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RESEARCH ARTICLE

Impact of European egg marking system in France: empirical time series analysis between 2017 and 2022

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Abstract

Voluntary labeling strategies, such as *Organic* label or *Label Rouge*, have long been considered as a potential solution to address environmental and social issues in the food sector. As a complement, the European political authorities developed a mandatory marking system for fresh eggs. This article questions the effectiveness of public intervention to support sustainable practices using analysis of the demand for fresh eggs in France. Unit root (augmented Dickey Fuller) tests, stationarity (KPSS) tests, and Seasonal Autoregressive Integrated Moving Average (SARIMA) models are used to investigate the unit root behavior of the prices and expenditure shares of fresh eggs in France between 2017 and 2022. We use the Almost Ideal Demand System model on scanner data to analyze the demand of six eggs' categories, including mandatory egg codes and two labels (*Organic* and *Label Rouge*). The results suggest that a low price does not compensate for low sustainability involvement in eggs from caged farming, favoring *free range* eggs. *Label Rouge* shows market weaknesses, while the organic label shows promising results with both a voluntary and a specific mandatory mark. The lack of elasticity observed, except between *cage* and *free range* eggs, implies that consumers who choose high-priced products with voluntary labeling strategies are less inclined to switch to alternatives. The mandatory marking system brings more transparency than voluntary labeling initiative, in favor of sustainable products. The case of eggs is a relevant example of how market intervention can push sustainable consumption and production without forbidding products in the market.

Keywords Demand analysis · Public intervention · Sustainable practices · Policymakers · Market dynamics

Introduction

Sustainable food production and consumption have become significant concerns due to their resource requirements (e.g., natural resources, human labor, investments) and resulting impacts (e.g., contributions to global warming, soil pollution,

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poverty alleviation). Sustainable development challenges the fundamental principles of capitalism by prioritizing social and environmental concerns that may not always align with economic profitability. The capitalist system, however, adapts and develops new systems to address these critics (Viguier, 2014). In response to the globalization of business and the industrialization of farming methods, the food sector commonly employs labeling to promote standardized market practices, providing assurance to consumers and society at large (DeQuero-Navarro et al., 2021). Nonetheless, the higher cost of sustainable and eco-labeled farming (Von Freymann, 2002) faces the challenge of consumers' price sensitivity (Aschemann-Witzel & Niebuhr Aagaard, 2014), posing an additional risk and jeopardizing the economic viability of sustainable practices. Previous research explored the capacity of sustainability to create value for consumers and businesses (McDonagh & Prothero, 2014; Prothero & McDonagh, 2015) investigating the relationship between marketing, markets, and society (DeQuero-Navarro et al., 2021). Therefore, the improvement of food systems is of collective interest and should be addressed with a macromarketing approach (Mittelstaedt et al., 2014).

The question of whether public authorities should take responsibility for the social and environmental performance of market activities has been raised as a subject in management literature (Wartick & Cochran, 1985). From a political perspective, a central question revolves around determining the types of interventions to be applied, including laws and conventions, taxes, regulations, mandatory systems, or the creation of new market opportunities (Lamarche, 2011). In addition to public policies, such as the common agricultural policy, the national and European public authorities have developed production standards (e.g., identification of pigs, egg marking system) and official quality signs (e.g., "Label Rouge," "Organic Label," "Protected geographical origins") to support sustainable practices in the agro-food sector.

The standardization of information levels help buyers in comparing products and encourage market competition based on sustainable criteria (Stein & de Lima, 2021). Labels are claimed to decrease the information asymmetry (Akdeniz et al., 2014; Spence, 1974) and to support economic development through positive changes in consumer behavior (Arquitt & Cornwell, 2007; Basu et al., 2003).

However, the voluntary nature of these systems is inherently tied to marketing and business strategy. Consequently, the system does not resolve information asymmetry but gives another marketing tool to companies to highlight positive credence quality. Conversely, a mandatory front-of-pack label mentioning all practices, including the less well perceived ones, gives clearer information to the consumers. This method can be a lever that does not prohibit the marketing of the product while let the consumers making their own choices (Stein & de Lima, 2021).

The information conveyed to consumers are through marketing actions that aim to influence positively customers' response (attitudes, willingness to buy, willingness to pay a price premium, etc.) (Katsikeas et al., 2016; Parrish et al., 2006; Rust et al., 2004) and consequently offer a better market position owing to a price premium and higher sales (Hooley et al., 2005; Uematsu & Mishra, 2012). Labels are an external marketing lever that is used to promote and sell a product to avoid market failure (Roosen et al., 2003) by creating value that benefits firms, consumers, and the society

(Kelleci, 2022). Because a labels' success relies on the anticipation of a positive consumers' response (Hughner et al., 2007), sustainable products have received a high interest in previous studies (Kelleci, 2022).

Marketing studies have mostly employed surveys to gauge consumers' attitudes and intentions. A survey conducted in Switzerland revealed an interesting finding: while eco-labels are not a predictor for green food purchase, consumers' attitudes towards environmental protection, fair trade, and domestic products, as well as action-related ecological knowledge, have a positive influence on consumers' choice (Tanner & Wölfing Kast, 2003). In another study, Kumar and Kapoor (2017) developed a questionnaire to assess the influence of labels on young Indian consumers' purchase decisions for food products. The study concluded that products' attributes, especially those related to health risks and nutritional quality, were important for educated consumers' purchase decisions and food labels contributed to final purchase intention.

Nevertheless, considering the persistent attitude-behavior gap (Carrington et al., 2010; Vermeir & Verbeke, 2006), the use of national and market data emerges as a more fitting approach compared to surveys and self-reported data for gauging sustainable food demand and market success (Grønholdt & Martensen, 2006). In a more recent study, Bougherara et al. (2022) estimated the substitutability of milk and coffee according to brand types and eco-labels and found that elasticity for eco-labeled goods varies according to the brand type. They also shed light on the positive effect of information campaigns on consumers' willingness to pay. They conclude that raising awareness and knowledge about the eco-labels increase predicted expenditure.

The success of food labels has led to a profusion of voluntary labeling initiatives (Organic, *Label Rouge*, V-Label) and mandatory labeling systems (nutritional value, allergen, origin of products). But the increased amount of information available in-store does not always result in a better knowledge or more transparency for consumers. This proliferation has resulted in confusion among consumers (Zander & Hamm, 2010) and can generate a loss of trust towards labels (Bismuth et al., 2018). Simultaneous signals can even be redundant and compete with each other, decreasing the product's value (Dufeu et al., 2014). For example, *Organic* labels and *Label Rouge* may create conflation and generate a competitive conditions among sustainable products called "green cannibalism" (Frank & Brock, 2019). Instead of expanding the market, the release of similar and alternative products (e.g., local, fair trade, organic) has fragmented existing market shares, impacting overall market performance. Karipidis et al. suggested that "additional policy measures must be implemented in order to improve the quantity and quality of information provided to consumers and product promotion through mandatory implementation of quality-assurance systems such as HACCP28" (2005, p. 72).

This article aims to analyze the market performance of the public European marking system in France. We employ an Almost Ideal Demand System to assess price elasticities. The discussion calls into question the effectiveness of public policies to improve the market by implementing a mandatory labeling scheme.

The egg market: Mandatory marking system and voluntary labeling initiatives

Since 2004, the European egg market has operated under a hybrid of voluntary and mandatory marking systems, regulated by (EEC) No 1274/91 and (EEC) No 2092/91. Each egg is stamped with a code indicating production criteria (country, producer) and method (Table 3 in Appendix 1), : (3) caged, (2) litter, (1) free range, and (0) organic. While *Label Rouge* and *Organic* label are two voluntary labeling initiatives, only the *Organic label* benefits from a specific and unique number in the European marking system. The *Label Rouge* is under the (1) *Free Range* category, and guarantees that the product has met stringent criteria related to its production methods, protecting traditional know-how and farmers practices such as animal breeding (Westgren, 1999). Despite a growing interest of consumers towards animal health (e.g., antibiotic) and welfare (e.g., housing) (Widmar & Ortega, 2014), *Label Rouge* has received little research interest and seems occasional (Lambotte et al., 2020).

Because consumers can't discern production methods through taste, eggs are considered as credence goods and can benefit from labels (Nelson, 1970; Roe & Sheldon, 2007). A survey on French consumers' concerns ranked the production method as the second most important criteria in choosing eggs, after the laying date and before the price (Guibert & Victoria, 2010). Several factors influence eggs' selection, including egg size, omega3 enrichment, package appearance, and the poultry feeding system, either organic or free range (Karipidis et al., 2005). Information available to consumers, including labels, influence consumers' decisions and contribute to a higher willingness to pay, and by extension higher expenditures (Boizot-Szantai et al., 2005).

The French segment seems quite insensitive to small price variation for organic eggs (Monier et al., 2009). A hedonic price analysis conducted in the French market of table eggs between 2012 and 2017 further suggested that products' attributes (cage free, free range, and organic) and the place of purchase (store type) significantly influence the price premium (Bosseaux et al., 2019). The authors also evaluated the price elasticities with average monthly market prices and the percentage of the monthly total sales volumes per eggs category. The results revealed asymmetrical and heterogeneous elasticities between categories in favor of organic eggs that benefit from a price increase of other categories, free range and *Label Rouge*.

Chang and all (Chang et al., 2010) confirmed the price premium observed for cage-free (including barn and free range eggs) and organic eggs, but noted their limited market. Organic products come with a higher price premium, indicating a greater willingness to pay compared to free range and barn eggs, perhaps due to a health attribute alongside improved animal welfare (Andersen, 2011).

The demand elasticity for eggs also has been assessed by Baltzer (2004) in Denmark with a detailed scanner data from a major retailer. The largely disaggregated data provided more substitution opportunities and price sensitivity than other studies using aggregated data. The three sets of elasticities that are displayed show negative own elasticities. The major difference between the sets is the consideration of eggs categories, which are either perceived as different products or as different varieties of the same product. The consumers were found to be conscious about food quality and safety and more responsive to social and animal welfare motives than to health motives. The author suggests that the high number of product categories in this narrow market confuses people and leads to a biased purchase choice.

The aim of the analysis presented in this paper is to comprehend how the mandatory marking system and the voluntary official quality signs create value in the French market. Two statistical analyses have been run, reflecting the market complexity, in order to give a realistic picture through a market demand analysis and a time series forecast.

Data and descriptive statistics

The data used in this paper is obtained from France Agrimer, a public administrative establishment responsible for agriculture and sea products, that provides economic monitoring and market insights for industries. France Agrimer publishes dashboards presenting the economic conditions of the egg market, compiled from data collected by the metropolitan French Kantar WorldPanel company based on purchases made by 12,000 households. The dataset includes information on average prices (euros) and purchases volumes (in units) of six varieties of eggs in the period from November 2017 and March 2022. Based on the European nomenclature, they monitored (1) caged, (2) deep litter, (3) regular free range, (4) *Label Rouge* free range, and (5) organic eggs. A last category named (6) no sign gathers the eggs that either do not have information due to a direct sales market or the inability to know the origin (e.g., alternative purchase places, personal hens' production).

From November 2017 to end of 2018, the data were collected over a 4 weeks' time span for a total of 13 reports per year. In January 2019, the report became monthly with 12 publications per year. The database gives 53 observations. The prices have been deflated with the French consumer price index[1]. The prices for each egg category are given in Fig. 1, and a further analysis of these prices is given in Table 1.

Table 1 and Fig. 1 shows average deflated prices (per 100 units) per product version. Prices all decreased, from 2.62% for the category "other," to 20.64% for deep litter. Despite this substantial decrease, deep litter registers an important premium of 33.24% on the cage category. Organic and *Label Rouge* prices have, respectively, decreased by 4.53% and 5.40%. The premia of organic eggs on *Label Rouge* and free range products are substantial (respective average of 3.89 € and 11.30 €) and increased over the period. Free range prices decreased by 10.10%.

Figure 2 illustrates the sales trends and market changes in the egg market in France since 2017. The *Cage* category sales dropped by 34.2% and have been

[1] Source: https://www.rateinflation.com/consumer-price-index/france-historical-cpi/ - Base year: 2015=100 - Updated: December 15, 2022

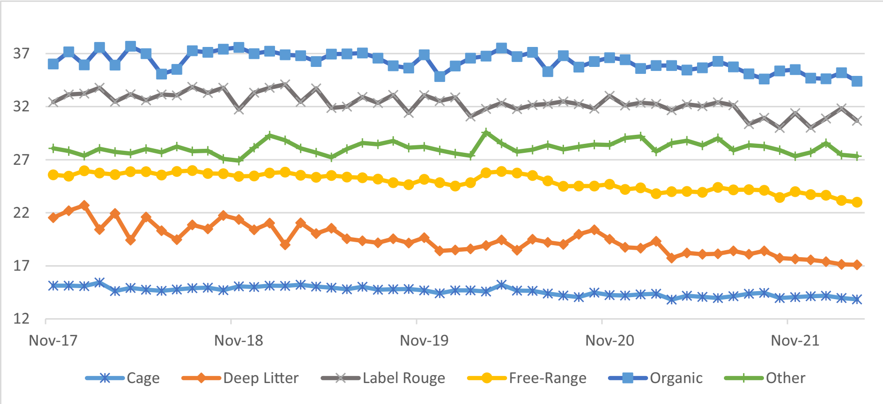

Fig. 1 Real price for fresh eggs (euros per 100 eggs)

Table 1 Average deflated prices (€) and premia per 100 fresh eggs between November 2017 and March 2022. ΔC, ΔFR and ΔLR stand, respectively, for premiums based on caged, free range, and Label Rouge. Growth rates are calculated over the whole time span

	Caged	Deep litter	Free range	Label Rouge	Organic	Other
Price (€)	**14.60**	**19.45**	**24.92**	**32.33**	**36.22**	**28.10**
Standard deviation	0.42	1.38	0.82	0.97	0.89	0.58
(Growth rate)	*(−8.51%)*	*(−20.64%)*	*(−10.10%)*	*(−5.40%)*	*(−4.53%)*	*(−2.62%)*
ΔC (€)		4.85	10.32	17.73	21.62	13.50
ΔC (%)		33.24%	70.69%	121.46%	148.12%	92.47%
(Growth rate)		(−49.23%)	(−12.42%)	*(−2.68%)*	*(−1.65%)*	*4.25%)*
ΔFR (€)				7.41	11.30	3.18
ΔFR (%)				29.74%	45.36%	12.76%
(Growth rate)				*(12.16%)*	*(9.12%)*	73.79%)
ΔLR (€)					3.89	-4.23
ΔLR (%)					12.04%	−13.09%
(Growth rate)					*(3.31%)*	(−23.27%)

surpassed by free range eggs that took the lead with an increase of 39.50%, reaching 161 millions of eggs sold in March 2022. *Deep Litter* eggs had an impressive gain of 290.62% over the period higher than organic eggs which showed a gain of 39.69%. *Label Rouge* represents the smallest number of eggs sold after a drop of 24.14%.

Figures 3 and 4 present the expenditure between November 2017 and March 2022. The abnormal peak in expenditure at the beginning of 2020, driven mainly by purchased units (Figs. 1 and 2), has been associated to lockdowns during the pandemics by the national committee for promoting eggs (CNPO[2]). The negative trends

[2] Comité National pour la Promotion de l'Œuf : https://oeuf-info.fr

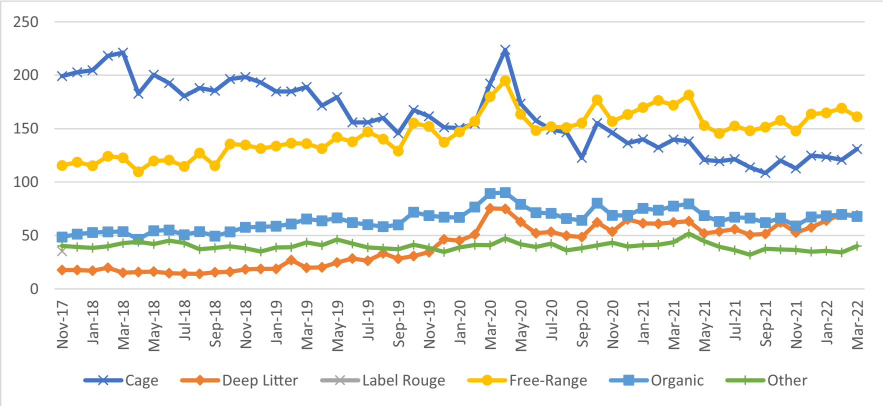

Fig. 2 Quantity of fresh eggs sold in France (in millions of units)

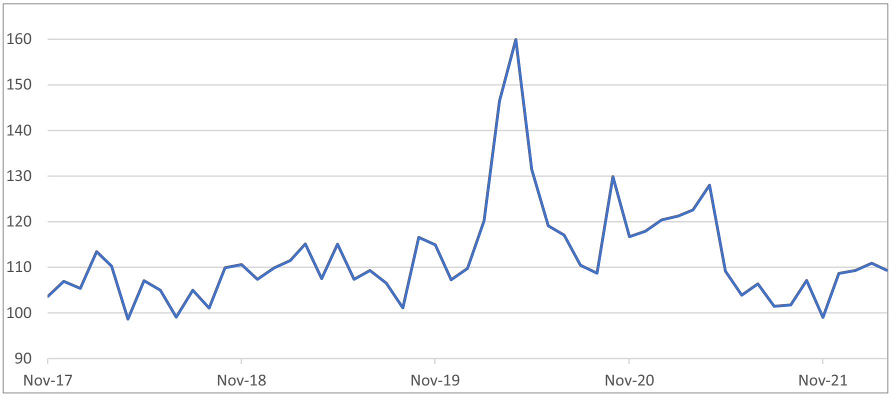

Fig. 3 Total real expenditure for fresh eggs (in millions of euros)

of the cage category described above contributed to the notable drop in expenditure. Since April 2018, the leader is the *Free Range* category, followed by the *Organic* eggs since September 2019. Deep litter and *Label Rouge* have similar results at the end of the period due to a respective growth of 210% and a loss of 28.23%. *Label Rouge* became the least important category in June 2020.

Empirical specification: Almost Ideal Demand System (AIDS)

The econometric strategy has been adopted according to the comparison of advantages and disadvantages of several demand systems. The objective of the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980) estimates a complete demand system consistently with the theory of demand. Despite its default in

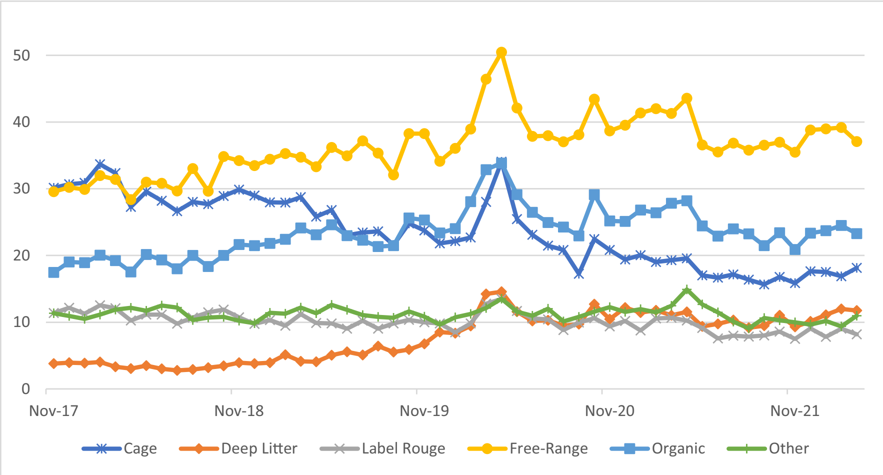

Fig. 4 Expenditure for fresh eggs (in millions of euros)

handling endogeneity, the advantages of the AIDS model are numerous: (1) it gives an arbitrary first order approximation to any demand system; (2) it satisfies the axioms of choice exactly; (3) it aggregates perfectly over consumers; (4) it has a functional form which is consistent with previous household budget data; (5) it is simple to estimate in its linear form, and (6) it can be used to test homogeneity and symmetry. The AIDS model is derived from an underlying structure of consumer preferences via a cost of expenditure function.

The full AIDS model is usually specified, in a time series context, as

$$W_{i,t} = \alpha_{i,t} + \sum_j \gamma_{ij} \ln P_{j,t} + \beta_i \ln\left(\frac{X_t}{P_t}\right) \tag{1}$$

where t denotes the time period, X is the total expenditure on the group of goods being analyzed, P is the price index for the group, P_j is the price of the j^{th} good, and W_i is the budget share of the i^{th} good (i.e., $W_i = \frac{P_i Q_i}{\chi}$, where Q_i is the quantity of purchased goods i, and the price index (P) is defined as

$$\ln P_t = \alpha_o + \sum_j \alpha_j \ln P_{j,t} + \frac{1}{2}\sum_j \sum_i \gamma_{ij} \ln P_{i,t} \ln P_{j,t} \tag{2}$$

Consumer theory implies four general restrictions that must be satisfied by any estimated demand system for theoretical consistency. Parameter restrictions have been imposed with an adding-up condition as in Eq. (3), the homogeneity condition as in Eq. (4), and the symmetry condition as in Eq. (5).

$$\sum_{i=1}^{K} \alpha_i = 1, \sum_{i=1}^{K} \gamma_{ij} = 0, \sum_{i=1}^{K} \beta_i = 0 \tag{3}$$

$$\sum_{i=1}^{K} \gamma_{ij} = 0 \tag{4}$$

$$\gamma_{ij} = \gamma_{ji} \tag{5}$$

The model above (in 1) can be augmented with other terms such as deterministic trends or other "demand shifters." It can also contain parameters that can evolve. In particular, we can allow the intercept term in (1) to evolve in a stochastic way that would be consistent with a random walk where the variance of this random walk is determined endogenously within the model. Specifically, we specify $\alpha_{i,t} = \alpha_{i,t-1} + v_{i,t}$ where the error term is assumed to be normally distributed and independent through time. In principle, other demand shifters of an exogenous nature could be added to this term. This might include "drift" terms which would imply a continuous tendency for the share to shift upwards or downwards, or structural breaks. However, these are not included in the current model. When adding demand shifters to budget share equations W_i, adding-up restrictions still apply.

Our aim was to determine the impact of the European nomenclature and labels on egg demand by distinguishing every category available in the market. The elasticities were estimated from results of the estimated AIDS models, at the mean of the variables. Marshallian (compensated) and Hicksian (uncompensated) were computed using the estimated parameters of the LA/AIDS model price elasticities. The formulas for these can be found in Chalfant (1987).

Univariate analysis

Habits in a structural demand model are a relevant determinant to understand food expenditure data. We produced three formal tests to verify whether the data contain trends of a stochastic or deterministic nature. First, the augmented Dickey Fuller (ADF) tests (Dickey & Fuller, 1979) is carried out to find the autocorrelation or existence of unit root in price and expenditure and therefore avoid spurious regressions and inconsistent parameter estimates (Silva & Dharmasena, 2016). The stationarity is tested using the KPSS tests (Kwiatkowski et al., 1992) to ensure an effective and precise prediction. All the ADF and KPSS tests contain seasonal dummies and have either a constant only or linear trend and constant included. Finally, the optimal choice of Seasonal Autoregressive Integrated Moving Average Models (SARIMA) using the Bayesian information criteria (Asteriou & Hall, 2011) was selected according to search over the space of models that contained up to first-order differencing (period and seasonal) and autoregressive and moving average components up to 2 for both seasonal and non-seasonal components, where models with intercepts or intercepts and trends were permitted (648 models in total).[3] The upshot of the unit root and stationarity analysis is that

[3] All unit root and stationarity tests and automated search of ARIMA were performed in Gretl https://gretl.sourceforge.net/.

while the variables of interest in most cases contain trends, we are not always clear in these cases whether they are of a deterministic or stochastic nature. However, the ARIMA selection in every case selects stochastic trends (d=1 and/or d^s =1 but with no time trend included) for each of the share variables and the real expenditure (see Table 4 in Appendix 2 for more details). This has implications for the AIDS model, since a simple regression model cannot account for models that contain dependent variables that have stochastic trends, if the explanatory variables do not account for these trends also. That's why we include a stochastic trend component as the intercept in our model.

Estimating the demand for egg categories

Expenditure share systems were estimated for eggs using the AIDS model described in the "Empirical specification: Almost Ideal Demand System (AIDS)" section. The model is simultaneously estimated for six categories of the product by using cross-sectional data from the Kantar panel. We opted for a Bayesian approach to estimation which generalized the model in the previous section by introducing a stochastic trend in the intercept, but also enforced the curvature restrictions, unlike the linear model (Moschini, 1995; Ryan & Wales, 1998). This approach can be used by simulating the unconstrained posterior distribution using Monte Carlo Markov Chains (MCMC)[4] but then only accepting that draws that obey these restrictions (van Ravenzwaaij et al., 2018). In this case, the algorithm was run until the number of draws obeying the curvature restrictions exceeded 10,000. The adding-up conditions are automatically fulfilled, and parameter restrictions ensure homogeneity and symmetry.

The parameter estimates and their standard deviations[5] to calculate price and expenditure elasticities, as well as the fit for the model ("R-square") are presented in (Table 6 in Appendix 3). The R-square measure is the ratio of the sum of squared errors relative to the model containing the random walk intercept. The actual fit is between 0.490 for *Other* category and 0.90 for *Label Rouge*, certainly due to the flexibility of the random walk intercept to capture trends (Fig. 5 in Appendix 4). The linear approximation to the full AIDS model was used here so as to simplify estimation. This involves replacing Equation 2 with an approximation which weights

[4] More specifically, this is implemented using Hamiltonian MCMC using the program STAN (see https://mc-stan.org/). A description of these procedures can be found in the documentation. In all cases, the model was run with a burn-in of 1000 iterations prior to the collection of the samples. Both the "Rhat" diagnostic tests and visual inspection of the trace plots indicated that this number of iterations was sufficient for convergence.

[5] Bayesian analysis does not produce standard errors or t-values. Instead, it has standard deviations, and the mean of the posterior divided by the standard deviation will generally signal that the mass of the posterior is quite far from zero if it exceeds classical critical values. We therefore shade those values that exceed this ± 1.64. We avoid the use of star notation to be clear that we are not producing hypothesis tests.

Table 2 Results of Bayesian elasticity analysis

Quantity	Cage	Deep Litter	Label rouge	Free Range	Organic	Other	Exp
	Prices						Exp
Hicksian (compensated, net) Price Elasticities							
Cage	-0.74	0.11	0.10	0.54	0.15	-0.17	1.11
Deep Litter	0.35	-1.68	0.46	0.30	0.101	0.46	1.57
Label rouge	0.24	0.35	-1.23	0.35	-0.05	-0.33	0.97
Free Range	0.36	0.63	0.10	-1.09	0.26	0.32	0.91
Organic	0.16	0.03	-.021	0.40	-0.70	0.13	1.04
Other	-0.36	0.31	0.30	1.02	0.28	-1.55	0.61
Marshallian (uncompensated, gross) Price Elasticities							
Cage	-0.98	0.04	0.00	0.18	-0.08	-0.28	
Deep Litter	0.17	-1.79	0.33	-0.20	-0.23	0.30	
Label rouge	0.03	0.28	-1.32	-0.04	-0.25	0.23	
Free Range	0.17	0.00	0.02	-1.38	0.06	0.23	
Organic	-0.06	-0.04	-0.11	0.07	-0.92	0.03	
Other	-0.48	0.27	0.24	0.825	0.15	-1.61	

each logged price by the expenditure share as follows: $\ln P_t = c_o + \sum_j w_{j,t} \ln P_{j,t}$. However, as can be seen from Fig. 6 in Appendix 4, the linear approximation is a good approximation of the full version indicating that the use of Stone's index does not greatly change the model parameters.

All the elasticities (compensated and uncompensated) are calculated at the sample mean of variables. The shaded region of Table 2 signals that the posterior mean of the distribution has a large majority of the posterior mass to the left or right of 0. For the expenditure elasticities, the table should be read right from left with the item in the row responding to a price change in the item in the column. A more detailed set of results including the parameter estimates are given in the appendix (Appendix 3, Tables 5 and 6).

The expenditure elasticities for the identified egg types are positive (they are normal goods) with some being above and below unity. That is, broadly speaking a 1% increase in real expenditure will result in a roughly corresponding increase in percentage expenditure. The two most divergent groups are *Deep Litter*, which appears to be the most expenditure elastic and the *Other* category being the least expenditure elastic. Thus, the evidence suggests that as expenditures on eggs as a group rises, the *Deep Litter* category will increase its market share, and the *Other* category will reduce its market share. Notably, a rise in the quantity of *Deep Litter* and a fall in of the *Other* category is also what we see in Fig. 2.

The uncompensated cross-price elasticities provide the "gross" cross effects, and the compensated cross-price elasticities represent the "net" effects of price change on demand. That is, the compensated elasticities "strip out" the expenditure effects of a price change. Therefore, given positive expenditure elasticities, the own-price uncompensated elasticities would be expected to be larger (more negative) than the compensated elasticities, which is precisely what is reflected in the two sets of elasticities. As shown in Table 2, all own-price elasticities have the expected signs. *Cage* and *Organic* appear to be moderately inelastic in terms of their own price elasticities, whereas the other four are moderately elastic.

Shaded cells are where the ratio of the mean of the posterior distribution to its standard deviation exceed ±1.64

A positive cross-price elasticity means that goods are substitutes (gross-uncompensated or net-compensated). The positive expenditure effects will also tend to make the gross cross-price elasticities smaller than the net elasticities. However, arguably the net-elasticities tell us more about whether consumers are ready to substitute one item for another. While *Free Range* is a net substitute with the *Cage* and *Other* categories, both labeled categories, *Label Rouge* and *Organic* do not show significant cross-elasticity. There is very weak evidence in favor of the substitution effects when the expenditure effect is included (the gross elasticity). Most of our findings lack statistical significance, although a notable exception is the symmetrically positive cross-elasticity observed between cage and free range categories. Our results contrast with the findings of Bosseaux et al. (2019), who reported elasticities favoring organic-labeled eggs. However, naturally caution should be exercised when interpreting elasticities that have high variability (in the sense of having high posterior mass either side of zero).

Discussion

Demand for sustainable products

The demand for sustainable products can be curbed by the price premia associated with their higher production costs (Von Freymann, 2002), as price is often mentioned as a purchase barrier for consumers (Aschemann-Witzel & Niebuhr Aagaard, 2014). In this study, we acknowledge the possibility of endogeneity. However, due to inconclusive results from testing conducted using available software packages, we opt not to adjust for this phenomenon in our model. Regardless of these limitations, the results provide insights into consumer demand for different variations of similar products based on sustainability criteria.

The elasticities indicate a price effect on the demand for unlabeled products like *Caged* and *Free Range*, but not for *Deep Litter*. A decline in sales units and prices for *Caged* eggs led to a large expenditure loss, suggesting a waning interest from consumers. *Caged* eggs, identified as the least sustainable option, adopted a low price strategy that does not seem to compensate the lack of social responsibility (Mohr & Webb, 2005). *Free Range* emerged as the market leader with a middle range price and large sales, assuming the role of the new market standard.

The results confirm the price inelasticity of *Organic* products (Boizot-Szantai et al., 2005; Monier et al., 2009) and also do not show any significant elasticity for *Label Rouge*. These findings suggest that consumers purchasing high-priced products with voluntary labeling strategy are less likely to switch to other qualities offered by similar products. The two labels are therefore not found to be either complementary or substitutes, despite their distinct sustainable dimensions and benefits, contrary to previous studies (Frank & Brock, 2019).

Despite a similar pricing strategy to *organic*, *Label Rouge* expenditure declined over time, suggesting that labels are not considered equal and may not systematically legitimate a higher price (Guo & Jiang, 2016). The success of *Organic* could be due to strong consumer segments and credence quality (Paul & Rana, 2012), indicating choices extend beyond price. The *Label Rouge* could suffer from a large proportion of occasional consumers that may be more price sensitive (Lambotte et al., 2020).

Rethinking information symmetry to change the market dynamics

Voluntary labeling systems such as Organic and Label Rouge aim to provide consumers with information. While they can be viewed as reducing informational asymmetry between the consumer and the company, this statement can be argued at the market level. Consumers face a range of similar products, yet not all products offer the same level of information, potentially leading to decision-making confusion. Stiglitz (2002, p. 469) defines information asymmetry as when "different people know different things," but we would add that it also occurs when "different companies mention different things."

Mandatory marking system could contribute to balancing information at the market level by providing details about all farming methods. The limited success of *Label Rouge* may be due to the overlapping information provided by the label and the marking code (Dufeu et al., 2014). Conversely, the *Organic* category, integrated into the marking system with a specific label and a unique egg code, demonstrates more promising results and a promising evolution.

The role of voluntary labels in the market needs reassessment, and the potential implementation of a more transparent and mandatory labeling system should be deliberated upon.

Co-marking with public policy: substitutability of signaling all quality

The European Union has implemented various long-term strategies in agro-food systems to protect society (e.g., employment, cultures, health) and lands (e.g., biodiversity, yield), while supporting the economy. Voluntary labeling systems like *Organic* label and *Label Rouge* encourage farmers, middlemen, and consumers to favor higher quality products. The singular egg marking system, implemented in 2002, facilitates product comparisons. This study suggests that a regulated and mandatory marking system favors higher quality products.

Supporting this perspective, the marking system has promoted products that have higher sustainability without banning other products. Public authorities' intervention has assisted in attaining responsible European agricultural objectives by increasing demand and product value for more sustainable products. This raises questions about the application of "Laissez faire" in free trade and the prevalence of the economic interests, emphasizing eco-social dimensions (Lamarche, 2011). Comparing demand before and after the European system's implementation could assess the effect of public authority intervention.

Conclusion

This study has examined the effect of the coexistence of mandatory marking systems and voluntary labels initiatives on the egg market demand. Two main contributions can be drawn from this research.

Firstly, it adds empirical evidence to the expanding research on the market performance of credence goods. The findings reveal encouraging market trends for higher quality products in a market that implements symmetrical information levels about farming practices. Notably, the shift in market leadership from *Caged* to *Free Range* category, regardless of a higher prices, underscores this trend. Additionally, it highlights disparities among labels, with *Label Rouge* showing limited promise despite a multi-marking strategy, whereas the *Organic* category ascended to become the second market leader. These results confirmed that a low-pricing strategy fails to compensate for low-quality and low responsibility.

Secondly, it prompts reflections about the consequences of public authorities' efforts to promote informational symmetry. In line with the objective of building a more sustainable agri-food system, the mandatory marking system emerges as a potential solution to enhance consumer knowledge and comparability of product versions without binding producers to modify their production method. While the outcomes appear successful, the potential threat of multi-marking looms over its success.

Our work suggests avenues for further exploration into the effective promotion of responsible production. Further research could delve into understanding the impact of marking system and symmetrical information for other products. Additionally, it should encompass the effect of other certifications (e.g., fair trade, country of origins) and various quality signals such as brand name, store name, and other potential signals (advertising, eco-packaging, etc.).

Appendix 1

Table 3 Egg Coding System: Detailed Production Criteria and Methods in the European Union

Code	Farming methods	Type of farm	Density (hens per square meter)	Hen food specificity	Control by the certification agency
0	Organic egg production	Free range	6, ground floor	Organic	Yes
1	Label Rouge eggs	Free range	9, ground floor	Cereals	Yes
1	Free range eggs	Free range	9, superimposed floor	None	No
2	Deep litter indoor housing	Indoor	9, superimposed floor	None	No
3	Caged farming	Indoor	13, superimposed floor	None	No

Appendix 2

Table 4 Unit root tests, stationarity tests, and optimal SARIMAs

	ADF(C+S)	ADF(C+T+S)	KPSS(C+S)	KPSS(C+T+S)	AutoSARIMA
Logged real prices					**(p,d,q)(p^s,d^s,q^s)**
Cage	0.74(1)	0.023(0)	0.046	>0.1	(2,0,0)(0,0,0)+C+T
Deep litter	0.65(2)	0.21(1)	0.039	>0.1	(2,0,2) (0,0,0)+C+T
Label Rouge	0.54(1)	0.09(1)	0.046	>0.1	(0,0,0) (0,0,0) +C+T
Free range	0.94(0)	0.029(0)	0.043	0.054	(1,0,0) (0,0,0)+C+T
Organic	0.48(1)	<.001(0)	0.057	0.062	(0,0,0) (1,0,1)+C+T
Other	0.001(1)	0.009(0)	>.10	0.08	(0,0,1)(0,0,0))+C+T
Expenditure shares					
Cage	0.72(1)	0.956(1)	0.044	0.072	(0,1,1)(0,1,1)+C
Deep Lltter	0.93(2)	0.85(2)	0.047	>.10	(0,1,1)(0,0,0) +C
Label Rouge	0.43(2)	0.30(1)	0.043	0.075	(0,1,1)(0,1,1) +C
Free range	0.50(2)	0.002(0)	0.04	>.10	(0,1,1)(0,1,1) +C
Organic	0.36(2)	0.97(2)	0.063	0.049	(1,1,2) (0,1,1) +C
Other	0.031(0)	0.09(0)	>.10	>.10	(1,0,0) (0,1,1) +C
Logged deflated expenditure	0.9024(1)	0.9951(2)	>.10	0.046	(1,1,1)(0,1,1) +C

All values not in parentheses are *p*-values. *C* constant, *T* trends, *S* seasonal dummies

Values in parentheses are lags selected using the AIC criteria

Appendix 3. Almost Ideal Demand System parameters

Table 5 A more detailed set of results including the parameter estimates (expenditure elasticities)

Expenditure elasticities (posterior means and standard deviations)						
	Standard	Deep litter	Label Rouge	Free range	Organic	Other
Mean	1.116	1.573	0.969	0.909	1.039	0.610
Std	0.093	0.265	0.205	0.066	0.090	0.366
Compensated elasticities (posterior means)						
	Cage	**Deep litter**	**Label Rouge**	**Free range**	**Organic**	**Other**
Cage	−0.742	0.111	0.102	0.543	0.154	−0.170
Deep litter	0.350	−1.685	0.470	0.303	0.101	0.462
Label Rouge	0.241	0.353	−1.230	0.354	−0.049	0.331
Free range	0.356	0.063	0.098	−1.091	0.257	0.318
Organic	0.157	0.033	−0.021	0.399	−0.703	0.135
Other	−0.357	0.310	0.296	1.022	0.279	−1.549
Compensated elasticities (posterior standard deviations)						
	Cage	**Deep litter**	**Label Rouge**	**Free range**	**Organic**	**Other**
Cage	0.313	0.141	0.185	0.320	0.208	0.209
Deep litter	0.444	0.440	0.379	0.519	0.397	0.541
Label Rouge	0.437	0.285	0.503	0.560	0.391	0.457
Free range	0.210	0.108	0.155	0.339	0.178	0.193
Organic	0.212	0.129	0.169	0.277	0.258	0.211
Other	0.441	0.363	0.408	0.620	0.435	0.716
Uncompensated elasticities (posterior means)						
	Cage	**Deep litter**	**Label Rouge**	**Free range**	**Organic**	**Other**
Cage	−0.978	0.036	0.002	0.183	−0.077	−0.282
Deep litter	0.017	−1.791	0.329	−0.206	−0.226	0.304
Label Rouge	0.036	0.288	−1.317	0.040	−0.250	0.234
Free range	0.164	0.002	0.017	−1.385	0.068	0.226
Organic	−0.063	−0.037	−0.114	0.063	−0.919	0.030
Other	−0.487	0.269	0.241	0.825	0.152	−1.610
Uncompensated elasticities (posterior standard deviations)						
	Cage	**Deep litter**	**Label Rouge**	**Free range**	**Organic**	**Other**
Cage	0.316	0.142	0.183	0.321	0.209	0.210
Deep litter	0.449	0.442	0.376	0.526	0.401	0.542
Label Rouge	0.442	0.287	0.498	0.564	0.395	0.459
Free range	0.211	0.109	0.154	0.339	0.179	0.193
Organic	0.213	0.130	0.167	0.278	0.260	0.211
Other	0.451	0.365	0.405	0.629	0.442	0.718

Table 6 A more detailed set of results including the parameter estimates (expenditure coefficients)

Expenditure coefficients (posterior means)						
	Standard	Deep litter	Label Rouge	Free range	Organic	Other
Mean	0.025	0.039	−0.003	−0.029	0.008	−0.039
std	0.020	0.018	0.018	0.021	0.019	0.037
Price coefficient (posterior means)						
	Cage	**Deep litter**	**Label Rouge**	**Free range**	**Organic**	**Other**
Cage	0.010	0.009	0.003	0.047	−0.011	−0.057
Deep litter	0.009	−0.051	0.026	−0.001	−0.007	0.024
Label Rouge	0.003	0.026	−0.029	0.003	−0.023	0.021
Free range	0.047	−0.001	0.003	−0.134	0.016	0.070
Organic	−0.011	−0.007	−0.023	0.016	0.019	0.007
Other	−0.057	0.024	0.021	0.070	0.007	−0.065
Price coefficient (posterior standard deviations)						
	Cage	**Deep litter**	**Label Rouge**	**Free range**	**Organic**	**Other**
Cage	0.066	0.030	0.039	0.068	0.044	0.044
Deep litter	0.030	0.030	0.026	0.035	0.027	0.036
Label Rouge	0.039	0.026	0.045	0.050	0.035	0.041
Free range	0.068	0.035	0.050	0.110	0.057	0.062
Organic	0.044	0.027	0.035	0.057	0.054	0.044
Other	0.044	0.036	0.041	0.062	0.044	0.072
R-square	0.670	0.340	0.900	0.680	0.890	0.490

Appendix 4. Almost Ideal Demand System plots

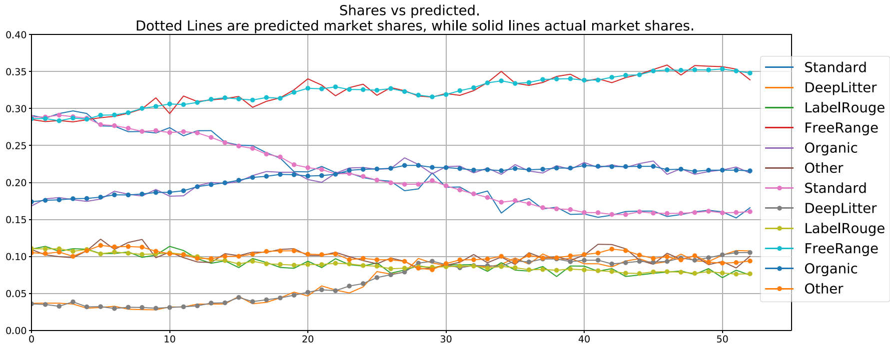

Fig. 5 Shares vs predicted. Dotted lines represent predicted market shares, while solid lines represent actual market shares.

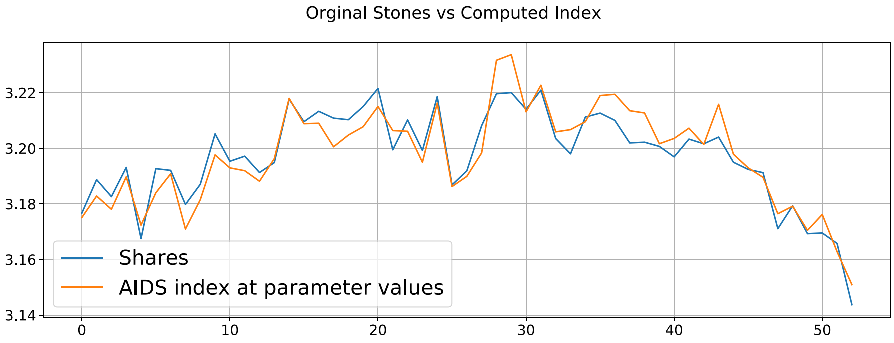

Fig. 6 Stones index vs full index at parameter values

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Code availability Code for data cleaning and analysis is fully displayed within the article. The standcode is attached to the application.

Author contribution Jessica Bosseaux collected and interpreted the data and was the major contributor in writing the manuscript. Kelvin Balcombe provided the statistical models. Philippe Aurier was supervising the whole process.

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Data availability Data are available on the French website of France Agrimer under the name "Conjoncture, les indicateur economiques suivi par FranceAgrimer" (https://www.franceagrimer.fr/Eclairer/Etudes-et-Analyses/Informations-de-conjoncture?moteur%5BfiltreFiliere%5D=1497&page=8). Other data has been transmitted with trust by France Agrimer.

Declarations

Ethics approval Not applicable. No human participants were involved.

Consent to participate Not applicable

Consent for publication Not applicable

Conflict of interest The authors declare no competing interests.

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