Received: 19 April 2023 | Accepted: 21 August 2023

DOI: 10.1002/jaa2.84

JOURNAL OF THE AGRICULTURAL AND APPLIED ECONOMICS ASSOCIATION
Open Access

ARTICLE

Meat and meat substitutes—A hedonic-pricing model for the German market

Thies Petersen[1,2] | **Milan Tatic**[3] | **Monika Hartmann**[3] | **Stefan Hirsch**[2]

[1]TUM School of Management, Professorship Agricultural and Food Economics, Technical University of Munich, Freising, Germany

[2]Department Management in Agribusiness, Institute of Farm Management, University of Hohenheim, Stuttgart, Germany

[3]Department of Agricultural and Food Market Research, Institute for Food and Resource Economics, University of Bonn, Bonn, Germany

Correspondence

Thies Petersen, TUM School of Management, Professorship Agricultural and Food Economics, Technical University of Munich, Alte Akademie 12, 85354 Freising, Germany.
Email: thies.petersen@uni-hohenheim.de

Funding information
None

Abstract

In this study, a hedonic pricing model with a stochastic frontier is applied to a sample of 183,717 observations of product sales of sausages in Germany to determine the valuation of attributes in the market. The average price of sausages is 1.14€/100 g, with meat substitutes valued at 1.53€/100 g and meat sausages at 1.01€/100 g. Our results show that credence attributes can induce a price premium, but that the effect strongly depends on the type of attribute. This may be important for deriving marketing strategies, as uniform measures may not be effective for both markets.

KEYWORDS

credence attribute, hedonic-pricing, meat, meat substitutes

JEL CLASSIFICATION

C20, Q10, Q01, Q11, C19, D12, D22, A00, Q18, I12, O15, C80, Q00

1 | INTRODUCTION

Meat is a traditional part of the German diet, with an annual per capita consumption of 55 kg (2021) (LfL & LEL, 2022). While meat is a source of high-quality protein, it also contains high levels of saturated fat and salt, and thus, nutrients whose intake should be limited (Petersen et al., 2021). In addition, excessive consumption of red and processed meat has been linked to adverse health conditions (Bouvard et al., 2015; Godfray et al., 2018). Moreover, a meat-rich diet has been criticized for its negative environmental impact (Willits-Smith et al., 2020) and concerns about animal welfare (Birkle et al., 2022).

Therefore, a new market emerged: the meat substitute (MS) market. Although MS can be characterized by a beneficial nutritional profile (Petersen et al., 2021) and a better environmental

footprint (Clark et al., 2022), they are considered artificial and unhealthy given their ultraprocessed nature (Wickramasinghe et al., 2021). Moreover, consumers have high expectations of MS, as they are expected to resemble meat in terms of taste and texture (Michel et al., 2021). Therefore, the consumption of these products, although increasing, is still limited. In Germany, MS accounted for only 0.9% of total meat market sales in 2020 (Zandt, 2022). Recent results from the United States also show that the market share of MS is low and unit prices are high compared to those of meat-based counterparts (Zhao et al., 2022). Since the price is one of the key factors influencing consumer purchasing decisions (Carlsson, Kataria, & Lampi, 2022; Lusk & Briggeman, 2009; Onwezen et al., 2021), higher prices have been identified as an important barrier to consumer acceptance of MS (Apostolidis & McLeay, 2019; Blanco-Gutiérrez et al., 2020; Clark & Bogdan, 2019; Elzerman et al., 2013; Kerslake et al., 2022). However, the factors that influence the prices of meat and MS are not sufficiently understood. Therefore, this study aims to investigate the product- and process-based attributes that influence the prices of meat and MS.

Previous studies on consumer choices for meat and MS products mostly analyze willingness-to-pay (WTP) using stated preference methods. de Araújo et al. (2022) highlight the relevance of credence attributes such as organic, regional origin, traditional production methods, or health benefits in consumers' meat choices. Studies that also include MS focus on product characteristics, e.g. main ingredients (e.g., Apostolidis & McLeay, 2016, 2019; Carlsson, Kataria, &Lampi, 2022) or WTP for credence attributes, such as the region of origin or carbon footprint (Apostolidis & McLeay, 2016, 2019). A recent study on the United States meat market combines a sensory experiment with a choice experiment, finding taste to be an essential predictor of preference (Caputo et al., 2023). Findings from stated-preference methods, however, depend on the setting and may have the limitation of suffering from hypothetical bias and potential overestimation of WTP for attributes (Murphy et al., 2005).

In addition to stated preference approaches, revealed preference techniques have been widely applied to study price premiums for product and process attributes in different food markets. Bimbo et al. (2016) apply a hedonic pricing model to the Italian yogurt market to evaluate the extent to which health claims contribute to product prices, finding that price premiums differ depending on the type of claim. While the hedonic pricing model has been applied to food products such as eggs (Karipidis et al., 2015), honey (Ballco et al., 2022) or alternative dairy beverages (Yang & Dharmasena, 2020), few studies exist for the meat market and, none, that considers the meat and MS market. Ribeiro et al. (2019) apply a hedonic pricing model to chicken purchase scanner data and find that UK consumers are willing to pay a 135% or £6.36/kg premium for organic. Staudigel and Trubnikov (2022) apply a hedonic pricing model to the German meat market. They find that consumers' valuation for product attributes differs by distribution channel, meat type, product type and that there are significant variations in price premiums for organic products, for example, depending on the meat type.

In situations where product quality is unclear, for example, if the producer has more information about the product's characteristics than the consumer, asymmetric information exists (Unnevehr et al., 2010). This can lead to market prices below the hedonic price from the producer's perspective and higher than the hedonic price from the consumer's perspective (Kumbhakar & Parmeter, 2010). The empirical approach to considering market asymmetry was introduced by Polachek and Yoon (1987) and applied to the labor market. Bonanno et al. (2019) recently applied the hedonic pricing approach with the stochastic frontier to the Italian yogurt market. In emerging markets like the MS market, information asymmetries between consumers and producers are of particular relevance, for example, in assessing the healthiness of the products (Siegrist & Hartmann, 2023). Hence, by applying a hedonic pricing model that considers information asymmetry, we add to the literature by providing novel evidence on the valuation of main ingredients, credence attributes, and nutritional facts for the meat and MS market under consideration of information asymmetry between consumers and producers.

The main objectives of this study are to (1) gain a better understanding of the price heterogeneity in the meat and MS market, (2) test the relevance of communicating information about credence attributes as a competitive strategy to secure a price premium, and (3) investigate similarities and differences between the meat and MS markets. Thus, we make two contributions to the literature: (i) we apply a hedonic-pricing model to the branded meat and MS market to investigate the factors that influence the market valuations of the products, (ii) we use a novel approach in hedonic price modeling, the stochastic frontier method that allows considering information asymmetry. Our findings are of relevance to market researchers and food manufacturers. For the former, as our results reveal differences in prices that are associated with product attributes, for the latter as they indicate how food manufacturers can achieve prices closer to the hedonic price by labeling credence attributes. Sausages were selected as the study object because they are consumed in large quantities in Germany (Deutscher Fleischer-Verband e.V, 2022). In addition, sausages are ideal for comparing the markets for meat and MS because of the similarity in appearance and use of the products.

The rest of the paper is structured as follows. First, we introduce the theoretical and empirical framework. Next, we provide information on the data used and the estimation process, followed by the presentation and discussion of the results. In the last section, conclusions are drawn.

2 | THEORETICAL AND EMPIRICAL FRAMEWORK

Products can be described as combinations of an attribute vector z. When making purchasing choices, consumers search for products with a combination of attributes that, according to their preferences, maximize their total utility (Lancaster, 1966). Two main ways exist to determine the resulting valuations reflected in the implicit prices for the product attributes (McCluskey & Winfree, 2022). First, stated-preference approaches like choice experiments or contingent valuation methods; and second, revealed preference approaches, like experimental auctions or hedonic pricing models (McCluskey & Winfree, 2022). Using revealed preference methods allows to go beyond the potential hypothetical bias of stated-preference methods. The hedonic pricing model also allows for comparing more product attributes as surveys are limited by the cognitive overload of participants (Chernev et al., 2015). Therefore, hedonic pricing models are highly suitable for investigating price premiums in highly differentiated and heterogeneous markets, like the sausage market (Costanigro & McCluskey, 2011).

The hedonic pricing model, as developed by Rosen (1974), can be specified as follows:

$$P_{\mathrm{h}} = h(z) + v. \tag{1}$$

The hedonic price P_{h} can be described as a function of the vector of product characteristics (z)—representing all relevant attributes of the buyer's value function and seller's offer function—and a random error v. Hence, the model in Equation (1) allows for determining the market valuations (implicit prices) for particular product characteristics z.

However, in the food market, there can be asymmetric information about the quality of products, especially regarding credence attributes (Unnevehr et al., 2010). Thus, the producer/seller has more information about the products than the consumer (Golan et al., 2001). An example of asymmetric information is the healthiness of MS, which consumers classify as unhealthy based on the heuristic that they are ultraprocessed foods (Siegrist & Hartmann, 2023) despite their more favorable nutritional composition relative to processed meat products (Petersen et al., 2021).

Asymmetric information can, according to Polachek and Yoon (1987) and Kumbhakar and Parmeter (2010) lead to a deviation from the price in Equation (1) resulting in a market price for the seller of:

$$P_m^s = P_b - u, \tag{2}$$

and, for the buyer of:

$$P_m^b = P_s + w, \tag{3}$$

where P_b is consumers' maximum WTP for a product and P_s is the sellers' lowest willingness to accept, u represents the costs to the seller of not being able to reach consumers with the highest WTP for a product with a particular set of attributes (Bonanno et al., 2019), while w is the cost to the buyer for being uninformed. It is assumed that both u and w are greater than or equal to 0. Therefore, the market price P_m can be rewritten as follows:

$$P_s + w = P_m = P_b - u, \tag{4}$$

leading to:

$$P_s + u = P_m + u - w = P_b - w. \tag{5}$$

Combining this with the hedonic pricing function (1) leads to:

$$P_m + u - w = h(z) + v \Rightarrow P_m = h(z) + v - u + w. \tag{6}$$

Therefore, the price of a good, P_m, can be described as a function of the vector of product characteristics and their influence on the price, a random error v, and the costs for being uninformed u and w for sellers and buyers, respectively. With perfect information $w = 0$ and $u = 0$ or with $w - u = 0$, the price should equal the hedonic price (Kumbhakar & Parmeter, 2010). The components v, u, and w can be combined into a single error term ε:

$$P_m = h(z) + v - u + w = h(z) + \varepsilon. \tag{7}$$

Originally, Kumbhakar and Parmeter (2010) apply their approach to the housing market to investigate which characteristics affect house prices (e.g., size) and which buyer/seller characteristics influence the deviation from the optimal price. Bonanno et al. (2019) apply the model to the Italian yogurt market to test whether producers can reduce information asymmetry based on credence attribute labels and achieve higher prices. They assume that $w = 0$, meaning that only the loss a seller may incur for not being able to target those consumers with the highest WTP is considered. In our study, we follow their approach.

3 | DATA AND ECONOMETRICAL IMPLEMENTATION

3.1 | Data sources

To estimate the price premiums associated with product characteristics in the German sausage market, we use a hedonic pricing model that accounts for the effects of information asymmetry. We compiled a comprehensive data set on product prices and respective attributes. Sales data are from the IRI database (IRI, 2023) that includes information on products sold, anonymous store id, prices/100 g, and discounts. The data are available on a weekly basis, but were aggregated to a monthly level, using the European Article Number (EAN), the barcode that uniquely identifies each product. The EAN-level price data were combined with the respective product-related attributes obtained from Mintel's Global New Product Database (Mintel, 2023), producers' websites, and other sources

such as "openfoodfacts.com." The product data were coded by two coauthors and six student assistants and then cross-checked. The coding included a set of 89 different product attributes ranging from the main ingredients and nutritional facts to packaging and credence attribute labeling. To code the products, it was necessary to have images of all sides of the packaging. If those images could not be obtained, the products were not considered in the analysis. Retail brands are not included in the sample for confidentiality reasons.

The final data set covers 24 months, from the first month of 2020 to the last month of 2021, and includes 183,717 product-price observations, which account for a sales value of 103.3 million Euro. Note that the sales volume of retail brands that were not included is 115 million Euro (49.8%), while the sales volume of products excluded due to missing information is 13 million Euro (5.5%). Hence, the final sales volume of the products included represents 44.7% of the total sales volume in the initial data set and 89% of the branded products available.

3.2 | Empirical implementation and variables

Our empirical model is based on the hedonic pricing model revealed in Equation (7) and allows us to estimate the influence of product characteristics on the price while considering the effect of information asymmetry. The model includes the following five vectors: Z^{MI}, Z^{NF}, Z^{CA}, Z^{PA}, and Z^{MC}. Following previous literature on price differences in the meat market (Staudigel & Trubnikov, 2022), we include a vector Z^{MI} that contains $s = 1,\ldots,S$ main ingredients. For meat, we distinguish between pork-based, beef-based, pork-beef-based, poultry-based, and other meat-based products, for example, pork and turkey combinations. For MS, we differentiate between egg-based, soy-based, wheat-based, pea-based and other/multi-ingredient-based products, for example, soy and egg combinations or mushrooms only.

Z^{NF} is a vector of $f = 1,\ldots,F$ nutritional values containing information about the protein content in g/100 g and thus enables to estimate the market valuation of protein. Moreover, Z^{NF} takes into account the negative points from the Ofcom-score,[1] the so-called A-score, which includes saturated fat, salt, sugar, and energy content. The higher the A-score, the more nutrients to limit in the product (Poon et al., 2018). Products that receive a lower A-score are considered healthier.

Z^{CA} is a vector of $a = 1,\ldots,A$ dummy variables covering the presence of credence attribute labels related to product and process attributes. André et al. (2019) argue that some labels target product healthiness through the presence or absence of specific attributes associated with either a scientific or a natural aspect. We follow their categorization of labels and include the following four dummy variables: (i) *Natural & Presence* for products labeled, for example, as fresh, (ii) *Natural & Absence* for products labeled as, for example, without flavor enhancers. (iii) *Science & Presence* for products labeled, for example, as being high in protein, and (iv) *Science & Absence* for products labeled as, for example, being low in fat. Organic is included in the *Natural & Presence* category in the study of André et al. (2019). However, we consider organic as a separate variable because of its high relevance in the market. Z^{CA} also includes information on whether a product is gluten- or lactose-free. Since the criticism of meat also includes its sustainability, we include as a dummy variable whether a product carries a label on the general topic of sustainability, recycling or renewable energy. In addition, we capture animal welfare with a dummy variable equal to one if the product has a corresponding label. This includes products that carry a label from an animal welfare initiative or have a reference to the husbandry conditions. For meat sausages, we include four additional dummy variables in Z^{CA}, which were found to be relevant only for the meat market: Two regional dummy variables, one of which captures whether there is a specific reference to the origin of the product, such as a claim that the sausage is a special product from the city of Frankfurt. The other

[1]The Ofcom-score is a well-known nutritional profile. As such it categorizes foods according to their nutritional composition (Scarborough et al., 2007, p. 330)

regional variable captures certified products with the EU label protected geographical indication (PGI), for example a "Thüringer" sausage. Furthermore, we include two dummies for labeling related to the product's quality (e.g., the label for superior product quality from the German agricultural society [DLG]) and for referring to tradition (e.g., since 1908).

Z^{PA} is a vector of dummies controlling for $k = 1,\ldots,K$ other product attributes. It contains the type of sausage, that is, whether it is primarily for roasting or primarily for cooking and/or direct consumption. It also includes a dummy capturing whether the product belongs to a national brand. We define a national brand if its products are sold in at least 80 of the 95 German two-digit postal code areas. In addition, the vector contains dummy variables for the packaging material: plastic, can, glass, and the combination of plastic and paper. Furthermore, we include the weight of the product in 100 g to capture the effect of packaging size.

Finally, Z^{MC} is a vector with information about $r = 1,\ldots,R$ retail and sales characteristics. It contains three dummies for the type of store where the price was observed, that is, discounter, supermarket and hypermarket. It also includes whether a product was sold under a discount in the given period. The corresponding dummy is equal to one if within the respective month, the price is at least once 20% lower than in the previous week. Finally, we include market and time-fixed effects B_m and G_t, respectively. Supporting Information: Table SA.1 shows the full list of variable definitions.

The final model is defined as follows:

$$P_{imt} = \beta_0 + \sum^{S} Z^{MI}_{smt}\beta_s + \sum^{F} Z^{NF}_{fmt}\beta_f + \sum^{A} Z^{CA}_{amt}\beta_a + \sum^{K} Z^{PA}_{kmt}\beta_k + \sum^{R} Z^{MC}_{rmt}\beta_r + \sum^{T} G_t\beta_t + \sum^{M} B_m\beta_m + \varepsilon_{imt}. \tag{8}$$

whereby P_{imt} reflects the observed market price of product i in market m at time t.

$$\varepsilon_{imt} = v_{imt} - u_{imt} + w_{imt}. \tag{9}$$

3.3 | Estimation

For the estimation of the hedonic pricing model defined by Equation (8), we assume that $w = 0$, similar to Bonanno et al. (2019). Hence, we focus only on the cost that a seller may incur for not being able to target those consumers with the highest WTP and attempt to explain these costs by seller characteristics. The stochastic frontier model is estimated using maximum likelihood estimation with the following distributional assumptions for the error term (Kumbhakar & Parmeter, 2010):

$$v_i \sim i.i.d.\ N\left(0, \sigma_v^2\right), \tag{10}$$

$$u_i \sim i.i.d.\ N^{+}\left(0, \sigma_u^2\right). \tag{11}$$

To account for the heterogeneity in the costs of incomplete information, u_i can be described by a vector of exogenous variables. Consequently, σ_u is a function of the seller's characteristics Z^U (Kumbhakar & Parmeter, 2010).

$$\sigma_u = e^{\psi_u' Z^U}. \tag{12}$$

We assume that credence attribute labels can reduce the information deficit and the corresponding loss that a seller may incur for not being able to target those consumers with the

highest WTP. We, therefore, attempt to explain the variance in u_i by the number of different credence attributes on a given product:

$$\sigma_u^2 = \exp(\psi_0 + \psi_{\text{NCA}} \times \text{Number of Credence Labels}). \tag{13}$$

The corresponding likelihood function is (Bonanno et al., 2019):

$$L = \prod_i \prod_m \prod_t \frac{2}{\sigma} \phi\left(\frac{\varepsilon_{jmt}}{\sigma}\right) \Phi\left(\delta \frac{\varepsilon_{jmt}}{\sigma}\right), \tag{14}$$

where, $\sigma = \sigma_u^2 + \sigma_v^2$; $\delta = \frac{\sigma_u}{\sigma_v}$ and ϕ and Φ are the standard normal pdf and CDF, respectively. We estimate Equation (14) separately for meat and MS sausages.

4 | RESULTS

4.1 | Descriptive statistics

Figure 1 presents the kernel density estimates of the prices of meat sausages, MS sausages, and the combined sausage market. The average price of sausages in the German meat market is 1.14€/100 g. From the distributions, it can be observed that prices of MS sausages are, on average, significantly higher (1.53€/100 g, $p < 0.001$) than those of meat sausages (1.01€/100 g). However, there is overlap, showing that the low-priced MS sausages are in the range of high-priced meat sausages.

Descriptive statistics are shown in Table 1. Regarding ingredients, the substitute sausages are mainly soy-based (38%) or based on other/multiple ingredients (32%). Pork is a dominant ingredient in the German meat sausage market (67.3%), followed by poultry (21%).

Credence attribute labels that are related to the product's healthiness (e.g., Nature & Presence, Science & Absence) are more frequently observed on MS sausages than on meat sausages. However, the opposite holds for health-related claims related to Nature & Absence (e.g., "without flavor enhancers") and products being lactose-free. 18.7% of MS sausages are labeled organic, while only 5% of meat sausages are. It can also be observed that more than three-quarters of MS products are

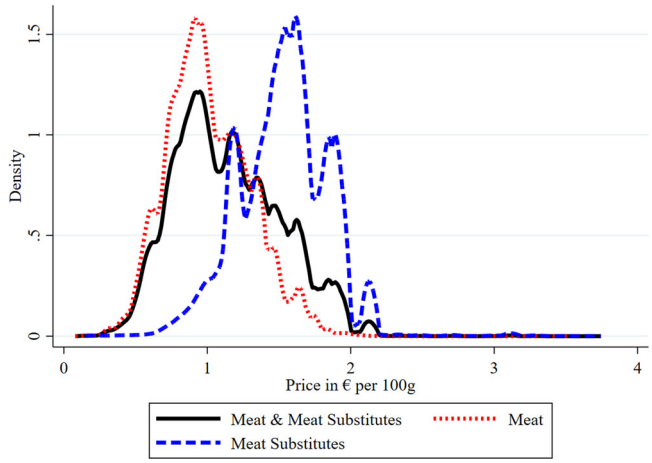

FIGURE 1 Kernal density estimates of the price in €/100g. The kernel function used to estimate the kernel density is the Epanechnikov kernel.

TABLE 1 Descriptive statistics of the sample from the German sausage market (2020–2021).

	Mean (standard deviation)		
		Individual markets	
Variable	**Total market**	**Meat**	**Meat substitutes**
Observations	183,717	136,545	47,172
Price	1.144 (0.369)	1.012 (0.228)	1.526[a] (0.306)
Main ingredients (Z^{MI})			
Pork-based	0.5	0.673	
Beef-based	0.019	0.025	
Beef and pork-based	0.051	0.069	
Poultry-based	0.159	0.214	
Other meats	0.014	0.019	
Egg-based	0.031		0.121
Soy-based	0.097		0.379
Wheat-based	0.015		0.057
Pea-based	0.032		0.126
Other/multi-ingredient-based	0.081		0.317
Credence attributes (Z^{CA})			
Nature & Absence	0.188	0.207	0.133
Nature & Presence	0.158	0.115	0.283
Organic	0.085	0.05	0.187
Science & Absence	0.03	0.026	0.045
Lactose-free	0.185	0.216	0.098
Gluten-free	0.265	0.262	0.273
Science & Presence	0.227	0.036	0.778
Ethical animal	0.057	0.038	0.111
Sustainability	0.26	0.111	0.688
Origin	0.197	0.26	
PGI label	0.051	0.068	
Traditional claim	0.204	0.262	
Quality claim	0.188	0.241	
Nutrition and diet (Z^{NF})			
A-score	17.256 (4.824)	19.773[a] (3.167)	11.021 (−2.159)
Protein content	14.858 (3.552)	14.309 (2.209)	16.447[a] (−5.623)
Product attributes (Z^{PA})			
Weight in 100 g	2.859 (1.551)	3.197[a] (1.665)	1.894 (−0.289)

(Continues)

TABLE 1 (Continued)

Variable	Mean (standard deviation)		
		Individual markets	
	Total market	Meat	Meat substitutes
Roasting sausage	0.533	0.426	0.844
National brand	0.61	0.582	0.692
Plastic packaging	0.638	0.737	0.353
Plastic and paper packaging	0.181	0.021	0.647
Glass packaging	0.115	0.154	
Can	0.066	0.089	
Retail characteristics (Z^{RC})			
Discounter	0.182	0.235	0.03
Supermarket	0.087	0.09	0.079
Hypermarket	0.731	0.675	0.892
Discounted observations	0.551	0.565	0.513

[a]Significant difference between the meat and meat substitute group at the 0.001 level. Variable descriptions are in Supporting Information: Table SA.1.

labeled with Science & Presence (e.g., "High in protein"). MS have a significantly lower A-score on average ($p < 0.001$) and thus contain less energy and unfavorable nutrients (salt [sodium], saturated fat and sugar). In addition, the protein content of MS is significantly higher ($p < 0.001$) at 16.4 g/100 g compared to 14.3 g/100 g for meat sausages.

4.2 | Results of the hedonic pricing model

In Figure 2, we present the results of the hedonic pricing model for the German meat sausage market. The underlying regression results are presented in Supporting Information: Table SA.2. Note that we estimate separate models for the meat sausage market and the MS sausage market. Figure 2 shows the marginal effects of product and retail characteristics along with their confidence intervals in red for the meat market and blue for the MS market. We find a lower market valuation for sausages based on beef, beef and pork, poultry, or other ingredients compared to pork. Thus, pork-based meat sausages command significantly higher prices by 0.03–0.14€/100 g. For MS, soy-based products are the reference category. While there is no difference in market valuation for the categories egg-based ($p = 0.811$) and wheat-based ($p = 0.214$), the market valuation for MS sausages based on peas (0.29€/100 g) and other/multi-ingredients (0.05€/100 g) is significantly higher than for soy-based products.

Regarding the nutritional facts, we observe that the marginal effect of the A-points on the price is positive for meat sausages (0.009€/100 g) and negative for MS sausages (−0.032€/100 g). While a higher protein content per 100 g is associated with a higher price in the meat market (0.024€/100 g), it is associated with a lower price in the MS market (−0.009€/100 g).

Market valuation for credence attribute labeling shows more differences than similarities between meat and MS. While the effect of Nature & Absence (e.g., "Without flavor enhancers") is negative in the meat market (−0.073€/100 g), it is positive in the MS market (0.289€/100 g). The association of Nature & Presence (e.g., "Natural Product") with the price is positive for both

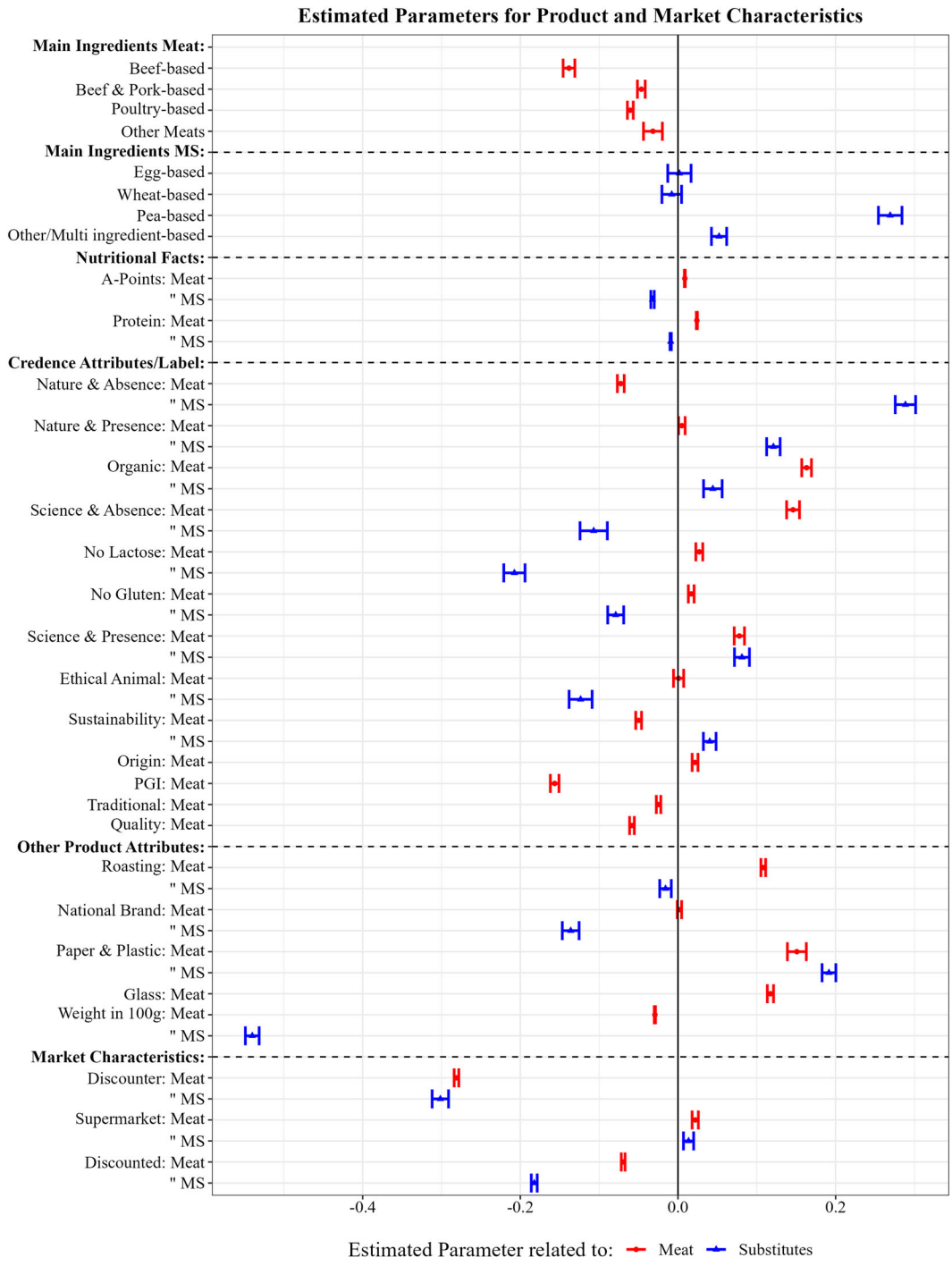

FIGURE 2 Estimation results from the hedonic pricing models for the German sausage market. The dependent variable is the price in €/100 g. MS indicates meat substitutes. Pork, canned or in plastic and sold in hypermarkets is the reference category for the meat market. Soy-based products in plastic packaging, sold in hypermarkets are the reference category for the meat substitute market. The respective table with the underlying regression results is presented in Supporting Information: Table SA.2. Month and region dummies are omitted for brevity. Observations: Meat = 136,545 and meat substitutes = 47,172.

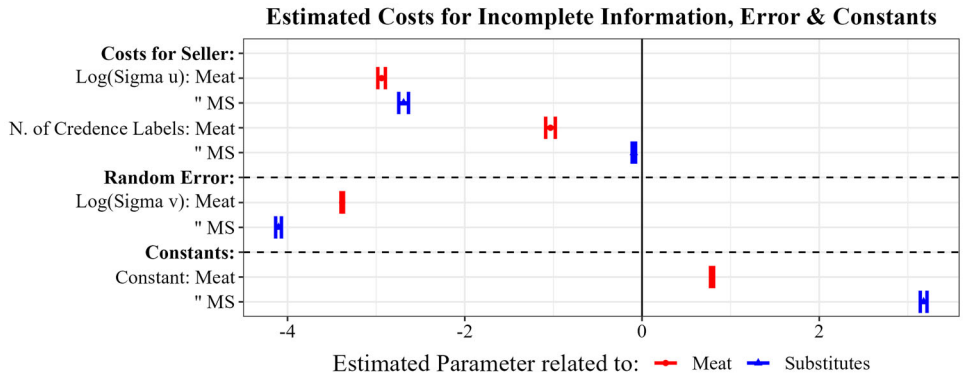

FIGURE 3 Estimation results for the error terms and the constants. The $\log(\sigma_u) = \log(\sigma_u^2)$ represents the variance of the half-normally distributed costs for producers for being unable to reach the consumers with the highest WTP. Number of credence labels represents a count variable for the number of different credence labels on a product. The $\log(\sigma_v) = \log(\sigma_v^2)$ represents the variance of the normally distributed error and the constants are related to the overall model. The results are presented in Supporting Information: Table SA.2. WTP, willingness-to-pay.

markets, but not significant for the meat market at a 1% significance level (0.005€/100 g; $p = 0.02$). The effect of organic labeling on the price is positive for both markets, though the estimated value is significantly lower (cf. Supporting Information: Table SA.2) for MS sausages (0.044€/100 g) than for the meat market sausages (0.163€/100 g). Focusing on the Science & Absence (e.g. "Reduced in fat") dimension, a contrasting picture emerges. Products with those claims receive a higher price in the meat market but a lower price in the MS market. Science & Presence (e.g. "High in protein") labels are associated with higher prices in both markets. Surprisingly, claims about the ethical aspects of livestock farming are not related to prices in the meat market ($p = 0.806$) and are negatively related to prices in the MS market (−0.124€/100 g). Finally, the estimated parameter of Sustainability is positively associated with prices in the MS market (0.040€/100 g) and negatively associated with the price in the meat market (−0.050€/100 g).

The estimated parameters for product and process characteristics exclusively present in the meat market model yield heterogeneous results. Products with the indication of a specific origin receive a positive market valuation (0.021€/100 g), while products with a PGI indication, Traditional or Quality label receive a lower price (−0.156€/100 g, −0.024€/100 g, −0.058€/100 g respectively).

Turning to the other product attributes reveals that roasting sausages have a slightly lower price (−0.016€/100 g) in the MS market and a higher price (0.108€/100 g) in the meat market. Thereby, sausages for cooking, sausages that can be consumed cold or combinations with roasting, are the reference category. The coefficient of the national brand dummy is not significantly different from zero in the meat market ($p = 0.179$) and negative in the MS market (−0.136€/100 g). Paper and plastic packaging is associated with a higher price in both markets, while glass is associated with a higher price in the meat market. Note that the reference category for MS is plastic, while the one for meat sausages is can and plastic. A higher weight of products in 100 g is associated with lower prices per 100 g in both markets. The prices per 100 g are by −0.281€ and −0.301€ lower in discounters for meat sausages and MS sausages and by 0.022€ and 0.013€ higher in supermarkets than in the reference category hypermarket, respectively. Finally, products that were sold under discount in a given time period have lower prices, as expected.

Figure 3 shows the results for the market inefficiencies. We test whether the number of credence attributes with which sellers tag a product can systematically reduce consumers' deviation from their highest WTP. First, we can observe from the estimated log (σ_u^2), which is −2.939 for the meat market

and −2.690 for the MS market that there is a systematic deviation from the highest WTP of consumers in the German sausage market. Thus, producers are unable to reach consumers with the highest WTP, indicating the importance of taking information asymmetry into account when estimating the hedonic price function. The calculation of $\frac{\sigma_u}{\sigma_v}$ shows that the variance of the half-normal error is two times larger than that of the normally distributed error in the MS market and 1.2 times larger than that of the normally distributed error in the meat market (Bonanno et al., 2019). However, this deviation can be reduced in both markets by the number of different credence labels on the products. Thus, the use of credence attribute labels can reduce information asymmetries and help sellers reach consumers with the highest WTP. When running the stochastic frontiers without the specifications of σ_u the $\frac{\sigma_u}{\sigma_v}$ is 1.8 for the MS market, however, the $\log(\sigma_u^2)$ turns out not to be significantly different from 0 in the meat market ($p = 0.748$).

5 | DISCUSSION

5.1 | Prices of meat and meat substitutes and the role of main ingredients

Meat prices, when considered in the context of environmental issues and health costs, are too low because they do not internalize social costs (Funke et al., 2022; Siegrist & Hartmann, 2023). Therefore, several studies model the impact of meat taxes as a tool to reduce meat consumption and (partly) internalize the negative external effects (Roosen et al., 2022; Springmann et al., 2018). Moreover, lower prices for MS could reduce meat consumption (Apostolidis & McLeay, 2016), mitigating the associated external costs. Our data, however, show that the price for MS sausages is 50% higher per 100 g than for meat sausages. These higher prices could act like a "vegan-tax" (Kerslake et al., 2022), confirming consumer preconceptions that MS are costly (Peschel et al., 2019), which acts as a barrier to adoption (Carlsson, Kataria, & Lampi, 2022). Zhao et al. (2022) challenge the notion of a substitution relationship between meat and meat alternatives, observing a complementary relationship instead. Therefore, the own price elasticities of MS are particularly relevant and prices would need to be lowered (e.g., through subsidies) to increase consumption.

Similar to previous literature on the German meat market, our results show that prices differ with the main ingredients. Staudigel and Trubnikov (2022), find that the price premium is higher for beef and the mix of beef and pork than for pork. We find that the price of pork is the highest in the meat market, the difference has to be attributed to the different product categories. While Staudigel and Trubnikov (2022) focus on fresh meat, this study investigates sausages, for which traditionally pork is the main ingredient. van Loo et al. (2020) find a higher WTP for pea-based MS than for cultured meat and yeast-based MS in a choice-experiment. Our study based on scanner data also shows a high market valuation for pea-based MS. More specifically, those products receive higher prices than soybean-based MS. One reason could be that consumers associate soy for MS with soy for animal feed produced in deforested areas of the Amazon rainforest (Marin et al., 2022), while some pea-based products are evaluated as more environmentally friendly (Hartmann et al., 2022). Peas could also induce a price premium because being perceived as regionally grown. Finally, the difference between soy- and pea-based MS might be explained by the association of consumers of soy with tofu-based MS, that is, first-generation MS. Kim et al. (2023) found first-generation tofu-based seafood alternatives are less popular than second-generation alternatives, which more closely resemble seafood.

5.2 | Nutrients and prices

Our results on the sausage market that MS have a lower A-score and, hence, contain fewer nutrients to limit per 100 g are consistent with the findings of Petersen et al. (2021). Also, the findings of the

hedonic pricing model for the meat market are in line with the ones of Petersen et al. (2021), revealing that products with a higher A-score obtain higher prices. However, the results of this study differ for the MS market. While Petersen et al. (2021) find a positive relationship between the price per 100 g and the A-score for the MS market, our results reveal a negative relationship, suggesting that sausage substitutes with fewer "nutrients to limit" have a higher valuation. Similar to Yang and Dharmasena's (2020) study on consumer preferences for the nutritional values of dairy and alternative dairy products, who find a positive effect of milk's protein content on the price, we find a positive market valuation of protein for meat sausages. However, they report the same relationship for alternative milk, while our results indicate a negative relationship between protein content and the price of MS sausages.

5.3 | Credence attributes and prices

Information on credence attributes of products has a distinct role in product pricing in the meat market. Martin et al. (2021) showed that information complementary to the information on packages increases consumers' WTP for MS. We observe that the share of products labeled with credence attributes is larger for MS sausages than meat sausages. Thereby, there is an emphasis on the aspect Science & Presence, which indicates that producers try to inform consumers that the products are nutritionally adequate. This might be because consumers (Weinrich, 2018) and nutritional experts perceive deficits regarding the nutritional quality of MS, especially regarding protein quality (Estell et al., 2021). This holds despite research pointing to a preferable composition of MS compared to (processed) meats (Alessandrini et al., 2021; Petersen et al., 2021).

Science Absence claims ("low in fat" and "low in sugar") are less common but still present in both markets, showing a negative relationship with MS prices but a positive relationship with meat sausage prices. Consumers may assume that MS carrying that claim may lack something. As there are general concerns about dryness and product texture, this could reduce the economic value of MS (Kerslake et al., 2022). In contrast, interest in fat avoidance is reported among meat consumers and might be especially relevant in the case of sausages (Apostolidis & McLeay, 2016; de Araújo et al., 2022).

Yang and Renwick's (2019) meta-analysis of consumers' WTP for credence attributes in livestock products shows a WTP a premium for animal-friendly production and organic claims. Our study also reveals that organic products receive a price premium, which is similar to Staudigel and Trubnikov's (2022) findings for the German fresh meat market. Interestingly, the market valuation for organic labeling differs between meat and MS sausages, with the latter receiving a smaller price premium. Organic is a multidimensional construct encompassing many sustainability dimensions, such as healthiness and animal welfare (Katt & Meixner, 2020). Consumers might consider that those domains are already covered by MS, leading to a lower market valuation of organic labeling for MS sausages.

Concerning the animal welfare findings, on the one side, a recent choice experiment from the Swedish meat market showed that there is a high WTP a price premium for animal welfare (Carlsson, Kataria, Lampi, Nyberg, et al., 2022). On the other side, Kerslake et al. (2022) showed that consumers consider animal (welfare) indications on MS as redundant and even "funny," which provides an explanation for the negative price effect of this claim in our study. Since this claim is found on 11.1% of products in the MS segment, manufacturers should reconsider whether they can credibly communicate this claim.

In the MS market, some established brands are (were) mainly meat producers (e.g., Rügenwalder Mühle). However, Kerslake et al. (2022) identified that MS consumers tend to distrust products from established meat producers, which corresponds to our findings, where national brands of MS receive lower prices. An implication could be that established meat producers, although more capable of investing in research and development and entering the new market, may encounter an

"image penalty." Finally, in contrast to the results of Yang and Renwick (2019), we find a lower market valuation per 100 g for the EU PGI label. The selected product category might explain this, as sausages are not considered premium products, so this claim is less relevant.

The type of retail outlet where the products are sold can play an important role in price building and for consumers' perceived price barrier. Consumers shopping in discounters are highly price-sensitive (Gottschalk & Leistner, 2013). Our findings show that the price for MS is on average 0.3€ lower in discounters compared to hypermarkets, thereby reducing the potential price barrier for purchasing MS in the former compared to the latter retail outlet. However, since meat sausages are also cheaper in the discounters, the relative price difference remains, potentially neutralizing the above mentioned effect.

Finally, the stochastic frontier results shed light on the cost to sellers of not being able to reach consumers with the highest WTP, suggesting a systematic deviation from the producer's optimal price. This deviation appears to be greater in the MS market than in the meat market. Similar to Bonanno et al. (2019), we find that producers can reduce the deviation from buyers' price frontier through credence attribute labels. Therefore, product differentiation through the labeling of credence attributes can be a competitive strategy (De Marchi et al., 2023).

6 | LIMITATIONS AND CONCLUSION

Although our analysis has several strengths, such as the large sample size, it is not without limitations. First, while retail brands play an important role in the meat market in general and the sausage market in particular (Braun, 2023), only producer-branded sausages could be considered. This limits the transferability of our results to the overall German sausage market, as the analyzed product attributes could have different effects on the prices of private labeled products. However, the recent trend of retail brands aiming at the high-quality market segment may lower those differences (Gielens et al., 2021). Nevertheless, further research is needed to investigate whether the relationships differ between branded products and private labels. In addition, our sample considers only prepackaged sausages, as the provision of information at the fresh counter is unknown, specific to each store, and generally much lower compared to prepackaged products.

Second, we do not consider the visibility of the information provided. As Grunert and Wills (2007) note, consumers have limited time to process information when grocery shopping. This leads to a similar problem as the attribute nonattendance problem of stated preference methods (Scarpa et al., 2013). Hence, a label on the front of the product might be easily recognized, thereby having a higher influence on the price than a label on the back. Third, we categorize the labels and assume that, for example, labels related to the product's healthiness affect the price similarly. Therefore, we cannot determine the extent to which, for example, "without genetically modified organism 2" or "without flavor enhancers" labels contribute to the overall effect of the Natural and Absence category. Fourth, although taste is an important characteristic in the meat and MS market for consumers' WTP (Caputo et al., 2023), our method and data do not allow us to consider this attribute. Nevertheless, it would be interesting to see whether the results of Caputo et al. (2023) could be replicated in the context of highly processed products like sausages. Finally, although we control for general price differences across regions by market fixed-effects, there could be differences in consumers' valuations for specific attributes by region. Future studies could, therefore, estimate geographically differentiated hedonic price models and analyze the potential differences across regions.

Our research aimed to understand the factors influencing the prices of meats and MS. Based on a sample of 183,717 observations from the German sausage market, we found that MS are significantly more expensive than meat sausages, which can be a barrier for consumers to adopt them. Here, differences within the market of meat sausages and MS sausages can be explained by the main ingredients, with pork in the case of meat and peas in the case of MS achieving the

highest market valuation. In addition, credence attributes are important factors explaining the price differences. However, the direction of the effects strongly depends on the credence attribute. Thereby, for some credence attributes, there are significant differences in valuation between meat and MS sausages. In addition, the greater use of credence attribute claims on MS packaging suggests that manufacturers are attempting to reduce information asymmetry with consumers. Finally, our results suggest that there is no one-size-fits-all approach to credence attributes and that different marketing strategies are required for meat sausage and MS sausages.

ACKNOWLEDGMENTS

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Open Access funding enabled and organized by Projekt DEAL.

DATA AVAILABILITY STATEMENT

Due to commercial and legal reasons the supporting data is not available. Research data are not shared.

ORCID

Thies Petersen http://orcid.org/0000-0001-7761-536X
Milan Tatic https://orcid.org/0000-0001-9733-3722
Monika Hartmann https://orcid.org/0000-0002-3631-164X
Stefan Hirsch https://orcid.org/0000-0003-2668-6824

REFERENCES

Alessandrini, Roberta, Mhairi K. Brown, Sonia Pombo-Rodrigues, Sheena Bhageerutty, Feng J. He, and Graham A. MacGregor. 2021. "Nutritional Quality of Plant-Based Meat Products Available in the UK: A Cross-Sectional Survey." *Nutrients* 13: 4225. https://doi.org/10.3390/nu13124225

André, Q., P. Chandon, and K. Haws. 2019. "Healthy through Presence or Absence, Nature or Science?: A Framework for Understanding Front-of-Package Food Claims." *Journal of Public Policy & Marketing* 38: 172–91. https://doi.org/10.1177/0743915618824332

Apostolidis, Chrysostomos, and Fraser McLeay. 2016. "Should We Stop Meating Like This? Reducing Meat Consumption through Substitution." *Food Policy* 65: 74–89. https://doi.org/10.1016/j.foodpol.2016.11.002

Apostolidis, Chrysostomos, and Fraser McLeay. 2019. "To Meat or Not to Meat? Comparing Empowered Meat Consumers' and Anti-Consumers' Preferences for Sustainability Labels." *Food Quality and Preference* 77: 109–22. https://doi.org/10.1016/j.foodqual.2019.04.008

de Araújo, Priscila Dinah, Wilma Maria Coelho Araújo, Luís Patarata, and Maria João Fraqueza. 2022. "Understanding the Main Factors that Influence Consumer Quality Perception and Attitude towards Meat and Processed Meat Products." *Meat Science* 193: 108952. https://doi.org/10.1016/j.meatsci.2022.108952

Ballco, Petjon, Fatma Jaafer, and Tiziana de Magistris. 2022. "Investigating the Price Effects of Honey Quality Attributes in a European Country: Evidence from a Hedonic Price Approach." *Agribusiness* 38: 885–904. https://doi.org/10.1002/agr.21760

Bimbo, Francesco, Alessandro Bonanno, and Rosaria Viscecchia. 2016. "Do Health Claims Add Value? The Role of Functionality, Effectiveness and Brand." *European Review of Agricultural Economics* 43: 761–80. https://doi.org/10.1093/erae/jbw002

Birkle, Ingo, Jeanette Klink-Lehmann, and Monika Hartmann. 2022. "Different and Alike: Level and Determinants of Public Acceptance of Fattening Pig, Beef Cattle and Broiler Farming in Germany." *Meat Science* 193: 108946. https://doi.org/10.1016/j.meatsci.2022.108946

Blanco-Gutiérrez, Irene, Consuelo Varela-Ortega, and Rhys Manners. 2020. "Evaluating Animal-Based Foods and Plant-Based Alternatives using Multi-Criteria and SWOT Analyses." *International Journal of Environmental Research and Public Health* 17: 7969. https://doi.org/10.3390/ijerph17217969

Bonanno, Alessandro, Francesco Bimbo, Marco Costanigro, Alfons Oude Lansink, and Rosaria Viscecchia. 2019. "Credence Attributes and the Quest for a Higher Price—A Hedonic Stochastic Frontier Approach." *European Review of Agricultural Economics* 46: 163–92. https://doi.org/10.1093/erae/jby024

Bouvard, Véronique, Dana Loomis, Kathryn Z. Guyton, Yann Grosse, Fatiha El Ghissassi, Lamia Benbrahim-Tallaa, Neela Guha, Heidi Mattock, and Kurt Straif. 2015. "Carcinogenicity of Consumption of Red and Processed Meat." *The Lancet. Oncology* 16: 1599–600. https://doi.org/10.1016/S1470-2045(15)00444-1

Braun, C. "Umsatzzuwachs resultiert allein aus Preissteigerungen. Analyse von NielsenIQ." *Lebensmittel Zeitung*, May 12, 2023. https://www.lebensmittelzeitung.net/handel/charts/analyse-von-nielseniq-umsatzzuwachs-resultiert-allein-aus-preissteigerungen-171256

Caputo, Vincenzina, Giovanni Sogari, and Ellen J. van Loo. 2023. "Do Plant-Based and Blend Meat Alternatives Taste Like Meat? A Combined Sensory and Choice Experiment Study." *Applied Economic Perspectives and Policy* 45: 86–105. https://doi.org/10.1002/aepp.13247

Carlsson, F., M. Kataria, and E. Lampi. 2022. "How Much Does it Take? Willingness to Switch to Meat Substitutes." *Ecological Economics* 193: 107329. https://doi.org/10.1016/j.ecolecon.2021.107329

Carlsson, F., M. Kataria, E. Lampi, E. Nyberg, and T. Sterner. 2022. "Red, Yellow, or Green? Do Consumers' Choices of Food Products Depend on the Label Design?" *European Review of Agricultural Economics* 49: 1005–26. https://doi.org/10.1093/erae/jbab036

Chernev, Alexander, Ulf Böckenholt, and Joseph Goodman. 2015. "Choice Overload: A Conceptual Review and Meta-Analysis." *Journal of Consumer Psychology* 25: 333–58. https://doi.org/10.1016/j.jcps.2014.08.002

Clark, Lisa Frances, and Ana-Maria Bogdan. 2019. "Plant-Based Foods in Canada: Information, Trust and Closing the Commercialization Gap." *British Food Journal* 121: 2535–50. https://doi.org/10.1108/BFJ-12-2018-0826

Clark, Michael, Marco Springmann, Mike Rayner, Peter Scarborough, Jason Hill, David Tilman, and Jennie I. Macdiarmid, et al. 2022. "Estimating the Environmental Impacts of 57,000 Food Products." *Proceedings of the National Academy of Sciences of the United States of America* 119: e2120584119. https://doi.org/10.1073/pnas.2120584119

Costanigro, M., and J. McCluskey. 2011. "Hedonic Price Analysis in Food Markets." In *The Oxford Handbook of the Economics of Food Consumption and Policy*, edited by J. L. Lusk, J. Roosen and J. F. Shogren, 152–80. Oxford: Oxford University Press.

Deutscher Fleischer-Verband e.V 2022. Jahrbuch Pro-Kopf-Verzehr 2021 in KG Wurst und sonstige Fleischerzeugnisse pro Kopf der Bevölkerung. www.fleischerhandwerk.de

Elzerman, Johanna E., Martinus A. J. S. van Boekel, and Pieternel A. Luning. 2013. "Exploring Meat Substitutes: Consumer Experiences and Contextual Factors." *British Food Journal* 115: 700–10. https://doi.org/10.1108/00070701311331490

Estell, Madeline, Jaimee Hughes, and Sara Grafenauer. 2021. "Plant Protein and Plant-Based Meat Alternatives: Consumer and Nutrition Professional Attitudes and Perceptions." *Sustainability* 13: 1478. https://doi.org/10.3390/su13031478

Funke, Franziska, Linus Mattauch, Inge van den Bijgaart, H. Charles J. Godfray, Cameron Hepburn, David Klenert, Marco Springmann, and Nicolas Treich. 2022. "Toward Optimal Meat Pricing: Is it Time to Tax Meat Consumption." *Review of Environmental Economics and Policy* 16: 219–40. https://doi.org/10.1086/721078

Gielens, Katrijn, Yu Ma, Aidin Namin, Raj Sethuraman, Ronn J. Smith, Robert C. Bachtel, and Suzanne Jervis. 2021. "The Future of Private Labels: Towards a Smart Private Label Strategy." *Journal of Retailing* 97: 99–115. https://doi.org/10.1016/j.jretai.2020.10.007

Godfray, Charles J. H., Paul Aveyard, Tara Garnett, Jim W. Hall, Timothy J. Key, Jamie Lorimer, and Ray T. Pierrehumbert, et al. 2018. "Meat Consumption, Health, and the Environment." *Science* 361: eaam5324. https://doi.org/10.1126/science.aam5324

Golan, Elise, Fred Kuchler, Lorraine Mitchell, Cathy Greene, and Amber Jessup. 2001. "Economics of Food Labeling." *Journal of Consumer Policy* 24: 117–84. https://doi.org/10.1023/A:1012272504846

Gottschalk, Ingrid, and Tabea Leistner. 2013. "Consumer Reactions to the Availability of Organic Food in Discount Supermarkets." *International Journal of Consumer Studies* 37: 136–42. https://doi.org/10.1111/j.1470-6431.2012.01101.x

Grunert, Klaus G., and Josephine M. Wills. 2007. "A Review of European Research on Consumer Response to Nutrition Information on Food Labels." *Journal of Public Health* 15: 385–99. https://doi.org/10.1007/s10389-007-0101-9

Hartmann, Christina, Patricia Furtwaengler, and Michael Siegrist. 2022. "Consumers' Evaluation of the Environmental Friendliness, Healthiness and Naturalness of Meat, Meat Substitutes, and other Protein-Rich Foods." *Food Quality and Preference* 97: 104486. https://doi.org/10.1016/j.foodqual.2021.104486

IRI. 2023. Scanner data. https://www.iriworldwide.com/de-de

Karipidis, P. I., E. Tsakiridou, N. M. Tabakis, and K. Mattas. 2015. "Hedonic Analysis of Retail Egg Prices." *Journal of Food Distribution Research* 36: 68–73. https://doi.org/10.22004/AG.ECON.27760

Katt, F., and O. Meixner. 2020. "A Systematic Review of Drivers Influencing Consumer Willingness to Pay for Organic Food." *Trends in Food Science & Technology* 100: 374–88. https://doi.org/10.1016/j.tifs.2020.04.029

Kerslake, Eleanor, Joya A. Kemper, and Denise Conroy. 2022. "What's Your Beef with Meat Substitutes? Exploring Barriers and Facilitators for Meat Substitutes in Omnivores, Vegetarians, and Vegans." *Appetite* 170: 105864. https://doi.org/10.1016/j.appet.2021.105864

Kim, Dahye, Vincenzina Caputo, and Valerie Kilders. 2023. "Consumer Preferences and Demand for Conventional Seafood and Seafood Alternatives: Do Ingredient Information and Processing Stage Matter." *Food Quality and Preference* 108: 104872. https://doi.org/10.1016/j.foodqual.2023.104872

Kumbhakar, Subal C., and Christopher F. Parmeter. 2010. "Estimation of Hedonic Price Functions with Incomplete Information." *Empirical Economics* 39: 1–25. https://doi.org/10.1007/s00181-009-0292-8

Lancaster, Kelvin J. 1966. "A New Approach to Consumer Theory." *Journal of Political Economy* 74: 132–57. https://doi.org/10.1086/259131

LfL & LEL. 2022. Agrarmärkte 2021. 8 Vieh und Fleisch. https://www.lfl.bayern.de/iem/agrarmarkt/210921/index.php

van Loo, Ellen J., Vincenzina Caputo, and Jayson L. Lusk. 2020. "Consumer Preferences for Farm-Raised Meat, Lab-Grown Meat, and Plant-Based Meat Alternatives: Does Information or Brand Matter?" *Food Policy* 95: 101931. https://doi.org/10.1016/j.foodpol.2020.101931

Lusk, Jayson L., and Brian C. Briggeman. 2009. "Food Values." *American Journal of Agricultural Economics* 91: 184–96. https://doi.org/10.1111/j.1467-8276.2008.01175.x

De Marchi, Elisa, Alessia Cavaliere, Flavia Pucillo, Alessandro Banterle, and Rodolfo M. Nayga. 2023. "Dynamics of Demand-Side and Supply-Side Responses to Front-of-Pack Nutrition Labels: A Narrative Review." *European Review of Agricultural Economics* 50: 201–31. https://doi.org/10.1093/erae/jbac031

Marin, Fabio R., Alencar J. Zanon, Juan P. Monzon, José F. Andrade, Evandro H. F. M. Silva, Gean L. Richter, and Luis A. S. Antolin, et al. 2022. "Protecting the Amazon Forest and Reducing Global Warming via Agricultural Intensification." *Nature Sustainability* 5: 1018–26. https://doi.org/10.1038/s41893-022-00968-8

Martin, Christophe, Christine Lange, and Stéphan Marette. 2021. "Importance of Additional Information, as a Complement to Information Coming from Packaging, to Promote Meat Substitutes: A Case Study on a Sausage Based on Vegetable Proteins." *Food Quality and Preference* 87: 104058. https://doi.org/10.1016/j.foodqual.2020.104058

McCluskey, J. J., and J. A. Winfree. 2022. "Product Differentiation in Food." In *A Modern Guide to Food Economics*, edited by J. Roosen and J. E. Hobbs, 47–61. UK: Edward Elgar Publishing.

Michel, Fabienne, Christina Hartmann, and Michael Siegrist. 2021. "Consumers' Associations, Perceptions and Acceptance of Meat and Plant-Based Meat Alternatives." *Food Quality and Preference* 87: 104063. https://doi.org/10.1016/j.foodqual.2020.104063

Mintel. Global New Product Database. Available at https://www.mintel.com/products/gnpd (last accessed 26 February 2023).

Murphy, J. J., P. G. Allen, T. H. Stevens, and D. Weatherhead. 2005. "A Meta-Analysis of Hypothetical Bias in Stated Preference Valuation." *Environmental & Resource Economics* 30: 313–25. https://doi.org/10.1007/s10640-004-3332-z

Onwezen, M. C., E. P. Bouwman, M. J. Reinders, and H. Dagevos. 2021. "A Systematic Review on Consumer Acceptance of Alternative Proteins: Pulses, Algae, Insects, Plant-Based Meat Alternatives, and Cultured Meat." *Appetite* 159: 105058. https://doi.org/10.1016/j.appet.2020.105058

Peschel, Anne O., Shahab Kazemi, Martina Liebichová, Stine Cecilie Mangaard Sarraf, and Jessica Aschemann-Witzel. 2019. "Consumers' Associative Networks of Plant-Based Food Product Communications." *Food Quality and Preference* 75: 145–56. https://doi.org/10.1016/j.foodqual.2019.02.015

Petersen, Thies, Monika Hartmann, and Stefan Hirsch. 2021. "Which Meat (Substitute) to Buy? Is Front of Package Information Reliable to Identify the Healthier and More Natural Choice?" *Food Quality and Preference* 94: 104298. https://doi.org/10.1016/j.foodqual.2021.104298

Polachek, Solomon W., and Bong Joon Yoon. 1987. "A Two-Tiered Earnings Frontier Estimation of Employer and Employee Information in the Labor Market." *The Review of Economics and Statistics* 69: 296. https://doi.org/10.2307/1927237

Poon, Theresa, Marie-Ève Labonté, Christine Mulligan, Mavra Ahmed, Kacie M. Dickinson, and Mary R. L'Abbé. 2018. "Comparison of Nutrient Profiling Models for Assessing the Nutritional Quality of Foods: A Validation Study." *British Journal of Nutrition* 120: 567–82. https://doi.org/10.1017/S0007114518001575

Ribeiro, J. E., A. Gschwandter, and C. Revoredo-Giha. 2019. "*Estimation of a Hedonic Price Equation with Instruments for Chicken Meat in the UK. Does the Organic Attribute Matter?*" School of Economics Discussion Papers, No. 1911, University of Kent, School of Economics, Canterbury.

Roosen, Jutta, Matthias Staudigel, and Sebastian Rahbauer. 2022. "Demand Elasticities for Fresh Meat and Welfare Effects of Meat Taxes in Germany." *Food Policy* 106: 102194. https://doi.org/10.1016/j.foodpol.2021.102194

Rosen, Sherwin. 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economy* 82: 34–55. https://doi.org/10.1086/260169

Scarborough, Peter, Mike Rayner, and Lynn Stockley. 2007. "Developing Nutrient Profile Models: A Systematic Approach." *Public Health Nutrition* 10: 330–6. https://doi.org/10.1017/S1368980007223870

Scarpa, Riccardo, Raffaele Zanoli, Viola Bruschi, and Simona Naspetti. 2013. "Inferred and Stated Attribute Non-Attendance in Food Choice Experiments." *American Journal of Agricultural Economics* 95: 165–80. https://doi.org/10.1093/ajae/aas073

Siegrist, Michael, and Christina Hartmann. 2023. "Why Alternative Proteins will Not Disrupt the Meat Industry." *Meat Science* 203: 109223. https://doi.org/10.1016/j.meatsci.2023.109223

Springmann, Marco, Daniel Mason-D'Croz, Sherman Robinson, Keith Wiebe, H. Charles J. Godfray, Mike Rayner, and Peter Scarborough. 2018. "Health-Motivated Taxes on Red and Processed Meat: A Modelling Study on Optimal Tax Levels and Associated Health Impacts." *PloS One* 13: e0204139. https://doi.org/10.1371/journal.pone.0204139

Staudigel, Matthias, and Aleksej Trubnikov. 2022. "High Price Premiums as Barriers to Organic Meat Demand? A Hedonic Analysis Considering Species, Cut and Retail Outlet." *Australian Journal of Agricultural and Resource Economics* 66: 309–34. https://doi.org/10.1111/1467-8489.12472

Unnevehr, Laurian, James Eales, Helen Jensen, Jayson Lusk, Jill McCluskey, and Jean Kinsey. 2010. "Food and Consumer Economics." *American Journal of Agricultural Economics* 92: 506–21. https://doi.org/10.1093/ajae/aaq007

Weinrich, Ramona. 2018. "Cross-Cultural Comparison between German, French and Dutch Consumer Preferences for Meat Substitutes." *Sustainability* 10: 1819. https://doi.org/10.3390/su10061819

Wickramasinghe, Kremlin, Joao Breda, Nino Berdzuli, Holly Rippin, Clare Farrand, and Afton Halloran. 2021. "The Shift to Plant-Based Diets: Are we Missing the Point?" *Global Food Security* 29: 100530. https://doi.org/10.1016/j.gfs.2021.100530

Willits-Smith, Amelia, Rodrigo Aranda, Martin C. Heller, and Donald Rose. 2020. "Addressing the Carbon Footprint, Healthfulness, and Costs of Self-Selected Diets in the USA: A Population-Based Cross-Sectional Study." *The Lancet. Planetary Health* 4: e98–e106. https://doi.org/10.1016/S2542-5196(20)30055-3

Yang, T., and S. Dharmasena. 2020. "Consumers Preferences on Nutritional Attributes of Dairy-Alternative Beverages: Hedonic Pricing Models." *Food Science & Nutrition* 8: 5362–78. https://doi.org/10.1002/fsn3.1757

Yang, Wei, and Alan Renwick. 2019. "Consumer Willingness to Pay Price Premiums for Credence Attributes of Livestock Products—A Meta-Analysis." *Journal of Agricultural Economics* 70: 618–39. https://doi.org/10.1111/1477-9552.12323

Zandt, F. 2022. Fleischersatz auf dem Vormarsch. Statista GmbH. https://de.statista.com/infografik/26536/geschaetzter-umsatz-mit-fleischersatzprodukten-im-dach-raum/

Zhao, S., L. Wang, W. Hu, and Y. Zheng. 2022. "Meet the Meatless: Demand for New Generation Plant-Based Meat Alternatives." *Applied Economic Perspectives and Policy* 45: 4–21. https://doi.org/10.1002/aepp.13232

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Petersen, Thies, Milan Tatic, Monika Hartmann, and Stefan Hirsch. 2023. "Meat and Meat Substitutes—A Hedonic-Pricing Model for the German Market." *Journal of the Agricultural and Applied Economics Association*. 2: 668–685. https://doi.org/10.1002/jaa2.84