per hen in m^2	Additional points
Organic	6	1667	4	Organic feed, no beak trimming, no regular use of antibiotics
Free-range	9	1100	4	Live in open barns
Barn	9	1100	0	Live in open barns
Battery	18	550	0	Live in cages

Source: `http://www.deutsche-eier.info/die-henne/haltungsformen/`; accessed 2 March 2016.

of this breeding category called "Kleingruppenhaltung" was introduced to replace battery eggs. This category was slightly better but still worse than barn eggs in terms of animal welfare. The German retail sector, however, decided to completely delist battery eggs from its assortment of fresh eggs at the end of 2010 and to not introduce the eggs from "Kleingruppenhaltung". Some retailers pre-empted this delisting and already banished battery eggs several months before the official deadline. For example Lidl, a large retailer in Germany, banished battery eggs already in 2009.[7] Since then German households consume battery eggs only indirectly as an ingredient of processed food products such as noodles, pastries and mayonnaise.

Data

The analysis is based on Nielsen Homescan data which track expenditures of German households on fast moving consumer goods (FMCG).[8] All participants are surveyed once a year and several demographic variables such as age, household size and income are recorded. For each year from 2008 to 2012, the Nielsen Company (Germany) GmbH drew a representative sample of German households. The panel of households is not necessarily identical over the years since a fraction is replaced by new households every year.[9] As a consequence, projection factors are adjusted each year. For our estimation, we therefore consider only households in the representative sample in 2008. This leaves us with a total of 10,843 households. In order to maximize the use of information on individual purchase histories, we also include later choices of households who were still observable in the subsequent years.

We focus on purchases of eggs in the German retail sector. Around 80% of all fresh eggs in Germany are bought in disounters and full-range supermarkets.[10] Only purchases at the top

[7] `https://albert-schweitzer-stiftung.de/aktuell/lidl-ohne-kaefigeier`; accessed 12 December 2016.

[8] We want to emphasize that only we authors are responsible for the contents, which do not necessarily represent the opinion of The Nielsen Company (Germany) GmbH.

[9] Besides of not participating anymore in the survey, Nielsen always validates whether a household continuously reports within a year and whether there are irregular patterns such as large gaps because of illness or especially long vacations.

[10] `http://www.daserste.de/information/ratgeber-service/lebensmittelcheck/wie-gut-sind-unsere-eier-fakten-rund-ums-ei-100.html`; accessed 12 December 2016.

ten retail chains were considered[11], because infrequent shopping trips to smaller chains make it difficult to impute prices for non-chosen alternatives and to cross-validate data. This represents approximately 75% of all egg purchases made in the German retail sector. Furthermore, we include only households in our sample that purchased eggs at least four times. This left us with a total of 6,961 households for our estimation. Table 2 compares our estimation sample with the full sample. We conclude that in terms of observable demographics the estimation sample seems comparable to the full sample.[12] For estimating our demand model, a product is defined

Table 2: Descriptives of household characteristics

	Mean	Stand. Dev.	Min	Max
Estimation sample				
Household size	2.38	1.18	1.00	9.00
Monthly net income in EUR	2363.70	1348.49	500.00	7992.00
Urban dummy	0.75	0.43	0.00	1.00
Age of oldest adult in household	52.21	14.09	19.00	99.00
Children in household	0.28	0.45	0.00	1.00
Share of female household members	0.50	0.27	0.00	1.00
Pet in household	0.48	0.50	0.00	1.00
No. of households	6,961			
Full sample				
Household size	2.28	1.16	1.00	9.00
Monthly net income in EUR	2338.54	1357.80	500.00	7994.00
Urban dummy	0.75	0.44	0.00	1.00
Age of oldest adult in household	53.56	14.48	19.00	99.00
Children in household	0.25	0.43	0.00	1.00
Share of female household members	0.50	0.29	0.00	1.00
Pet in household	0.45	0.50	0.00	1.00
No. of households	10,843			

Note: The urban dummy equals one if the household lives in a municipality with at least 50,000 inhabitants.

as an egg category-package size-combination offered at one of the ten stores.[13] Similarly to Dubé, Hitsch, and Rossi (2010), we define an aggregate of purchase incidents in related product categories as an outside option.[14] As we analyze only fresh hen's eggs, we define boiled and painted eggs as well as eggs from other type of poultry, e.g. quails and gooses, as outside good.

[11]For reasons of confidentiality all brand and retailer names were made anonymous in this article.

[12]Note that the income variable was originally a categorical variable. Thirteen different income ranges are recorded. We constructed a continuous income variable for each household by drawing from a uniform distribution within the respective income range.

[13]Specific brands of eggs are not considered here. We do not regard them as important because in the data period most egg brands are private labels and there often exists only one brand within each store. The main differentiation here comes through the different egg labels. Furthermore, there is no advertising for egg brands in Germany.

[14]For example, Dubé et al. (2010) take any other fresh or canned juice product purchase as an outside good for refrigerated orange juice and any other margarine or butter than considered margarine brands as an outside option for margarine.

In contrast to the inside egg products, the outside good is an aggregate that is assumed to be not owned by any of the stores.

Table 3 displays market-share weighted average prices across retailers and market shares for the products considered for estimation. We also compare average prices and market shares between the years 2008 and 2012. We regard the prices in 2012 as long-run new equilibrium prices after the ban on battery eggs. In 2008, when battery eggs are still listed by German retail chains, both barn and battery eggs exhibit similar market shares and together constitute around 60 % of all egg purchases. The difference between average prices for ten eggs of both breeding categories is 0.33 EUR in 2008. Comparing average prices for a package of ten barn eggs between 2008 and 2012, we observe that they are 0.16 EUR lower in 2012, when battery eggs are no longer offered by retailers. In 2012, barn eggs account for around 53 % of all egg purchases in our sample.[15] This comparison suggests that typical battery egg consumers are likely harmed and typical barn egg consumers likely benefit from the ban on selling battery eggs. Also a package of ten free-range eggs becomes cheaper in 2012. The odd observation that average prices for a package of six barn eggs may become more expensive than a package of ten barn eggs is related to the difference in product assortments between discounters and full-range stores. While most discounters typically have only packages of ten eggs for each egg category, full-range stores usually offer two package sizes (six and ten) at higher prices. Finally, we find that average prices for a package of ten organic eggs increases.

We want to point out that these changes in average prices alone cannot be used to quantify the effect of banning battery eggs on prices and consumer welfare. While we think that some part of the price decrease for barn and free-range eggs is due to the ban, we cannot control for all other supply side factors that might drive these results such as changes in costs and market structure. As a consequence, we employ a structural model to isolate the impact of a higher minimum quality standard on consumer welfare. For our structural model, we estimate individual demand parameters using all 343,384 purchase incidents of our 6,961 households between 2008 and 2012. As the panel of households is only complete in 2008, however, we base our counter-factual experiments and consumer welfare calculations on purchases made in this year.[16]

[15] Note, however, that market shares are not necessarily representative anymore in 2012 because some households drop out after 2008. The panel is only representative for 2008.

[16] Also because after 2008 some retailers already pre-empted the ban and start delisting their battery eggs in 2009.

Table 3: Data description

	Average price (EUR)			Market share (%)		
Egg product	2008-2012	2008	2012	2008-2012	2008	2012
Organic 10 units	2.59	2.47	2.62	3.49	3.13	3.77
Organic 6 units	1.66	1.67	1.66	4.66	2.91	6.15
Free-range 10 units	1.58	1.54	1.45	17.04	18.26	18.43
Free-range 6 units	1.24	1.13	1.36	4.40	4.78	3.59
Barn 10 units	1.26	1.27	1.11	45.06	28.97	52.84
Barn 6 units	1.20	1.16	1.14	2.04	1.10	3.00
Battery 10 units	0.99	0.94		12.55	31.25	
Outside good				10.77	9.60	12.22
No. of households				6961	6961	5224
No. of purchase incidents				380,790	87,449	63,355

Note: We weight average prices by market shares across retailers.

4 Empirical Framework

Demand Model

A household makes a discrete choice among J_t egg products during each purchase occasion. The incidence and timing of a trip to a retail store and the egg purchase incident are assumed to be exogenous. This assumption can be justified by the fact that households typically buy a whole basket of goods where eggs ($1-3$ EUR per egg product) are of minor relevance compared to the whole basket (typically worth more than 10 or 20 EUR).[17] As it is usually the case in the context of empirical demand estimation, we do not observe the specific set of egg alternatives across stores that a household might consider at the time of purchase. However, the structure of the data allows us to infer individual store preferences for the ten retailers that effectively locate the alternatives most likely to be considered and offer valuable information about the level of competition between retailers required for the counter-factual analysis below. Accordingly, we include the egg alternatives of all ten stores into the consideration set and household i's indirect utility from egg product g in store l at period t is

$$U_{iglt} = \gamma_{i,g} + \alpha_i p_{glt} + \beta_i \mathbf{1}\{units_g = 6\} + \psi_{i,l} + \varepsilon_{iglt}, \tag{1}$$

where $g \in \{Battery, Barn, Free\text{-}range, Organic\}$ and $l \in \{1, \ldots, 10\}$ in our application. The indicator variable, $\mathbf{1}\{\}$, denotes whether egg label g has the package size six instead of ten eggs. The price is given by p_{glt} and we normalize the mean utility of the outside option to zero, $u_{iglt} = 0$. We set $j := (g, l)$ to simplify notation in what follows.

The specification of our demand model assumes that all households have complete information about the egg products offered by the ten retailers and the final purchase decision is not only determined by the product itself (e.g. an egg label in a given package at a particular price) but also by the preference for the specific store where the product is offered. For the individual demand specification in Equation 1, we expect coefficients of stores the household never purchased eggs from to approach $-\infty$ in the limit of sufficient individual data. This is a crucial property as it attenuates a likely bias in the estimate of $(\alpha_i, \{\gamma_{i,g}\}, \beta_i)'$ caused by including alternatives the household did not consider at time of purchase.

The deterministic part of utility is defined as $V_{ijt} = \gamma_{i,g} + \alpha_i p_{jt} + \beta_i \mathbf{1}\{units_g = 6\} + \psi_{i,l}$ for household i and every choice alternative j at time t. Assuming that ε_{ijt} follows a type I extreme

[17] Furthermore, the fact that only very few retailers offer promotions on eggs, which indicates that it is not a product that can attract price-sensitive shoppers. We think that only if egg prices increase substantially, violating prior expectations about the price distribution from previous purchase incidents, would consumers actively search across stores.

value distribution, individual choice probabilities are given by a multinomial logit model

$$Pr_{it}\left\{j|p\right\} = \frac{e^{V_{ijt}}}{1+\sum_{k=1}^{J_t} e^{V_{ikt}}}. \tag{2}$$

We have fifteen parameters to estimate on the household level, denoted as $\theta_i = \left(\alpha_i, \gamma_{i,Battery}, \ldots, \gamma_{i,Organic}, \beta_i, \hat{\psi}_{i,2}, \ldots, \hat{\psi}_{i,10}\right)'$.[18] As outlined in Section 3, we observe sufficient demand in each egg label category to make it particularly important to rely on a model that explicitly accounts for preference heterogeneity. We rely on a hierarchical Bayesian multinomial logit model with a mixture of normals first-stage prior to estimate individual demand parameters θ_i. This approach not only allows approximate deviations from standard normal heterogeneity distributions as described in Rossi et al. (2005), but is also well suited for the purpose of estimating reliable individual level coefficients when the amount of data provided by each panel unit is rather small. Table 4 shows the varying amount of information provided by each household in the sample. The hierarchical Bayesian approach effectively pools information

Table 4: Distribution of the number of egg purchase incidents across $N = 6961$ individuals in the estimation sample

	Min.	1st Qu.	Median	Mean	3rd. Qu.	Max.
Purchases	4	21	43	55	77	338

across households through the prior and thereby shrinks extreme coefficient estimates (implied by a short history of observations on the individual level) towards the sample mean that is usually considered economically more reliable. We believe that this is a desirable property in our model as we have only a rather short history of purchases for the majority of households in the sample.

As an additional property, we want our model to provide estimates of $\{\theta_i\}$ in line with basic economic theory. At first, price coefficients should be constrained to be negative for every household, i.e. $\alpha_i \leq 0$.[19] Similarly, everything else being equal, households should not be worse off if they choose ten instead of six eggs. We restrict the package size six coefficients to be negative, i.e. $\beta_i \leq 0$. Finally, preferences for the four different egg labels should satisfy the ordering implied by the perceived quality differences associated with the four breeding categories. Therefore, $\gamma_{i,Battery} \leq \gamma_{i,Barn} \leq \gamma_{i,Free\text{-}range} \leq \gamma_{i,Organic}$ has to hold for all households. While

[18] We estimate individual store preferences relative to a baseline store in order identify the likelihood. For $l \neq 1$, $\hat{\psi}_{i,l} = \psi_{i,l} - \psi_{i,1}$ measures household i's preference for the lth retailer relative to the first as the baseline level.

[19] In an unconstrained model, the marginal posterior distribution of the price coefficient has non-negligible support for positive values in the right tail due to the small number of observations on the individual level. This is problematic for computing counter-factual prices because it would be optimal to charge infinitely high prices and only keep consumers with weakly positive price coefficients in the market.

the ordering of the egg coefficients is implied by vertical quality differentiation in this market and clear a priori, we do not restrict the sign of the battery coefficient, $\gamma_{i,Battery}$, as it measures the utility a household perceives from consuming a battery egg relative to the outside good which possibly varies in sign across households. Similarly, it is unclear in general whether a household prefers the lth-store ($l \neq 1$) a priori over the first one and we therefore do not constrain individual store preferences $\{\hat{\psi}_{i,l}\}$. These restrictions on households' utility coefficients are essential for the reliability of the counter-factual analysis we perform later on. Throughout the study we measure each household's individual WTP for a package of ten eggs from the respective category in comparison to a package of ten battery eggs

$$WTP_{i,g} = \frac{\gamma_{i,g} - \gamma_{i,Battery}}{-\alpha_i} \text{ for } g = Barn, Free\text{-}range, Organic. \tag{3}$$

Without order constraints imposed on $\{\gamma_{i,g}\}$ and sign restrictions on $\{\alpha_i\}$, we may obtain some households with a lower WTP for organic eggs than for battery eggs. For instance, Andersen (2011) separates the two factors that increase a household's WTP for different egg product labels: animal welfare and product safety. The author's result, however, is a negative mean WTP for barn, free-range and organic eggs compared to battery eggs.[20] This contradicts any economic reasoning regarding vertical product differentiation. According to our understanding, all households should be at least indifferent between organic and battery eggs if they are given the same price. The problem is that with real market data we rarely observe high quality products, e.g. organic eggs, offered at lower prices than low quality products, e.g. battery eggs. Usually price differentials only vary across choice occasions. Explicitly incorporating the quality differences between egg labels into the demand estimation is therefore an important ingredient in our model as it is usually difficult to identify the ordering without such constraints.

The Bayesian implementation of our demand model follows the approach in Pachali et al. (2017). They propose a Markov Chain Monte Carlo (MCMC) algorithm similar to Rossi et al. (2005) that effectively samples from the posterior distribution of a model imposing sign and/or order constraints on some coefficients. The basic idea is that unconstrained coefficients have a standard normal prior while sign and order constraints are imposed through a log-normal distribution. MCMC inference is performed on a transformed space exploiting the property that coefficients are jointly normally distributed after the transformation.

We specify our constraints on θ_i by defining the functional form $g : \mathbb{R}^k \to \mathbb{R}^k_c$ mapping conditionally normally distributed variates θ_i^* to sign and order constrained coefficients θ_i that enter the

[20] Andersen (2011), Table 2a p.574.

likelihood, where k denoting the number of coefficients in θ_i. The hierarchical prior is specified as follows in this application

$$\theta_i^* = \begin{pmatrix} \alpha_i^* \\ \gamma_{i,Battery}^* \\ \gamma_{i,Barn}^* \\ \gamma_{i,Free\text{-}range}^* \\ \gamma_{i,Organic}^* \\ \beta_i^* \\ \hat{\psi}_{i,2}^* \\ \vdots \\ \hat{\psi}_{i,10}^* \end{pmatrix} = g^{-1}(\theta_i) = \begin{pmatrix} ln\big(-\alpha_i\big) \\ \gamma_{i,Battery} \\ ln\big(\gamma_{i,Barn} - \gamma_{i,Battery}\big) \\ ln\big(\gamma_{i,Free\text{-}range} - \gamma_{i,Barn}\big) \\ ln\big(\gamma_{i,Organic} - \gamma_{i,Free\text{-}range}\big) \\ ln\big(-\beta_i\big) \\ \hat{\psi}_{i,2} \\ \vdots \\ \hat{\psi}_{i,10} \end{pmatrix} \sim N\left(\bar{\theta}^*, V_{\theta^*}\right)^{(\mathrm{ind}_i)}, \tag{4}$$

for the mixture of S multivariate normals as a first-stage prior model on the transformed coefficients and ind_i is the latent indicator variable denoting component membership of household i, with $\mathrm{ind}_i \in \{1, \ldots, S\}$. The specification in Equation 4 nests the set of constraints discussed above

$$\begin{aligned} \alpha_i &= -e^{\alpha_i^*} \\ \gamma_{i,Barn} &= \gamma_{i,Battery} + e^{\gamma_{i,Barn}^*} \\ \gamma_{i,Free\text{-}range} &= \gamma_{i,Barn} + e^{\gamma_{i,Free\text{-}range}^*} \\ \gamma_{i,Organic} &= \gamma_{i,Free\text{-}range} + e^{\gamma_{i,Organic}^*} \\ \beta_i &= -e^{\beta_i^*} \end{aligned} \tag{5}$$

Appendix A.1 provides more details about the MCMC approach and information about prior specifications.

As in most demand estimation applications there are endogeneity concerns about the price parameter since supply side reactions on (by the econometrician unobserved) demand shocks may bias the price parameter estimates. Typically, we expect that firms raise (or lower) prices if they observe positive (or negative) demand shocks. This leads to a bias of the price parameter towards zero, the so-called attenuation bias. One possible approach to compensate would be to apply instrumental variable techniques. Although we have access to cost shifters that are typically suggested as instruments, such as hen fodder prices or wholesale prices for some egg labels, retail prices do not directly respond to changes in these cost drivers. Thus, the instrument candidates are rather weak. Most of the price variation is across egg labels. We control for that dimension through egg-label intercepts. Another dimension of price variation is across stores, e.g. low price discounters vs. high price full-range supermarkets. The decision to visit a certain store is assumed to be exogenous from the egg category and driven mainly by other factors, such as proximity and high value items in the shopping basket. We control for that dimension by including individual store preference parameters that affect the likelihood of purchasing a certain egg label in a particular store. Finally, there is temporal price variation, especially since, on average, prices for barn and free-range eggs dropped after the ban on battery eggs. This pricing reaction, however, was not due to a demand shock but due to changes in supply. Therefore, it does not cause an attenuation bias. We also note that during peak demand seasons such as Eastern or Christmas, retailers made no price adjustment and hence do not seem to react to typical short-term demand shocks. Even though we cannot completely rule out possible endogeneity concerns, it would not affect our conclusions much or at least it should not do so in favor of our findings. First, if the price parameter was biased towards zero, the calculated losses and gains in consumer surplus must be rather underestimated in absolute terms. In that case, our findings of the redistributive effects on consumer welfare can be regarded as conservative estimates. Second, as there was a similar fraction of battery egg purchasers in every retail chain and uniform pricing across consumer demographics, we cannot think of any way that the bias might systematically affect typical purchasers of certain egg labels differently.

5 Estimation results

We estimate the model described in Section 4 and Appendix A.1 with a successively larger number of mixture components to compare models with more flexible prior heterogeneity specifications and compute their log marginal likelihoods using the Newton-Raftery method on the values trimmed by 1 % on the bottom and the top of likelihood draws, as suggested in Dubé et al. (2010) and Gamerman and Lopes (2006).[21] According to Table 5, the five normal component model dominates for model fit based on our estimates for the log marginal likelihood. Figure 1 shows marginal posterior densities of the egg preference coefficients implied by the five component model. The left panel of the figure illustrates the posterior densities of the price and the package size six coefficients. As restricted in the hierarchical prior, both densities only support values in the negative domain. The shape of the marginal posterior density of the price

[21] We run the sampler for $R = 300,000$ iterations and keep every 30th draw. We decided to burn the first 5000 kept draws after inspecting time series plots of individual level posterior distributions as well as draws from the posterior of upper level model parameters. Posterior inference is based on 5000 draws from the converged posterior distribution.

Table 5: Log marginal likelihood values for demand models

	Value
One normal component	-539017.9
Five normal component	-538645.6
Ten normal component	-538726.4
Fifteen normal component	-539159.2

coefficient is uni-modal and does not seem to deviate from the standard one component model. Moreover, the density represents several households in its left tail with a low parameter value being very sensitive to changes in the price of egg products. The marginal posterior density of the package size six coefficient, on the other hand, depicts a deviation from the standard one component model with a bi-modal shape and one peak near zero and another around minus three. Notably, the variance of the density seems to be larger compared to the price coefficient. The right panel of the figure plots the marginal posterior densities of the egg label intercepts. All coefficients agree with the order constraints specified in Section 4 and the densities indicate heterogeneous preferences for the different egg labels across German households. For all four egg label coefficients, the marginal posterior densities have some households in the left tails with negative preferences for the respective egg label (compared to the outside good) while supporting households with a decent taste in the right tails as well. Overall, the marginal posteriors of the egg label intercepts do not indicate deviations from the one component model.

Table 6 summarizes quantiles and first two moments of the marginal posterior distributions of all estimated coefficients implied by the five component model. The implementation of the constraints is reflected in all quantiles of the marginal posterior distributions and the numbers confirm the key observations derived from Figure 1. Notably, the marginal posterior distribution of the package size six coefficient exhibits, by far, the largest standard deviation.
Table 6 summarizes marginal posterior distributions of the store parameters as well. All distributions exhibit a large standard deviation indicating heterogeneous preferences for the ten major retailers in Germany. In Section 4, we argue that it is crucial for our demand framework to recover negative parameter estimates for stores a household did not consider. Figure 2 verifies that posterior mean estimates of store parameters are indeed negative for those stores from which a household was never observed to purchase eggs. The histogram only includes posterior mean estimates of households who purchased at least twice in Store 1 that has been the baseline level in the estimation. In our setting, negative parameter estimates of stores a household never purchased eggs from are only plausible once a household actually prefers the baseline, i.e. was observed to purchase in Store 1.

Figure 1: Marginal posterior densities of the egg preference coefficients $(\alpha, \gamma_{Battery}, \ldots, \gamma_{Organic}, \beta)$ for the five component model

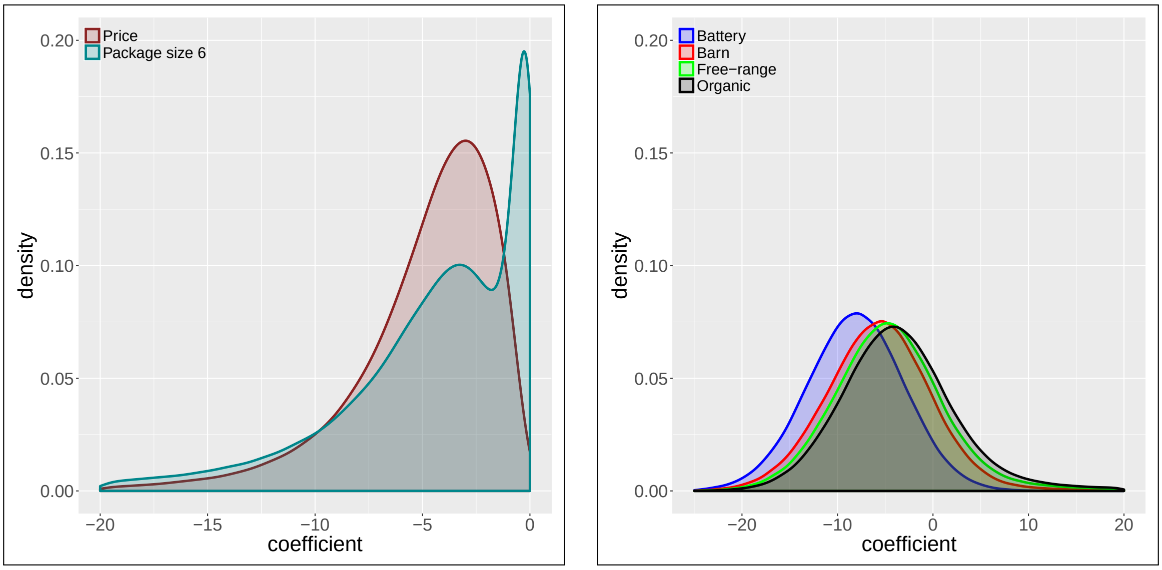
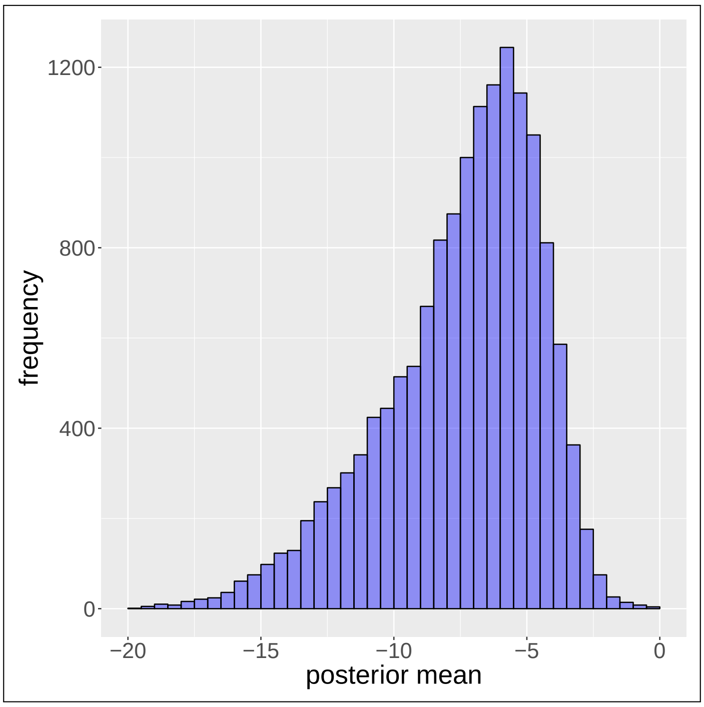


Table 6: Quantiles and first two moments of the the marginal posterior densities for the five component model

Coefficients	Quantiles						
	5%	25%	50%	75%	95%	Mean	Stand. Dev.
Price	-12.148	-6.475	-4.171	-2.530	-1.035	-5.121	4.425
Battery	-16.642	-11.523	-8.081	-4.683	0.241	-8.113	6.104
Barn	-14.741	-9.273	-5.620	-2.022	3.793	-5.182	12.083
Free-range	-13.705	-8.271	-4.596	-0.804	7.062	-3.302	17.961
Organic	-12.937	-7.511	-3.782	0.174	9.150	-2.293	18.256
Package size 6	-66.711	-8.231	-4.058	-1.092	-0.033	-58.653	3530.428
Store 2	-11.915	-4.835	0.098	5.025	12.180	0.115	8.152
Store 3	-5.442	-0.976	2.016	4.993	9.358	1.991	5.797
Store 4	-8.264	-3.278	0.199	3.754	8.968	0.266	6.221
Store 5	-13.502	-7.383	-3.100	1.302	7.967	-2.979	7.285
Store 6	-8.227	-3.733	-0.584	2.660	7.541	-0.497	5.950
Store 7	-7.590	-3.065	0.100	3.304	8.096	0.150	5.901
Store 8	-8.423	-3.565	-0.180	3.258	8.415	-0.122	6.151
Store 9	-8.167	-3.572	-0.311	3.054	8.183	-0.200	6.127
Store 10	-17.177	-10.655	-6.146	-1.627	4.910	-6.130	7.473

Figure 2: Store preference posterior mean estimates for the stores a household never purchased eggs from



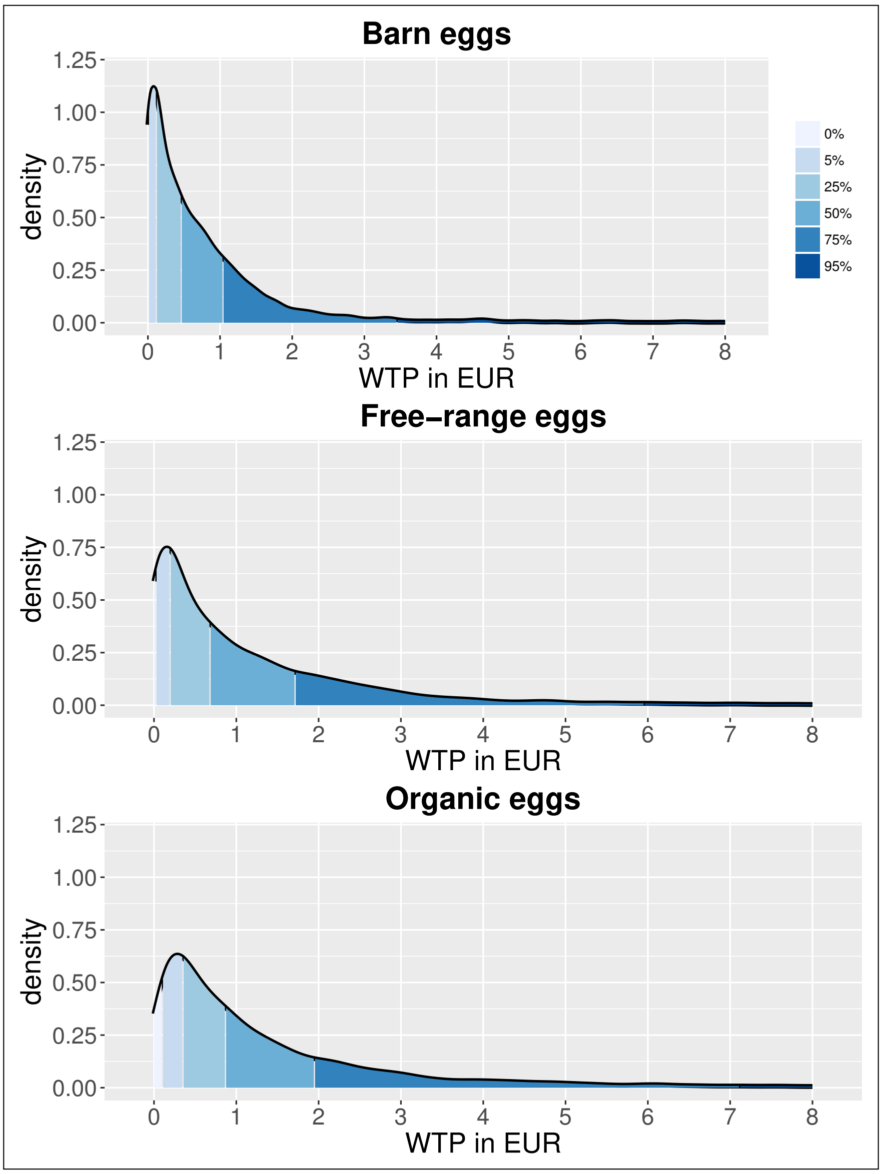
Note: The histogram shows posterior means of 2433 households who purchased at least twice in Store 1.

For the purpose of our analysis it is particularly relevant to analyze the distribution of WTP for different egg labels across households. We compute posterior expected WTP for ten barn, free-range and organic eggs compared to ten battery eggs according to Equation 3 for each household based on draws from individual level posterior distributions. Figure 3 displays the distribution of posterior expected WTP across all households. We observe that the fraction of households who are indifferent between battery eggs and the respective other egg labels, in other words the WTP equals zero, diminishes when we move up from barn to organic eggs. In addition, the mass center of the distribution moves farther away from zero. This is also reflected by the mean and median of each distribution as shown in Table 7. The mean (median) of the WTP distribution for barn eggs is 1.196 EUR (0.467 EUR). For free-range and organic eggs, 1.890 EUR (0.684 EUR) and 2.223 EUR (0.862 EUR) respectively.[22] Indifferent households get harmed by banning battery eggs, since they are forced to buy more expensive eggs. Although prices for barn eggs drop after the ban, new equilibrium prices do not match the previous ones of battery eggs. Thus, households with a WTP for barn eggs that is lower than the difference between former battery egg and new barn egg prices, $p_{barn}^{new} - p_{battery}^{old}$, also suffer due to the ban.

[22] Appendix A.2 contains a robustness check for the estimated WTP distributions shown in Figure 3 and Table 7 based on a model assuming limited information available to households at time of purchase.

In contrast, all households that have a higher WTP for barn eggs than $p_{barn}^{new} - p_{battery}^{old}$ benefit from the policy.

Figure 3: Distribution of households' posterior expected WTP for different egg categories compared to battery eggs



Note: We compare a pack of 10 eggs of the respective category to a pack of 10 battery eggs.

Table 7: Distribution of households' posterior expected WTP for different egg categories compared to battery eggs for the five component model

Coefficients	Quantiles						
	5%	25%	50%	75%	95%	Mean	Stand. Dev.
Barn	0.010	0.124	0.467	1.048	3.452	1.196	3.437
Free-range	0.030	0.191	0.684	1.707	5.963	1.890	5.202
Organic	0.097	0.350	0.862	1.948	7.118	2.223	5.737

In order to asses which types of households are more likely to be positively or negatively affected by the ban, we regress posterior expected WTP on households' demographics.[23] Table 8 depicts the resulting estimates. While demographic variables such as household size, children indicator or age are never significant, variables such as income, urban indicator, share of women in household and pet in household are significant, in at least one specification at the 10% level. Notably, income is across all specifications highly significant and an increase in the monthly net income per adult by 1000 EUR is associated with a higher WTP for barn eggs by 0.495 EUR on average. For free-range eggs the increase is around 0.964 EUR and for organic eggs about 1.122 EUR. Thus, the results in Table 8 suggest that households with lower income are more harmed by a ban on battery eggs if prices of barn eggs do not decrease to the previous price level of battery eggs. The effect on the consumer welfare of higher income households is also determined by the equilibrium price changes of the remaining egg labels after the ban. For instance, if prices of the remaining egg products fall after the policy intervention, banning the low quality alternative has a regressive policy impact transferring consumer surplus from less wealthy households to wealthier ones.

Table 8: Relationship between WTP and demographics

Explanatory Variables	WTP above battery eggs for		
	Barn eggs	Free-range eggs	Organic eggs
Household size	-0.046	-0.072	-0.068
	(0.05)	(0.08)	(0.09)
Income per adult in 1000 EUR	0.495***	0.964***	1.122***
	(0.06)	(0.09)	(0.10)
Urban dummy	0.222**	0.410***	0.489***
	(0.10)	(0.14)	(0.16)
Age of head of household	-0.000	-0.003	-0.006
	(0.00)	(0.00)	(0.01)
Share of women in household	0.268*	0.343	0.421*
	(0.15)	(0.23)	(0.25)
Children in household	0.116	0.117	0.143
	(0.14)	(0.22)	(0.24)
Pet in household	-0.171**	-0.266**	-0.323**
	(0.09)	(0.13)	(0.14)
Constant	0.418*	0.594	0.763*
	(0.25)	(0.38)	(0.42)
Sample size	6961	6961	6961
R squared	0.013	0.020	0.023

Note:* p<0.1, ** p<0.05, *** p<0.01
Standard errors in parentheses.

[23] We do not directly include demographic variables into our demand framework because of the change of variable we use to perform MCMC inference. On the transformed space, the convenient linear relation $\theta_i^* = \Delta_z' z_i + \bar{u}_i$ is likely miss-specified with $\bar{u}_i \sim N(0, V_{\theta^*})$ and z_i being the n_z vector of covariates for household i.

6 Redistributive effects on consumer welfare and policy implications

In the previous section, we illustrate that higher income households have, on average, a higher willingness to pay for eggs that provide greater animal welfare. This suggests that low-income households are more harmed by the ban on battery eggs as - everything else equal - we do not expect prices of the new minimum quality alternative, barn eggs, to fall below pre-ban battery egg prices. We theorize that the effect on consumer welfare of higher income households is determined by the equilibrium price changes of the higher animal welfare egg products after the ban. In order to quantify these effects, we introduce an explicit supply side model for the ten major retailers in Germany that enables us to isolate the redistributive mechanism on consumer welfare from increased egg minimum quality standards.[24]

This section is composed of two parts. The first part, 6.1, introduces the supply model and defines how we estimate changes in consumer welfare after a policy change. The second part, 6.2, quantifies equilibrium price reactions on the supply side and implied changes in consumer welfare followed by increasing minimum quality standards for different counter-factual settings. In addition, this section estimates the required cost reduction to protect specific types of consumers that are harmed by introducing higher minimum quality standards and discusses policy implications.

6.1 Supply model

The supply model closely follows the established notation in the empirical industrial organization literature, as in Nevo (2001), and the structural marketing literature, as in Sudhir (2001). We assume M companies and L multi-product retailers. Each retailer l belongs to a company m and offers a set of quality differentiated products. Each company maximizes its profits

$$\pi_m = \sum_{j \in S_m} [p_j - c_j]\, s_j(p) D, \tag{6}$$

[24]While we could use realized prices after the ban on battery eggs to evaluate its redistributive effects, this would not isolate the effect of the increased minimum standard on equilibrium prices since other factors such as changes in costs or market structure may drive the observed price changes. We therefore employ a structural model to perform counter-factual experiments to analyze the question.

for $m = 1, \ldots, M$ where $s_j(p)$ equals the market share of product j, D denotes the market size and S_m is the set of products offered by retailers belonging to company m.[25] Retailers compete in a pure-strategy Nash-Betrand game with differentiated products. This leads to the following first-order conditions

$$s_j(p) + \sum_{k=1}^{J} \Omega(k,j) \left[p_k - c_k\right] \frac{\partial s_k}{\partial p_j} = 0, \tag{7}$$

for $j = 1, ..., J$ where Ω is a $(J \times J)$-matrix defining the product ownership structure from the perspective of the company with $\Omega(k,j) = 1$ if both product k and product j are offered by retailers of the same company (and zero otherwise). Matrix notation allows for a more elegant representation of the first order conditions

$$s(p) + \left[\Omega * \Delta\right](p - c) = 0, \tag{8}$$

where Δ denotes a matrix of partial demand derivatives with respect to price with $\Delta(k,j) = \frac{\partial s_j}{\partial p_k}$. The $*$ represents an element-by-element matrix multiplication. The vectors of market shares, prices and and marginal costs are represented by $s(p)$, p and c respectively.

In our setting, market share $s_j(p)$ is a function of households' preferences, as specified in Equation 2. As our model incorporates heterogeneous preferences, expected market share is obtained by integrating over the distribution of households' preferences. We follow Pachali et al. (2017) and rely on a procedure defined as lower level model non smoothed (n.s.) to estimate the preference distribution representing the relevant population of German households. The implied estimate of posterior expected market share is given by

$$s_j(p) = \frac{1}{W} \sum_{i=1}^{N} w_i \int Pr\left\{j|p, \theta_h\right\} \delta(\theta_h|y_i, \phi)\delta(\phi|Y) d(\theta_h, \phi), \tag{9}$$

where $Y = (y'_1, \ldots, y'_i, \ldots, y'_N)$ and $\{w_i\}$ are household-specific projection factors denoting the number of households in the population represented by each observation i in the sample and

[25] Since there are no prominent brands for eggs in Germany and retailers maintain relationships with several fragmented egg suppliers, we assume that egg suppliers have no market power on the upstream market. Otherwise we would have to explicitly model the vertical relation between retailers and egg suppliers.

$W = \sum_{i=1}^{N} w_i$. The estimator in Equation 9 uses y_i both to inform the posterior of parameters in the hierarchical prior, $\delta(\phi|Y)$, as well as predicting to new households' preferences based on individual level posteriors $\delta(\theta_h|y_i, \phi)$. Intuitively, this approach integrates over individual level posterior distributions and is not only less dependent on the functional form assumed in the first-stage model but also allows us to rely on projection factors to form a representative distribution of preferences from the posterior output of the model.[26]

We make the following two simplifying assumptions to reduce the complexity in our supply side model. First, since computing market equilibrium prices with several stores and a high degree of preference heterogeneity is computationally burdensome, we restrict ourselves to use average prices and the market size recorded in 2008.[27] We implicitly assume that retailers set their prices only once a year. Second, in order to ease comparability, we assume only packages of ten eggs can be offered.[28]

As part of our policy evaluation, we seek to illustrate the redistributive effects of higher minimum quality standards on consumer welfare. We follow Small and Rosen (1981) and Train (2009) to calculate changes in expected consumer welfare for multinomial logit demand models. As specified in Equation 1, each household's indirect utility from choice alternative j can be separated into a deterministic part V_{ij} and non-deterministic part ε_{ij}. Small and Rosen (1981) derive the solution for the case that ε_{ij} is *iid* extreme value distributed and the price coefficient is constant with respect to income. We measure the change in consumer welfare as

$$\Delta E(CW_i) = \frac{1}{-\alpha_i} \left[ln \left(\sum_{j=1}^{J^{**}} e^{V_{ij}^{**}} \right) - ln \left(\sum_{j=1}^{J^{*}} e^{V_{ij}^{*}} \right) \right], \tag{10}$$

where $E(CW_i)$ is a function of preferences θ_i and the superscripts $*$ and $**$ refer to the status quo and to the counter-factual scenario respectively (in our case, before and after increasing the minimum quality standard for eggs). We approximate total changes in consumer welfare by taking the aggregate of Equation 10 evaluated at all draws from the preference distribution

[26] One has to be aware that the composition of the sample used for estimation is not in conflict with the population, e.g. that it does not contain too many observations that have almost no weight in the population. This would distort pooling of information by shrinking individual estimates to a sample mean that is not representative of the population. We tested for this problem by re-estimating the model based on a sample that is representative for the German population of households, i.e. we created a modified sample by drawing from the 6,961 observations with replacement in line with the projection factors. We concluded that the properties of the posterior distributions implied by the two samples are almost identical.

[27] Particularly, because with the exception of retailer 1, battery eggs were available everywhere in 2008.

[28] If a retailer only offers a package of six eggs or both package sizes, we compute the average price per egg for a certain category and calculate the effective price for a package of ten eggs.

implied by lower level model n.s. with weights in order to extrapolate the total market size D observed in 2008, i.e.

$$\sum \Delta E(CW_r) := \sum_{r=1}^{R} g \cdot \Delta E(CW_r), \tag{11}$$

for $r = 1, \ldots, R$ and $g = D/R$.[29]

We note that Equation 10 likely underestimates the change in consumer welfare because it integrates over the idiosyncratic logit taste term distribution. As implied by the model, a consumer receives (in expectation) utility even from irrelevant products. By definition, we can increase consumer welfare by simply duplicating the existing products. On the other side, removing products will substantially decrease consumer welfare although almost identical products sold at comparable prices are still available.[30]

6.2 Counter-factual simulations

The supply model enables us to isolate equilibrium price reactions caused by a policy change and to identify the redistributive effects on consumer welfare.[31] As shown in Equation 8, equilibrium price reactions depend on retailer-specific marginal costs and a realistic estimate of the latter is a crucial ingredient for the counter-factuals we perform later on. As market prices for every retailer and every egg category are observed in the data in 2008, we use average prices for different egg products in every retailer and extract retailer-specific marginal costs by solving Equation 8. The ownership matrix Ω is specified in a realistic manner with $M = 5$ and $L = 10$, i.e. the ten retail chains are owned by five major companies. Table 9 illustrates the resulting estimates of marginal costs (c), the average of prices in 2008 (p), margins ($p - c$) as well as estimates of market shares (s) for egg products offered at all retailers. We observe a substantial heterogeneity in marginal costs across retailers. Notably, for all retailers, margins increase as we move up from battery eggs to organic eggs. This pattern is reasonable since less price sensitive households value animal welfare more highly.

[29] In the applications that follow below, we use $R = 10,000$ draws from the consumer preference distribution that is implied by lower level model n.s..

[30] As a consequence, we report our results on the redistributive effect across consumer types also based on changes in the deterministic part of the indirect utility in Appendix A.3. We measure then changes in consumer welfare as $\Delta CW_i = \frac{1}{-\alpha_i}\left[max\left(V_{ij}^{**}\right) - max\left(V_{ij}^{*}\right)\right]$.

[31] For computing equilibrium prices we follow the advise in Morrow and Skerlos (2011) to use the mark-up version of the first-order conditions instead of the literal first-order conditions because the latter approach is not always ensured to deliver reliable results.

Table 9: Marginal costs, prices, margins and market shares

Retailer : Egg Product	c	p	$p-c$	s
Retailer 1: Free-range 10 units	0.88	1.51	0.64	5.26
Retailer 1: Barn 10 units	0.78	1.25	0.47	7.45
Retailer 2: Organic 10 units	0.99	2.45	1.46	2.43
Retailer 2: Free-range 10 units	0.73	1.51	0.78	5.10
Retailer 2: Barn 10 units	0.70	1.28	0.58	3.53
Retailer 2: Battery 10 units	0.53	0.95	0.41	2.80
Retailer 3: Organic 10 units	1.59	2.29	0.70	0.83
Retailer 3: Free-range 10 units	0.93	1.51	0.57	5.13
Retailer 3: Barn 10 units	0.75	1.25	0.50	8.25
Retailer 3: Battery 10 units	0.49	0.94	0.45	5.38
Retailer 4: Organic 10 units	1.61	2.49	0.89	0.48
Retailer 4: Free-range 10 units	0.96	1.63	0.66	1.75
Retailer 4: Barn 10 units	0.78	1.36	0.58	1.76
Retailer 4: Battery 10 units	0.36	0.89	0.54	8.96
Retailer 5: Organic 10 units	1.86	3.04	1.18	0.32
Retailer 5: Free-range 10 units	1.40	2.17	0.77	0.42
Retailer 5: Barn 10 units	1.11	1.71	0.60	0.26
Retailer 5: Battery 10 units	0.51	1.03	0.52	1.15
Retailer 6: Organic 10 units	1.94	2.54	0.60	0.23
Retailer 6: Free-range 10 units	1.15	1.52	0.37	0.67
Retailer 6: Barn 10 units	1.19	1.54	0.35	0.29
Retailer 6: Battery 10 units	0.65	0.91	0.25	3.29
Retailer 7: Organic 10 units	1.38	2.39	1.01	0.87
Retailer 7: Free-range 10 units	0.91	1.52	0.61	2.41
Retailer 7: Barn 10 units	0.84	1.25	0.41	2.39
Retailer 7: Battery 10 units	0.56	0.92	0.36	4.00
Retailer 8: Organic 10 units	1.94	3.04	1.10	0.36
Retailer 8: Free-range 10 units	1.36	2.05	0.69	0.85
Retailer 8: Barn 10 units	1.15	1.58	0.43	0.89
Retailer 8: Battery 10 units	0.75	1.09	0.34	1.99
Retailer 9: Organic 10 units	2.13	3.04	0.91	0.30
Retailer 9: Free-range 10 units	1.46	2.11	0.65	0.60
Retailer 9: Barn 10 units	1.07	1.53	0.46	0.49
Retailer 9: Battery 10 units	0.67	1.03	0.36	1.88
Retailer 10: Organic 10 units	1.92	2.87	0.95	0.05
Retailer 10: Free-range 10 units	1.30	2.06	0.76	0.15
Retailer 10: Barn 10 units	1.15	1.82	0.67	0.08
Retailer 10: Battery 10 units	0.67	1.07	0.40	0.25

Next, we use retailer-specific cost estimates in Table 9 to simulate equilibrium prices after a ban on battery eggs.[32] The first three columns in Table 10 show market share-weighted average marginal costs ($\bar{c}$) for each egg label implied by Table 9, the across retailer market share-weighted average of prices in 2008 ($\bar{p}$) as well as the simulated market share-weighted average of adjusted prices ($\bar{p}'$) after increasing minimum quality standards.[33] We observe that prices of the remaining egg products fall according to our model, on average, after a ban on battery eggs. Thus, the ban definitely benefits some type of consumers: households who already prefer barn, free-range and organic eggs over battery eggs under pre-ban prices face lower post-ban prices on average. As higher income households have, on average, a greater willingness to pay for welfare differentiated eggs, the results provide evidence of a regressive effect of the ban, which transfers welfare from low-income to high-income households. From the policy maker's perspective, this is an unintended side effect of the ban, a point we further elaborate on at the end of the section.

According to Figure 3 in Section 5, a fraction of households are always indifferent between battery eggs, the old minimum quality standard, and barn eggs, the new minimum quality standard. Thus, in order to offset the regressive effects of setting barn eggs as the new minimum quality standard, new equilibrium prices of barn eggs must match the previous battery egg prices.
We estimate the required marginal cost reduction for barn eggs in order to offset the regressive effect. This cost reduction can be motivated by economics of scale in the production function or other efficiency gains due to a narrower product assortment. Decision makers and consumer protection agencies, such as the FTC, can use our approach to infer the necessary marginal cost reduction and compare it to the expected reduction in costs stated by industry experts. If the expected reduction in costs is close to the necessary cost reduction, the policy of increasing the minimum quality standard is unproblematic in terms of consumer harm and regressivity. Otherwise a tailored subsidy can be proposed as another way to soften the regressive effect.
We use the term subsidy and marginal cost reduction interchangeably since a per-unit subsidy shifts the marginal cost curve downward. Let τ^* be the required subsidy to offset the regressive effect, then $T = \tau^* \hat{s}^*_{barn} D$ denotes the total expenditure for financing the subsidy if marginal costs were staying constant.[34] In this case, T can be interpreted as the implied cost to society of increasing the minimum quality standard without harming poorer consumers.

The fourth column in Table 10 corresponds to the average equilibrium price vector $\bar{p}^*$ in the situation where barn egg producers are subsidized. Accordingly, barn egg producers would be

[32]New equilibrium prices for the counter-factual scenarios are computed by solving the system of non-linear equations given by FOCs in Equation 8. We use the Gauss-Newton method. The maximum number of iterations is set to 20,000 and the tolerance level to 0.1^4. Convergence criteria are always achieved.

[33]We drop the adjective market share-weighted for a better readability in what follows.

[34]$\hat{s}^*_{barn}$ denotes the sum of market shares for barn eggs across retailers after imposing the subsidy τ^*.

subsidized by 0.33 EUR per package of ten eggs. Furthermore, we compute the change in industry profits $\sum \Delta\Pi_m$ and the change in consumer welfare $\sum \Delta CW_r$ as well as the total expenditure for financing the subsidy given by T. Notably, average prices of free-range and organic eggs rise as a consequence of the subsidy.

In the remaining columns of the table, we vary the degree of retail competition by altering the product ownership matrix Ω to highlight the relevance of market structure in determining the outcomes. Besides the realistic benchmark case, we consider two other cases: a duopoly case with $M = 2$, in which all discounters are owned by one company and all full-line supermarkets are owned by another, and a monopoly case with $M = 1$. In the last case, we assume the whole retail market to be monopolized. The results show that margins for all types of eggs increase, on average, with a lower degree of retail competition.

In all three scenarios of competition, we observe that prices of the remaining egg products fall, on average, after a ban on battery eggs, suggesting that the regressive effect of the ban is evident across different scenarios of market power. The monopoly case is an exception. Under a monopoly, average prices for organic eggs would increase after the ban on battery eggs.

Table 10: Optimal subsidy and welfare effects of product bans under different scenarios of competition

		Retail market structure								
		Ω^{real}			$\Omega^{Duopoly}$			$\Omega^{Monopoly}$		
Product	$\bar{c}$	$\bar{p}$	$\bar{p}'$	$\bar{p}^*$	$\bar{p}$	$\bar{p}'$	$\bar{p}^*$	$\bar{p}$	$\bar{p}'$	$\bar{p}^*$
Organic 10 units	1.39	2.53	2.29	2.65	2.82	2.77	3.03	3.30	3.50	4.56
Free-range 10 units	0.92	1.57	1.50	1.69	1.87	1.77	2.09	2.18	2.10	3.09
Barn 10 units	0.79	1.29	1.24	0.94	1.50	1.40	1.04	1.71	1.58	1.26
Battery 10 units	0.51	0.94			1.04			1.26		
τ^*				0.33			0.51			0.83
In million EUR:										
T				65.28			101.85			154.98
$\sum \Delta\Pi_m$			-12.90	4.86		-15.93	-1.86		-20.88	13.73
$\sum \Delta CW_r$			-13.20	21.57		-15.84	29.54		-9.61	6.98

The extent and direction of the price reactions depend on two factors: the degree of substitutability and market structure. A close substitute of the old minimum quality standard will usually exhibit a drop in equilibrium prices. The higher the degree of market power, the steeper the drop in prices for the close substitute products. This is due to the trade-off between margin and quantity that becomes stronger with higher levels of market power. As a consequence, the change in aggregate consumer welfare ΔCW after increasing the minimum quality standard is smallest in the monopoly case in absolute terms.

Table 11: Market shares after product bans under different scenarios of competition

	Retail market structure								
	Real ownership structure			Duopoly			Monopoly		
Product	$\hat{s}$	$\hat{s}'$	$\hat{s}^*$	$\hat{s}$	$\hat{s}'$	$\hat{s}^*$	$\hat{s}$	$\hat{s}'$	$\hat{s}^*$
Organic 10 units	5.87	7.47	5.35	5.28	5.60	4.53	4.14	3.52	2.29
Free-range 10 units	22.34	27.96	14.67	17.57	22.14	9.81	13.80	16.11	4.35
Barn 10 units	25.39	43.81	65.61	22.22	41.86	67.45	20.04	35.50	62.54
Battery 10 units	29.70			30.43			22.47		
Outside good	16.70	20.76	14.37	24.50	30.40	18.21	39.55	44.87	30.82

The price reaction of the highest quality alternative organic eggs is mainly driven by market structure. While observing a steep fall in average equilibrium prices of organic eggs for the real mode of competition, average prices even rise in the monopolistic case.

The degree of market power determines the optimal level of the subsidy τ^*. The more market power retailers have, the higher the subsidy τ^* must be to offset the regressive effect of a higher minimum quality standard. This observation can be explained by the relationship between pass-through rates and market power. Typically, changes in costs are not fully transmitted to final prices unless firms have zero margins. With higher market power, i.e. higher margins, a smaller fraction of changes in costs is passed on to final consumers. Firms with more market power will tend to keep a higher portion of this subsidy/cost reduction to themselves.[35]

If the marginal cost reduction is not achieved by efficiency gains but an explicit subsidy, there are, however, some drawbacks. First of all, the subsidy does not restore social welfare completely as the sum of producer and consumer surplus is only a fraction of total subsidy expenditure. The second drawback is with respect to substitution patterns towards egg products providing lower animal welfare incentivized by a subsidy. Table 11 illustrates an increase in market share of barn eggs as a consequence of the low price induced by the subsidy. In addition, the subsidy would need to be financed by taxes. Preferably, a progressive tax scheme is in place because we would otherwise undermine our attempt to offset the regressive effects of increasing minimum quality standards. We note that a subsidy has already a progressive policy implication as prices of the higher quality egg labels rise in equilibrium.[36]

In the next step, we successively increase the minimum quality standard until only organic eggs remain on the market. This scenario considers a possible future where only organic and sustainable products are allowed. Furthermore, we again determine the subsidy to offset the

[35] Further information on the relationship between pass-through and market power can be found in recent studies such as Weyl and Fabinger (2013), Fabra and Reguant (2014) and Kim and Cotterill (2008).

[36] As the subsidy reduces barn egg unit costs, they become more profitable and retailers would try to divert more demand towards barn eggs. This indicates that there is a negative cross-product cost pass-through rate.

Table 12: Higher minimum quality standards and negating the regressive effect

			New Minimum Quality Standard					
			Barn		Free-range		Organic	
Product	$\bar{c}$	$\bar{p}$	$\bar{p}'$	$\bar{p}^*$	$\bar{p}'$	$\bar{p}^*$	$\bar{p}'$	$\bar{p}^*$
Organic 10 units	1.39	2.53	2.29	2.65	2.10	2.75	1.93	0.94
Free-range 10 units	0.92	1.57	1.50	1.69	1.39	0.94		
Barn 10 units	0.79	1.29	1.24	0.94				
Battery 10 units	0.51	0.94						
τ^*				0.33		0.50		1.05
In million EUR:								
T				65.28		125.61		276.47
$\sum \Delta\Pi_m$			-12.90	4.86	-28.40	6.22	-67.70	18.47
$\sum \Delta CW_r$			-13.20	21.57	-36.22	53.53	-140.60	62.05

Table 13: Market shares and higher minimum quality standards

		New Minimum Quality Standard					
		Barn		Free-range		Organic	
Product	$\hat{s}$	$\hat{s}'$	$\hat{s}^*$	$\hat{s}'$	$\hat{s}^*$	$\hat{s}'$	$\hat{s}^*$
Organic 10 units	5.87	7.47	5.35	10.73	4.08	41.06	88.49
Free-range 10 units	22.34	27.96	14.67	62.20	84.58		
Barn 10 units	25.39	43.81	65.61				
Battery 10 units	29.70						
Outside good	16.70	20.76	14.37	27.08	11.33	58.94	11.51

regressive effects. Table 12 shows our findings. τ^* increases with a higher minimum quality standard as does the extent of the regressive effect. If only organic eggs remain on the market, the majority of consumers loses surplus and only a minority benefits from the policy. Table 13 shows the impact on market shares under higher minimum quality standards. Similarly as before, the subsidy incentives households to substitute higher animal welfare egg products for the new subsidized minimum quality alternative.

Finally, we further examine changes in consumer welfare across specific types of egg consumers. Table 14 and 15 contain the redistribution of consumer welfare across typical egg type consumers[37] for the counter-factual scenarios discussed before. We report also the average income per adult for each egg type group. Average income per adult increases as we move from typical battery egg purchasing households up to typical organic egg purchasing households. This is in line with our regression results of WTP for higher animal welfare egg labels on consumer demographics. Starting with the real mode of competition in Table 14, we observe that through the drop in prices for eggs that provide higher animal welfare ($p \rightarrow p'$), consumer welfare is redistributed from typical battery and barn egg purchasing households to typical free-range and organic egg purchasing households. The redistributive effect is therefore regressive.

As we increase the degree of market power in the retail sector, the welfare losses for typical battery egg purchasing households become smaller and typical barn egg consumers turn to gain welfare. In general, households typically preferring eggs that are close substitutes of battery eggs gain more as the market structure becomes less competitive. This result is explained by the steeper price reactions following the rise of the minimum quality standard if retailers have more pricing power. Furthermore, the regressive effect softens in less competitive scenarios due to the decreased drop in average equilibrium prices of organic eggs - that even turns to be negative in the monopolistic scenario.

The subsidy τ^* is able to offset the regressive effect and typical battery egg purchasing households exhibit an increase in consumer welfare. As a consequence of the steep drop in the price of the new minimum quality alternative, typical barn egg purchasing households benefit the most. Furthermore, the subsidy leads to higher prices for the remaining higher quality eggs and organic as well as free-range egg purchasing households may be worse off if the price reduction for barn eggs is not strong enough to compensate them. Thus, the effect of the policy would be rather progressive.

The welfare effects of a feature scenario of further increasing the minimum quality standards can be observed in Table 15. As the new minimum quality standard is increased to free-range

[37] For instance, a household is defined as an organic egg type consumer if the majority of his egg purchases in 2008 had the organic label.

eggs, a larger share of households are negatively affected but those who have a high valuation for quality benefit even further. When only organic eggs remain on the market, the majority of consumers, i.e. typical battery, barn and free-range purchasing households, lose surplus but a minority of households who prefer organic eggs benefit. In this case, the regressive effect becomes even stronger as only a rather wealthy minority benefits from this policy.

Table 14: Redistributive effects across consumer groups and retail market structure

		Retail market structure					
		Ω^{real}		$\Omega^{Duopoly}$		$\Omega^{Monopoly}$	
		$p \to p'$	$p \to p^*$	$p \to p'$	$p \to p^*$	$p \to p'$	$p \to p^*$
Consumer type	Avg. Income	$\sum \Delta CW_r$ in million EUR					
Organic eggs	1605.64	1.86	-1.02	0.14	-1.74	-1.49	-8.49
Free-range eggs	1346.32	2.24	1.89	1.44	2.17	0.84	-7.80
Barn eggs	1122.57	-0.06	17.56	0.16	21.93	1.78	18.03
Battery eggs	1120.00	-16.73	1.92	-16.95	5.94	-10.34	5.10
Outside good	1270.92	-0.51	1.21	-0.63	1.24	-0.41	0.14
Overall	1223.64	-13.20	21.57	-15.84	29.54	-9.61	6.98

Table 15: Redistributive effects across consumer groups and higher minimum quality standards

		New Minimum Quality Standard					
		Barn		Free-range		Organic	
		$p \to p'$	$p \to p^*$	$p \to p'$	$p \to p^*$	$p \to p'$	$p \to p^*$
Consumer type	Avg. Income	$\sum \Delta CW_r$ in million EUR					
Organic eggs	1605.64	1.86	-1.02	2.71	0.66	0.22	17.00
Free-range eggs	1346.32	2.24	1.89	0.82	25.19	-42.47	17.51
Barn eggs	1122.57	-0.06	17.56	-11.69	20.89	-48.66	12.95
Battery eggs	1120.00	-16.73	1.92	-26.51	3.75	-45.15	8.63
Outside good	1270.92	-0.51	1.21	-1.54	3.04	-4.54	5.96
Overall	1223.64	-13.20	21.57	-36.22	53.53	-140.60	62.05

7 Conclusion

In this paper we examine the redistributive effects of higher minimum quality standards on consumer welfare. As animal welfare is a form of product quality, we use German household purchase data on eggs to answer this question. We study the EU's ban on battery eggs, the previous minimum quality standard, and evaluate its redistributive effect on consumer welfare. In our main analysis, we estimate a hierarchical Bayesian multinomial logit model with normal mixtures to account for consumer heterogeneity.

The results show substantial heterogeneity in preferences for animal welfare-differentiated eggs. We observe that households with higher income are, on average, willing to pay more for those grades of eggs that provide higher animal welfare. Our structural model makes it possible to isolate the effect of higher minimum quality standards on consumer welfare: as prices for the majority of higher quality eggs fall after increasing the minimum quality standard, consumer welfare is distributed from low-income to high-income households. This provides evidence of the regressive nature of minimum quality standards.

Using counter-factual studies, we show how consumer protection agencies can estimate the necessary reduction in marginal costs of the new minimum quality standard in order to offset the regressive effect. This marginal cost reduction can be achieved, for instance, by economics of scale. If the expected reduction in costs is close to the necessary cost reduction, the policy of increasing the minimum quality standard is less problematic in terms of harming low-income households. Otherwise a tailored subsidy scheme can be proposed as another way to soften the regressive effect. As market power increases, the marginal cost reduction must be higher.

Finally, we examine hypothetical future scenarios by successively increasing the minimum quality standard until only organic eggs remain on the market. The regressive effect becomes larger as we increase the new minimum quality standard. Our model finds that the costs of the compensating subsidy increase with higher minimum quality standard levels.

Our results should sensitize policy makers to the possible regressive effects of increasing minimum quality standards. Ideally, policy makers should assess equilibrium price effects and expected reduction in marginal costs before implementing a new regulation as is done in merger cases. Future research should extend our analysis to markets with asymmetric information such as insurance markets or markets with externalities. Another interesting direction would be to study dynamic effects of minimum quality standards on product innovation and variety.

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A Appendix

A.1 MCMC sampler and prior settings

Parameters in the hierarchical prior from Equation 4 can be separated between k_c constrained and k_{uc} unconstrained coefficients for each household i (conditional on component membership $\text{ind}_i = s$)

$$\theta_i^* = \begin{pmatrix} \theta_i^{*c} \\ \theta_i^{*uc} \end{pmatrix} \sim N\left(\begin{pmatrix} \mu_{c_s}^* \\ \Gamma'_s \mu_{c_s}^* + z_s \end{pmatrix}, \begin{pmatrix} V_s^* & V_s^* \Gamma_s \\ \Gamma'_s (V_s^*)' & \Gamma'_s V_s^* \Gamma_s + \Sigma_s \end{pmatrix}\right), \tag{12}$$

where $\theta_i^{*c} = \left(\alpha_i^*, \gamma_{i,Barn}^*, \ldots, \gamma_{i,Organic}^*, \beta_i^*\right)'$ and $\theta_i^{*uc} = \left(\gamma_{i,Battery}^*, \hat{\psi}_{i,2}^*, \ldots, \hat{\psi}_{i,10}^*\right)'$ here. The set of parameters $\left\{(z_s, \Gamma_s, \Sigma_s), (\mu_{c_s}^*, V_s^*)\right\}$ is characterized through two multivariate regression equations conditional on N_s household parameters, $\{\Theta_s^{*uc}, \Theta_s^{*c}\}$, clustered into each of the S components

$$\begin{aligned} \Theta_s^{*uc} &= \Theta_{z_s}^{*c} \Gamma_{z_s} + U \\ \Theta_s^{*c} &= \iota(\mu_{c_s}^*)' + U_{V_s^*}, \end{aligned} \tag{13}$$

with $vec(U') := u \sim N(0, I_{N_s} \otimes \Sigma_s)$, $U_{V_s^*} := u_{V_s^*} \sim N(0, I_{N_s} \otimes V_s^*)$, (Γ_{z_s}, Σ_s) being a $(k_c{+}1 \times k_{uc})$ coefficient matrix with the intercept vector z_s included in the first row as well as the $(k_{uc} \times k_{uc})$ variance-covariance matrix of unconstrained coefficients respectively and $(\mu_{c_s}^*, V_s^*)$ are the k_c-size mean vector as well as $(k_c \times k_c)$ variance-covariance matrix of constrained coefficients respectively. ι denotes a $(N_s \times 1)$-vector of 1's.

The MCMC we apply here is a standard "Gibbs"-style sampler with an RW-Metropolis step to draw individual level parameters $\{\theta_i^*\}$ similar to the one described in Rossi et al. (2005). The modification is a two-stage update of the parameters entering the hierarchical prior. More specifically, the sampler draws from the following conditionals in each iteration (omitting subjective prior parameters for simplicity)

1. $\theta_i^* | (\mu_{c_{\text{ind}_i}}^*, V_{\text{ind}_i}^*), (\Gamma_{z_{\text{ind}_i}}, \Sigma_{\text{ind}_i}), y_i, \; i = 1, \ldots, N$
2. $\{\Gamma_{z_s}, \Sigma_s\} \,|\, \{\Theta_s^{*uc}, \Theta_s^{*c}\}, \{\text{ind}_i\}$
3. $\{\mu_{c_s}^*, V_s^*\} \,|\{\Theta_s^{*c}\}, \{\text{ind}_i\}$

This approach allows us to specify subjective priors of unconstrained and constrained coefficients separately from each other. This is necessary as the two represent distinct distributions on the retransformed θ-space. We use the natural conjugate prior to perform step 2 and the conditionally conjugate prior to perform step 3 of the MCMC sampler. More specifically,

$$
\begin{aligned}
p(\Gamma_{z_s}, \Sigma_s) &= p(\Gamma_{z_s}|\Sigma_s)p(\Sigma_s), \\
vec(\Gamma_{z_s})|\Sigma_s &\sim N(\bar{\gamma}_z, \Sigma \otimes A_{\Gamma_z}^{-1}) \\
\Sigma_s &\sim IW(\nu_\Sigma, \bar{\Sigma}) \text{ and} \\
p(\mu_{c_s}^*, V_s^*) &= p(\mu_{c_s}^*)p(V_s^*), \\
\mu_{c_s}^* &\sim N(\bar{\mu}_c^*, A_{\mu_c^*}^{-1}) \\
V_s^* &\sim IW(\nu_{V^*}, \bar{V}^*)
\end{aligned}
\tag{14}
$$

Explicit posteriors associated with these priors can be found in Pachali et al. (2017). The conditionally conjugate prior implies that mean and variance-covariance matrix are a priori independent which allows it to affect $\mu_{c_s}^*$ more explicitly through $A_{\mu_c^*}^{-1}$. We use standard weakly informative subjective priors for the parameters entering the hierarchical prior of unconstrained coefficients, $\bar{\gamma}_z$, A_{Γ_z}, ν_Σ, $\bar{\Sigma}$. Note that these priors mainly affect posterior inference of $\theta_i^{*uc} = \left(\gamma_{i,Battery}^*, \hat{\psi}_{i,2}^*, \ldots, \hat{\psi}_{i,10}^*\right)'$. We use "informative" specifications for the parameters entering the hierarchical prior of constrained coefficients, mainly affecting posterior inference of $\theta_i^{*c} = \left(\alpha_i^*, \gamma_{i,Barn}^*, \ldots, \gamma_{i,Organic}^*, \beta_i^*\right)'$. More specifically, $\bar{\mu}_c^* = \begin{pmatrix}0 & \ldots & 0\end{pmatrix}'$ and $A_{\mu_c^*} = \text{diag}\begin{pmatrix}1/4 & 1/2 & 1/2 & 1 & 1/4\end{pmatrix}$ for all mixture models. The specification of $A_{\mu_c^*}$ seems informative or restrictive at first glance. There are two reasons we believe this is a reasonable prior for our data. First of all, this prior is set on the log-transformed space and standard specifications would imply an unreliably high prior variance of θ_i^{*c}. Second, we have several households included in the sample who are extreme in the sense of only purchasing a specific type of egg label (like organic or battery), no matter how prices evolve. For instance, the individual level likelihood of households who buy only battery eggs would be maximized by setting $\alpha_i^* \to \infty$, and $\gamma_{i,Barn}^* = \cdots = \gamma_{i,Organic}^* \to -\infty$ which translates to an infinite price sensitivity and complete indifference between quality differences. These extremes are ideally shrunk towards more reliable estimates in a hierarchical model. The functional form of our log-normal prior, however, puts additional prior support to these kinds of extreme outliers if its variance is large enough. We do not find this plausible since it implies that such households would suffer from almost infinite losses after banning battery eggs. We therefore restrict $A_{\mu_c^*}$ to make such extreme posterior outcomes less likely through the prior.

The subjective priors entering the Inverted Wishart prior for V_s^* are similar as in Allenby, Brazell, Howell, and Rossi (2014), implying $\nu_{V^*} = 30(40, 50, 60)$ as well as $\bar{V}^* = c^*\nu_{V^*}I_{k_c}$ with

$c^* = 0.25(0.05, 0.025, 0.015)$ for mixture models with $S = 1(5, 10, 15)$ components respectively where I_{k_c} is the identity matrix of dimension $k_c \times k_c$.

A.2 Robustness check: posterior expected WTP distribution

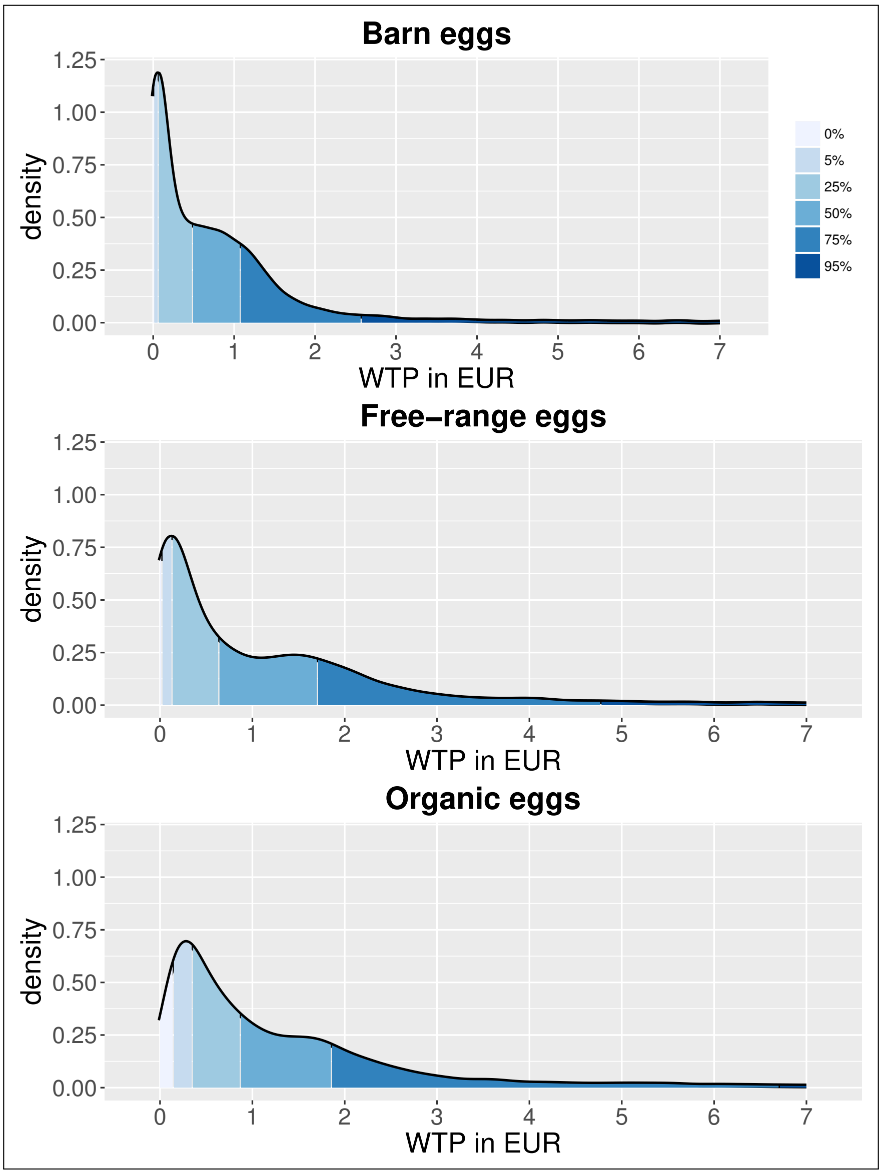
Our demand framework assumes that households have complete information about the egg products offered by the ten retailers. We argue that individual-specific store preference parameters included in the demand model attenuate the likely bias in egg preference estimates caused by the full information assumption and including product alternatives the household did not consider at time of purchase. In this part, we provide a robustness check of the egg preference estimates, $(\alpha_i, \gamma_{i,Battery}, \ldots, \gamma_{i,Organic}, \beta_i)'$, by comparing the WTP heterogeneity distributions implied by the full information model as specified in Section 4 as well as a more parsimonious model specification that assumes limited information available to households at time of purchase. The latter essentially limits the egg product alternatives in a given choice occasion to the eggs offered in the store of purchase. This approach effectively reduces the danger of including product alternatives from a different store a household did not consider at the time of purchase and is therefore probably a more robust approach to estimate household-specific egg coefficients. The main drawback of this approach, however, is that it does not make it possible to infer individual preferences for the ten stores, which is crucial for the counter-factual analysis and the policy analysis we perform in Section 6. Table A.1 summarizes the distribution of households' posterior expected WTP implied by the model with limited information and is directly comparable to Table 7, its counterpart assuming full information.[38] While the differences between the two distributions seem negligibly small for the 5%, 25%, 50% as well as 75% quantiles and do not provide evidence for a systematic difference in any specific direction, the WTP estimates implied by the 95% quantile are systematically higher according to the model assuming full information. As a consequence, first moments are higher as well. The model assuming full information therefore implies more households with a strong evaluation of eggs providing higher animal welfare.

Table A.1: Distribution of households' posterior expected WTP for different egg categories compared to battery eggs implied by the model with limited information

Coefficients	Quantiles						
	5%	25%	50%	75%	95%	Mean	Stand. Dev.
Barn	0.006	0.068	0.492	1.071	2.574	0.829	1.423
Free-range	0.016	0.124	0.638	1.711	4.780	1.362	2.386
Organic	0.143	0.343	0.864	1.859	6.711	1.777	3.279

[38] Prior specifications were the same for both models.

Figure A.1: Distribution of households' posterior expected WTP for different egg categories compared to battery eggs implied by the model with limited information



Note: We compare a pack of 10 eggs of the respective category to a pack of 10 battery eggs.

Figure A.1 shows a graphical illustration of the WTP distribution, similar to Figure 3. Compared to Figure 3, the estimated densities show small variations in the functional form. However, we have to take into account that the posterior distributions have different dimensions due to the increased number of parameters to estimate in the model assuming full information. This could explain differences in the functional form of the marginal posteriors as well.

A.3 Additional Tables

Table A.2: Redistributive effects across consumer groups and retail market structure: Changes in deterministic utility

		Retail market structure					
		Ω^{real}		$\Omega^{Duopoly}$		$\Omega^{Monopoly}$	
		$p \to p'$	$p \to p^*$	$p \to p'$	$p \to p^*$	$p \to p'$	$p \to p^*$
Consumer type	Avg. Income	$\sum \Delta CW_r$ in million EUR					
Organic eggs	1605.64	2.64	-0.87	0.58	-1.39	-1.02	-7.45
Free-range eggs	1346.32	3.40	3.48	3.14	4.33	2.59	-3.37
Barn eggs	1122.57	1.77	23.49	2.42	27.57	3.24	21.79
Battery eggs	1120.00	-16.31	5.07	-15.52	9.34	-7.88	7.04
Outside good	1270.92	0.11	1.64	-0.03	1.21	0.04	0.35
Overall	1223.64	-8.38	32.81	-9.42	41.07	-3.03	18.36

Table A.3: Redistributive effects across consumer groups and higher minimum quality standards: Changes in deterministic utility

		New Minimum Quality Standard					
		Barn		Free-range		Organic	
		$p \to p'$	$p \to p^*$	$p \to p'$	$p \to p^*$	$p \to p'$	$p \to p^*$
Consumer type	Avg. Income	$\sum \Delta CW_r$ in million EUR					
Organic eggs	1605.64	2.64	-0.87	4.83	1.90	5.96	22.82
Free-range eggs	1346.32	3.40	3.48	8.30	36.60	-24.16	34.29
Barn eggs	1122.57	1.77	23.49	-4.02	30.50	-35.69	23.41
Battery eggs	1120.00	-16.31	5.07	-22.60	8.38	-35.70	14.78
Outside good	1270.92	0.11	1.64	0.13	3.71	-0.32	7.53
Overall	1223.64	-8.38	32.81	-13.36	81.09	-89.92	102.82