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Price Differences Between Organic and Conventional Products in E-Commerce

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Abstract: The global market for organic foods is expanding, with consumers willing to pay more for their perceived health and sustainability benefits. However, expressing willingness to pay does not guarantee that sellers can charge a price premium for organic products and pass it along the supply chain. Empirical evidence on the extent to which sellers can set a price premium for organic products is fragmented, especially for e-commerce. This paper uses big data on online prices to provide first insights into the relationship between the product price and the organic attribute across the entire food and beverages variety of the largest full assortment of e-grocers in Germany, the world's second-largest organic market. Our findings show that, on average, organic products are about 5% more expensive than conventional products in the same product category, although the individual estimates vary widely, calling for more data collection efforts and in-depth research for individual products categories.

Keywords: Organic Products, E-Commerce, Food Retailing, Price Premium, Germany

1 Introduction

The global market for organic foods has been steadily expanding. Whether driven by ethical and ecological reasons or health and food safety concerns, support for organic production and consumption depends on willingness to pay (Aschemann-Witzel, Zielke, 2017; Rousseau, Vranken, 2013). Digitalization increases the role of Internet channels in information provision and food retailing, influencing consumers' willingness to pay. Already now, multichannel retailers mostly grow via their online platforms (HDE, 2021), and Amazon belongs to the most relevant food retailers both in the US and Europe (LZ, 2021; PG, 2022).[1] Following the rapid COVID-19-triggered expansion of the grocery e-commerce sector, the relevance of online channels in marketing food, including organic products, is expected to grow over time. This calls for a better understanding of the pricing of conventional and organic products in digital markets and across the distribution channels of e-commerce.

This paper aims to assess the link between the product price and the organic attribute for the entire grocery assortment of large online sellers by leveraging the opportunities provided by e-commerce and digital data availability. As such, this study is linked to two broader research strands: organic price premiums, and digitalization and online pricing.

[1] Amazon was the largest seller in the entire European grocery retailing and German grocery e-commerce at the time of data collection (LZ, 2021), it also belongs to the top 6 German food retailers (Hölting, 2017).

The first strand investigates hedonic prices, i.e., price premiums for various product attributes. Hedonic price analysis assumes individual products to be valued for their utility-generating attributes that consumers assess upon making buying decisions (Rosen, 1974). Globally, public interest in sustainable products is growing, and organic products mostly enjoy a positive willingness to pay and a price premium (Connolly, Klaiber, 2014; Meas et al., 2015). The second strand addresses the role of e-commerce and digitalization in retailing markets and research opportunities due to big data availability. These studies rely on highly detailed firm- and product-level data, available at high frequency, to explore key pricing behaviors. For instance, they examine the impacts on prices in response to changing market conditions (Gorodnichenko, Talavera, 2017; Hillen, Fedoseeva, 2021; Fuest et al., 2021; Fedoseeva, Van Droogenbroeck, 2023) and analyze product price differences within and between e-commerce retailers (Aparicio et al., 2023; Fedoseeva, Irek, 2022).

Empirical evidence on non-food sectors often confirms the prediction of the economics of the information approach, showing that online markets experience smaller price differences and more responsive pricing to changes in market conditions (Gorodnichenko, Talavera, 2017). For the food sector, evidence is scarcer and mixed, which might be, at least partially, driven by the sector peculiarities (e.g., challenges of arbitrage in international markets), the later food industry digitalization, or still limited data availability (Fedoseeva et al., 2017).

Our study integrates insights from the two research strands to quantify price differences between organic and conventional products across the entire grocery assortment, and also in response to the most recent global economic shock, using the largest available dataset on online grocery prices for a single country - Germany, up to date. Although performing a proper hedonic price analysis for every product group of the observed variety of foods and beverages (our data includes over 900,000 products in over 2,000 product categories defined at the retailer level) is not feasible within a single study, the availability of big data enables us to contribute to existing knowledge on organic price premiums in various ways. First, our dataset includes prices of the entire range of foods and beverages offered by the six largest full-assortment e-sellers over time, allowing us to quantify the average organic price difference across multiple data dimensions for the entire grocery assortment, including visualized distribution of individual retailer-product-category effects. Second, the time dimension of our data allows us to identify price responses of conventional and organic products to the most recent global shock, the COVID-19 pandemic. Finally, our dataset includes online price and organic/conventional product attribute data from online-only and hybrid retailers, i.e., multichannel grocers selling offline and online. Given that grocery multichannel retailers increasingly use the same pricing strategy across their channels (Cavallo, 2017), including both types of retailers in the sample might provide first insights into organic price differences (if any) in online and hybrid markets.

The remainder of this article is structured as follows. We begin by reviewing previous literature on the determinants of organic product price premiums over conventional products and how pricing behavior may change in response to global economic conditions. Subsequently, we describe our data and empirical strategy for calculating price differentials. We then present and discuss our findings, address the limitations of our analysis, and conclude.

2 Background and Derived Research Questions

The prices of goods are influenced by the interaction of demand-side factors that affect firms' ability to exert market power and several supply-side factors that influence firms' production costs (Jafari et al., 2022). The relevance and strength of supply- and demand-side factors may vary between organic and conventional products, resulting in a price difference between these two product types.

The demand-side factors consist of a set of socio-economic factors, such as consumers' income level, religious and cultural factors, and other factors, such as information provisions, affecting consumer preferences. As consumers' perceptions of organic and conventional products may be affected by demand factors, this can lead to differences in their willingness to pay for these products (markup effect). In general, consumers may value organic products more than conventional ones because they value the inherent quality characteristics of organic products, that is associated with food safety, and the organic production process, that is, they respect environmental sustainability practices (Huang, Lin, 2007; Van Doorn, Verhoef, 2015; Janssen, 2018; Herrmann et al., 2019; Katt and Meixner, 2020; Bissinger, Herrmann, 2021; Eyinade et al., 2021; Yormirzoev, Teuber, 2021; Hu et al., 2024). The changes in consumers' perceptions may also influence the demand quality elasticity. If the quality elasticity of demand is high, firms producing organic products may reduce their prices to generate higher profits (sale effect) (Chenavaz, 2017). Consequently, two opposing forces on the demand side influence the price premium (or discount) of organic versus conventional products: the positive markup effect and the potentially negative sale effect.

On the supply side, the larger the production cost differences between organic and conventional goods, the greater the price differences between these products, all else being equal. Empirical evidence suggests that the costs of producing and distributing organic products exceed those of conventional products (Abraben et al., 2017; Gschwandtner, 2018). Production of organic products is more labor-intensive and expensive than that of conventional products (Serra et al., 2008). It requires specialized equipment and the use of organic inputs, such as organic seeds and naturally derived pesticides, instead of synthetic chemicals (Oberholtzer et al., 2005; Veldstra et al., 2014). In addition, the production of organic products is more expensive due to organic regulations, such as avoiding sewage sludge, irradiation, and genetic engineering (Carlson, Jaenicke, 2016). Transport and distribution of organic products may incur higher costs due to regulations prohibiting mixing organic and nonorganic products during transport or storage (Carlson, Jaenicke, 2016).[2]

Thus, the overall effect of organic production on price is linked to (positive) cost, (negative) sales, and (positive) markup effects (Chenavaz, 2017). The price premium of organic products may be positive, negative, or neutral, depending on the relative weight of each effect. Although the theory does not answer whether organic products are priced higher than conventional products, empirical studies often suggest that organic food products command a price premium (Maguire et al., 2004; Oberholtzer et al., 2005; Bjørner et al., 2004; Suciu et al., 2019; Katt, Meixner, 2020; FAO, 2020; Hu et al., 2024). However, anecdotal evidence suggests that price discounts for organic products also exist (Bissinger, Herrmann, 2021).

The literature provides a vast array of price premiums (Padel, Foster, 2005; Willer, Sahota, 2020; Winterstein, Habisch, 2021). Depending on consumer segments and product groups, this ranges from 30% to 70% (Jaenicke, Carlson, 2015), from 7% to 60% (Carlson, Jaenicke, 2016), up to 53% (Roediger et al., 2016), from 0% to 105% (Aschemann-Witzel, Zielke, 2017), and from 0% to above 200% (Winterstein, Habisch, 2021). Other studies conclude that a price premium of 10% to 30% is expected, depending on the type of product and location (Huang, Lin, 2007; Gschwandtner, 2018).

Most recently, Liu, Sam (2022) applied the hedonic price model to the Nielsen consumer panel to test how willingness to pay for organic baby products varies along several dimensions: organic label, developmental stage, retail channel, purchasing frequency, and time. The authors show that the willingness to pay is, on average, 17%-27% higher than for conventional alter-

[2] Organic agriculture support programs, such as subsidies to farmers or retailors, may reduce cost differences, but sustaining such support over the long term could be challenging.

natives. Badruddoza et al. (2022) use machine learning to explore the patterns and determinants of monthly organic dairy premiums for whole milk, other fluid milk, yogurt, and eggs over the period 2008-2017 using US retail scanner data, which they estimate in the range 27-56%.

Price premiums may vary significantly across products (Huang, Lin, 2007) due to disparities in their associated demand and across retailers due to heterogeneity in reputation and distribution costs (Fedoseeva et al., 2017). Our primary research question (RQ1) is whether organic products are associated with a price premium or a discount and how large the magnitude of those price differences is on average.

Both demand- and supply-side factors may change over time, resulting in a fluctuating price premium (Fedoseeva, 2020). The COVID-19 pandemic and policy responses to curb the virus's spread are recent examples of disrupted supply chains and changed consumer behavior due to an economic shock (Engemann, Jafari, 2022). Although the pandemic may be viewed as a significant factor in boosting demand for organic products as consumers take better care of themselves when purchasing food at retail locations (Śmiglak-Krajewska, Wojciechowska-Solis, 2021), the economic downturn might have negatively affected some consumers, forcing them to cut back on spending, including on organic products. The pandemic also disproportionally increased demand for particular product categories, such as storable and ready-to-eat convenience foods, that were subject to panic buying and stockpiling (Hillen, 2021, Fedoseeva, Van Droogenbroeck, 2023). On the supply side, the effects are also uncertain. The increased trade barriers and domestic containment measures tend to increase costs. In contrast, the tendency of retailers to clear warehouses due to demand uncertainties, especially if products are perishable, tends to decrease marketing margins. Therefore, our second research question (RQ2) relates to the direction and magnitude of changes in organic price premiums (if any) caused by COVID-19.

The store type, i.e., operating online-only or as a multichannel retailer, is a purchasing venue-related factor that might affect the relative price premium of organic products. Multichannel stores may involve a higher recognition of product quality attributes because consumers can directly obtain information about the products, see, touch, and smell the actual food that they want to purchase, or obtain information online and buy the products in physical stores and vice versa (Kalyanam, Tsay, 2013). Conversely, online-only retailers may offer a wider variety of products associated with the store's ability to command a higher price (Fedoseeva, Herrmann, 2023). Consequently, the impact of store type on the premium for organic products is unclear. This leads to our final research question (RQ3), which examines the direction and magnitude of the store type's impact on the price difference between organic and conventional products.

3 Data and Empirical Specification

3.1 Dataset and Empirical Sample Adjustments

In the empirical part, we use Fedoseeva (2023), the most comprehensive dataset on online food and beverage prices over time available for Germany. The raw data includes daily price quotes for the entire online assortments of foods and beverages for six online-only or multichannel retailers that belong to the largest full-assortment players of the German grocery sector in terms of sales in 2018. The data collection took place from September 1, 2019, to September 30, 2020, for the location Berlin (center), Germany. There are 120,141,112 price quotes in the sample and 910,508 products in the dataset. The resulting panel is unbalanced since not each product is available every day of price collection. Most product price quotes come from the largest online retailer in the country, Amazon.de, and its grocery subsidiary, Amazon Fresh. These are online-only retailers in our sample. Retailers 3-6 are multichannel sellers (Bringmeister, MyTime, Real, and Rewe).

For each product, besides its price and seller identification number (ID), some categorical variables that classify each product price according to the retailer type (online-only or multichannel) or organic attribute are included. Organic products are defined according to Article 23 of European Regulation No 834/2007, which states that only products that satisfy the definition of organic products may include the terms “organic” (“ökologisch” and “biologisch” in German) and their derivatives or diminutives, such as “bio” and “eco” (“öko”) in their label, advertising material, or commercial description (see Fedoseeva for more detail). About 11% of all price observations and products refer to organic products. Across individual retailers, the share of organic products/price quotes for organic products varies between 4 and 20% (Table 1).

Table 1. Share or organic product and individual price quotes across retailers

	Retailer1	Retailer 2	Retailer 3	Retailer 4	Retailer 5	Retailer 6
Share price observations	83.0	2.9	3.6	2.5	3.1	4.9
Share organic product price quotes	10.4	20.4	20.5	3.8	4.8	14.2
Share organic products	10.7	20.0	21.8	4.5	6.1	15.3

Source: own calculations based on Fedoseeva (2023)

All products in the dataset are assigned to the three levels of data aggregation: (i) A broad product groups that are foods and non-alcoholic beverages (97,608,944 observations) vs. alcoholic beverages (22,532,168 observations) according to the Classification of Individual Consumption According to Purpose (COICOP), (ii) 14 aggregated product categories constructed similarly to assortment structure of the largest online retailer in the country, Amazon.de (incl. alcoholic beverages, baby food, cooking ingredients, dairy products, fresh and chilled products, frozen products, fruits and vegetables, instant meals, jams, and spreads, muesli and cereals, non-alcoholic beverages, oils and vinegar, pantry products, snacks and sweets) and (iii) retailer product-group level, the most detailed level of individual product classification at a retailer level. These most detailed product groups were identified before data collection by mapping the entire assortment structure of each retailer’s online shop. The data were collected daily in each initially defined group, with groups remaining unchanged for the analysis period (i.e., eventually added groups after 01.09.2019 are not included). In the raw data, there are 2,578 product groups specified at the retailer level, and the number of product groups and the related precision in the group definition differ significantly across sellers (see Fedoseeva (2023) or online link to the data). These differences in product group classification and disparities in the retailer-specific product ID systems complicate product-on-product comparison as well as direct comparison across disaggregated groups and influence our specification choices in the empirical part. The raw data also does not include the other product characteristics (such as packaging size, brand, and labeling standards) that might be relevant, and this limitation influences our specifications. One important product characteristic missing in the data is the size information, which is not easily extractable on the product pages within and across retailers after a time gap. Ex-post extraction of such information would require item-tailored scraping efforts and detailed matching information that is not revealed in the data openly available. Consequently, while standardizing prices to price per volume units or controlling for size differences would be ideal, data availability remains our main limitation in this regard.[3] Table 2 summarizes the entire dataset across store types and the organic attribute.

[3] It is also important to consider that products come in various volumes (e.g., kilograms, liters, or single units), which complicates this approach (see Edenbrandt et al., 2018, for a discussion of the challenges and proper treatment).

Table 2. Summary statistics for raw data across store type and product type (organic attribute)

Product attribute	Mean price	Median price	Std. dev.	Min	Max	N groups	Distinct products	Observa-tions	Share in total
All retailers	23.16	10.87	48.30	0.01	999.99	2,578	910,508	120,141,112	100
Conventional	23.78	10.98	49.70	0.01	999.99	2,560	808,416	107,022,489	89
Organic	18.14	9.90	34.34	0.01	999.99	1,677	102,092	13,118,623	11
Online-only	26.11	12.99	51.35	0.01	999.99	1,056	828,723	103,257,943	86
Conventional	26.76	12.99	52.81	0.01	999.99	1,046	737,608	92,155,773	77
Organic	20.74	11.99	3.68	0.01	999.99	822	91,115	11,102,170	9
Multichannel	5.14	2.47	9.62	0.05	401.87	1,552	81,785	16,883,169	14
Conventional	5.31	2.40	10.11	0.05	401.87	1,514	70,808	14,866,716	12
Organic	3.83	2.59	4.47	0.16	153.54	855	10,977	2,016,453	2

Source: own calculations based on Fedoseeva (2023)

The distribution of the prices in the raw data has a long right tail (Figure A1 in the Appendix), with individual prices climbing above 999 euros (belonging to alcoholic beverages). We use the interquartile range (IQR) method to remove extreme values that may not be representative of typical grocery retailing, excluding observations that fall below (above) the value of the 25th (75th) percentile of price distribution minus (plus) 1.5 times IQR from the analysis. This process resulted in the removal of 10,193,759 prices. All prices exceeding 53.82 euros, the maximum price considered in the database used for the analysis, were excluded. The estimated lower bound of prices is negative, and no prices are to be dropped from the bottom of the price distribution according to the interquartile method. To eliminate extremely low prices that are sometimes reported for non-foods at the most prominent retailer platform, we truncate prices below 0.1 euro per product. Prices as low as 1 cent may correspond to individual confectionery pieces or noise prices – prices of products that do not belong to a defined product category but are advertised anyway. As a result, 21,742 prices are further removed.

Furthermore, we limit our sample only to include products with more than 100 price observations in the dataset, ensuring they are available for at least 25% of the sample period (10,968,110 observations eliminated). We further drop all products with fewer than 5,000 price observations in total (2,399,749 observations removed) and those that do not include any organic (9,024,037 observations eliminated) or any conventional products (15,566 observations dropped). This sample adjustment allows us to reduce the number of product groups to analyze at the most disaggregate stage and eliminate the noise from product groups and products with only a few observations.

The resulting sample consists of 87,518,149 observations (Table 3). It represents the core of the total product variety (Table 2) online sellers offer, with rarely sold and higher-priced products truncated and organic and conventional products available.[4] Proceeding with a truncated sample allows us to directly compare empirical results obtained from estimations performed at different levels of product aggregation. However, as the threshold choices at each step are somewhat arbitrary, we discuss the limitations of our analysis in conclusions and report the aggregated results obtained with unabridged data (whole sample) and with (only) outliers removed.

[4] The descriptive statistics for the 14 aggregated groups in the truncated sample are included in the Appendix (Table A1)

Table 3. Summary statistics for the empirical sample

Product attribute	Mean price	Median price	Std. dev.	Min	Max	N groups	Distinct products	Observa-tions	Share in total
All retailers	14.13	9.99	12.24	0.10	53.82	1,018	391,191	87,518,149	100
Conventional	14.35	9.99	12.39	0.10	53.82	1,018	343,120	76,849,200	88
Organic	12.55	9.31	12.55	0.15	53.82	1,018	48,071	10,668,949	12
Online-only	15.57	11.90	12.28	0.10	53.82	513	350,662	76,472,645	87
Conventional	15.76	11.95	12.42	0.10	53.82	513	308,879	67,478,763	77
Organic	14.19	11.14	11.06	0.15	53.82	513	41,783	8,993,882	10
Multichannel	4.14	2.40	5.41	0.12	53.79	505	40,529	11,045,504	13
Conventional	4.21	2.30	5.62	0.12	53.79	505	34,241	9,370,437	11
Organic	3.79	2.65	4.03	0.16	50.99	505	6,288	1,675,0673	2

Source: own calculations based on Fedoseeva (2023)

3.2 Empirical Specification(s)

Our empirical method is inspired by a hedonic price function, which assumes that goods are valued based on the utility-generating attributes consumers consider when purchasing them (Rosen, 1974). Under this assumption, the competitive market price of a product equals the sum of the implicit prices paid for specific product characteristics (Edenbrandt et al., 2018). Precise estimation of implicit prices for product attributes requires information regarding all relevant product traits (Edenbrandt et al., 2018) to eliminate omitted variable bias as a source of endogeneity and single out the implicit price of the organic attribute.

Although related and inspired by the literature on hedonic price analysis, our study is not a hedonic price analysis. In contrast, we make use of big data availability, including the complete grocery assortments offered by major retailers, and focus primarily on the price difference between organic and conventional products. We account for factors influencing product group/category prices across retailers, time, and several product groups and categories using fixed effects.

Naturally, there is a trade-off between the degree of data generalization and the precision of the estimated outcomes. Given the scope of the dataset, we are not able to compare the virtually identical products that only differ by their organic status or to account for the multitude of factors (e.g., origin, labeling standards, and packaging size) that contribute to price formation in addition to the organic attribute at the individual product level, as would be possible in a more focused case-study format with more descriptive data on each item available.

Given the data limitations, we assume that the distinction between organic and conventional products is not correlated with other product attributes. This assumption implies no systematic differences between the products offered or purchased through e-commerce, aside from their organic or conventional labelling. This might lead to over- or underestimation of the organic effect depending on how this unaccounted correlation runs. In many cases, however, there is no clear-cut evidence as to why some attributes should affect prices differently for organic vs conventional products. While this assumption may not fully capture the complexity of organic pricing, it is plausible in specific contexts or product categories. Examples include low-differentiation commodities, standardized products by some retailers, and simplified listings on e-commerce platforms. While our assumption could be strong, given the data limitations it enables the analysis by simplifying the relationship between organic labelling and other product characteristics.

To compare prices of organic and conventional products, we use the most granular assortment classification unit available at each grocer to construct retailer-product-group specific fixed effects when estimating sample average organic effects. We note that the large number of observations in our study, the inclusion of all products offered by the included retailer, and the extensive adjustments within each retailer-specific product group have significantly minimized potential bias associated with variations in product composition and size within these detailed groups. We later show that our results remain robust when performing analyses across different data samples.

As a result, our estimates are average product price differences between the population of conventional and organic products. Even if the assumption of independence between the organic label and other attributes is violated, the coefficients can still be considered correlation coefficients between the product price and the organic attribute.

Using (almost) complete grocery assortments for the analysis, we provide an average estimate of the organic price differential in online grocery retailing. Additionally, we demonstrate how these price differentials vary by retailer, and also in response to the most recent global economic shock.

To quantify the price difference between organic and conventional products, we regress (the natural logarithm of) $Price$ of the product i on a binary variable $Organic$, which takes the value of 1 for organic products and 0 for conventional products. We focus on the organic price difference and control for other price determinants by fixed effects. The full set of retailer-specific product-group fixed effects, μ_{jr}, controls for the existing differences in price levels across retailers and product groups. Retailer-specific product groups, j, are the most disaggregated classification of items sold within each retailer, r. Each product, i, can be assigned to a retailer-specific most disaggregated product group, j, which can be further assigned to one of 14 aggregated product categories discussed above, k, or further matched to broader product groups food and non-alcoholic beverages or alcoholic beverages according to COICOP classification, l.

Following Fuest et al. (2021), we include month-product group effects, ϖ_{lt}, to capture the specific price development over time for the broad product group. We distinguish between alcoholic beverages vs. food and non-alcoholic beverages according to the 2-digit level of the COICOP classification. We also add retailer-weekday fixed effects, ψ_{rt}, to capture possible weekly price-adjustment patterns (e.g., price promotions), and cluster standard errors at the product level to account for possible within-cluster correlation.

The baseline model (1) we bring to data to quantify the price difference between organic and conventional products (RQ1) is

$$lnPrice_{i(j,k,l)rt} = \alpha + \beta\, Organic_i + \mu_{jr} + \varpi_{lt} + \psi_{rt} + \upsilon_{irt}. \tag{1}$$

where α and β denote the price of the conventional product (when *Organic*=0) and the organic price difference (when *Organic*=1), respectively. The dependent variable is the natural logarithm of the respective price, and the organic price difference in percent can be calculated as $\left(e^{\beta} - 1\right) \times 100$ (Halvorsen and Palmquist 1980).

To account for pandemic-driven price adjustments (RQ2), we augment Equation 1 by the *Covid* variable, approximated by the stringency index (see Hale et al. (2021) for stringency index definition; Fedoseeva, Van Droogenbroeck (2023) for an application), which measures the severity of pandemic restrictions:

$$lnPrice_{i(j,k,l)rt} = \alpha + \beta\, Organic_i + \gamma Covid_t + \mu_{jr} + \varpi_{lt} + \psi_{rt} + \upsilon_{irt}, \tag{2}$$

and an interaction term between *Organic* and *Covid* variables to test whether prices for organic products were affected differently by the pandemic restrictions than prices of conventional products:

$$lnPrice_{i(j,k,l)rt} = \alpha + \beta\ Organic_i + \gamma Covid_t + \delta Organic_i \times Covid_t + \mu_{jr} + \varpi_{lt} + \psi_{rt} + \upsilon_{irt}, . \quad (3)$$

In Equation 3, γ describes a change in (log) prices of conventional products as the value of the stringency index increases by one unit, while the coefficient related to the interaction term, delta, shows the difference in pandemic-induced response in prices of organic products compared to conventional products.

Finally, we interact the *Organic* variable with the store type (online-only vs. multichannel) to address RQ3:

$$lnPrice_{i(j,k,l)rt} = \alpha + \beta\ Organic_i + \gamma Covid_t + \delta Organic_i \times Covid_t + \varepsilon\ Organic_i \times Online_r + \mu_{jr} + \varpi_{lt} + \psi_{rt} + \upsilon_{irt}, \quad (4)$$

Online takes the value of 1 if the price comes from the retailers in our sample that operate online only and is 0 for multichannel retailers. The binary variable for the store type, as a standalone explanatory variable, is omitted from the model due to its collinearity with fixed effects. As in Equation 1, the constant α represents the average price of conventional products (with no pandemic-related restrictions implemented). Hybrid retailers are the reference group in Equation 4, and the organic price differential associated with multichannel retailers (*Organic*=1 and *Online*=0) is captured by the coefficient β. The coefficient ε refers to the price difference for the organic attribute associated with online-only retailers (*Organic*=1 and *Online*=1).

Since COVID-19 restrictions asymmetrically affected prices of multichannel and online-only retailers (Fedoseeva and Van Droogenbroeck 2023), we augment the final specification with an interaction term for pandemic-related price change for organic products sold by online-only retailers:

$$lnPrice_{i(j,k,l)rt} = \alpha + \beta\ Organic_i + \gamma Covid_t + \delta Organic_i \times Covid_t + \varepsilon\ Organic_i \times Online_r + \epsilon Organic_i \times Covid_t \times Online_r + \mu_{jr} + \varpi_{lt} + \psi_{rt} + \upsilon_{irt}, \quad (5)$$

in which the coefficient ϵ refers to the price difference for the organic attribute associated with online-only retailers (*Organic*=1 and *Online*=1) as the stringency index increases by one unit).

In the following section, we estimate Equations 1-5 for the whole empirical sample, and provide some details about the results for the disaggregated product groups. We only report outcomes obtained from the final specification in Equation 5 for the disaggregated results.

4 Results

One needs to keep in mind that our organic price estimates are average price differences between conventional and organic products in the sample once we control for a variety of retailer-, product category/group- and time-specific effects. They are a product of various non-observable product attributes (origin, producer reputation, etc) and the organic trait and, as such, are rather correlation coefficients than hedonic prices and need to be taken with a grain of salt.

Table 4 displays the results corresponding to empirical specifications in Equations 1-5 evaluated with data with outliers and not frequent observations eliminated, as described in the previous section. Results for the raw data (Table A2 in the Appendix) and for data adjusted for outliers only (Table A3 in the Appendix) suggest that the empirical sample approximates the full dataset quite well at the aggregate level as the estimation results are robust to sample selection.

On average, organic products are approximately 4.8% - 5.5% more expensive than conventional products under the ceteris paribus assumption[5]. Average prices declined somewhat due to pandemics (-0.08%). Such price development within product categories has been earlier attributed to changes in product composition within product groups: As the pandemic spread, many sellers gradually shifted to less expensive products in their assortments, while prices of goods that remained in the assortment rather increased (Fedoseeva, Droogenbroeck, 2023). The pandemic effect on average organic prices is smaller in magnitude: -0.03% and -0.04% per unit change in stringency index for conventional and online-only retailers, respectively ((-0.0008+0.0005) ×100 vs (-0.0008+0.0005-0.0001) ×100). The price difference between organic and conventional products seems to be somewhat lower online only, although the coefficient at the interaction variable is not always statistically significant.

Table 4. Price differences between organic and conventional products (empirical sample)

	(1)	(2)	(3)	(4)	(5)
Organic	0.047***	0.047***	0.052***	0.079***	0.054***
	(0.004)	(0.004)	(0.004)	(0.008)	(0.008)
Covid		−0.0008***	−0.0008***	−0.0007***	−0.0008***
		(0.000)	(0.000)	(0.000)	(0.000)
Organic x Covid			−0.0002***	−0.0002***	0.0005***
			(0.000)	(0.000)	(0.000)
Organic x Online				−0.031***	−0.002
				(0.009)	(0.010)
Organic x Covid x Online					−0.001***
					(0.000)
Constant	2.208***	2.228***	2.227***	2.227***	2.227***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Retailer- product group FEs	Yes	Yes	Yes	Yes	Yes
Retailer- day of the week FEs	Yes	Yes	Yes	Yes	Yes
Month-product category FEs	Yes	Yes	Yes	Yes	Yes
Adj. R-squared	0.44	0.44	0.44	0.44	0.44
Number of observations	87,518,149	87,518,149	87,518,149	87,518,149	87,518,149
Number of products	391,191	391,191	391,191	391,191	391,191

Notes: ***p < 0.001, **p < 0.01, *p < 0.05. All equations are estimated in Stata 15 with a reghdfe estimator (Correia, 2017). Robust standard errors (in parentheses) are adjusted for 391,191 clusters in product ID.
Source: estimation results

Splitting the products into alcoholic and food and non-alcoholic beverages according to a two-digit COICOP classification (Table 5) and re-estimating as in column 5 of Table 4 (i.e., estimating Equation 5) suggests that the latter category primarily drives the sample average estimate. For alcoholic beverages, the organic coefficients are not statistically significant, while those for grocery items closely follow sample averages.

5 See Section 3.2 for the calculation of the numbers, following Halvorsen, Palmquist (1980).

Table 5. Relative price premium for the organic attribute
(food and non-alcoholic beverages vs. alcoholic beverages)

	Food and non-alcoholic beverages	Alcoholic beverages
Organic	0.057***	-0.019
	(0.008)	(0.049)
Covid	−0.001***	0.0001***
	(0.000)	(0.000)
Organic x Covid	0.0006***	0.0002
	(0.000)	(0.000)
Organic x online	−0.003	-0.042
	(0.009)	(0.055)
Organic x Covid x online	−0.001***	0.001
	(0.000)	(0.009)
Constant	2.096***	2.978***
	(0.001)	(0.002)
Retailer-product group FE	Yes	Yes
Retailer-day of the week FEs	Yes	Yes
Month-product category FE	Yes	Yes
Adj. R-squared	0.40	0.26
Number of observations	74,627,155	12,890,994
Number of products	335,089	56,102

Notes: ***p < 0.001, **p < 0.01, *p < 0.05. All equations are estimated in Stata 15 with a reghdfe estimator (Correia, 2017). Robust standard errors (in parentheses) are clustered at the product level.
Source: estimation results

Descending to the next level of product disaggregation would provide more insights across the product categories and facilitate the cross-category comparison. However, a proper explanation of the possible differences in size and magnitude of price differences within each product category requires more detailed data on product-specific attributes in each product group, which we do not possess. Nonetheless, to provide insights into the heterogeneity of the price differences, we repeat the analysis at each retailer's most detailed classification level.

The magnitudes of price differences between organic and conventional products increase when we individually assess each retailer's most detailed classification level. Here, we calculate interaction terms between the organic variable and vector of disaggregated retailer-level product categories. Over half (582) of 1,018 coefficients for organic price difference at the retailer classification level are positive. 632 coefficients are not statistically significant at the 95% level. Of the remaining 387 statistically significant coefficients, 245 are positive, and 142 are negative. Figure 1 plots the cumulative distribution of all coefficients (left) and the distribution of statistically significant coefficients (right) across retailer groups. While positive and negative correlations exist within some of the retailer product-group level, the number of positive coefficients prevails.

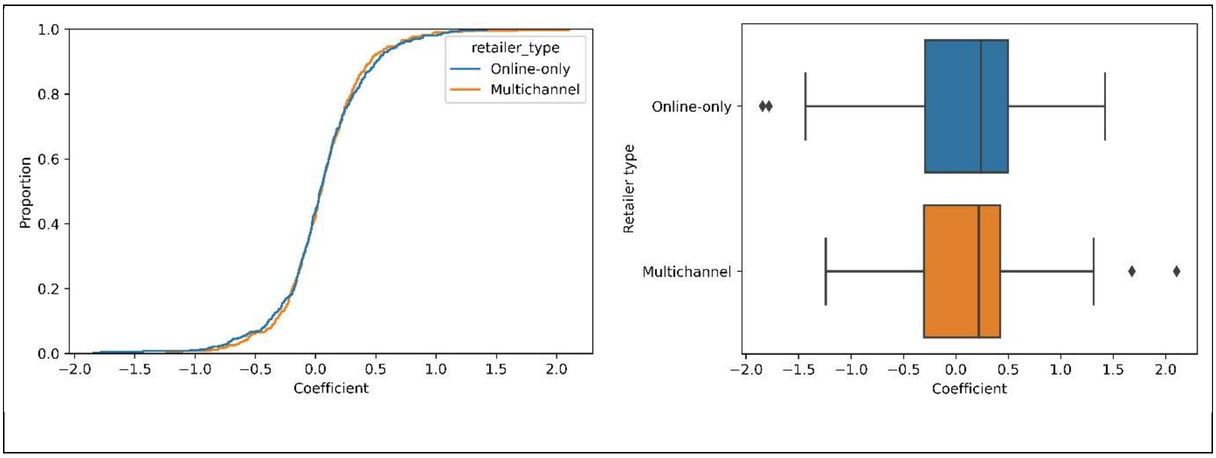

Figure 1. Cumulative distribution of all (left) and statistically significant (right) estimated organic price differences at the detailed retailer-product group level across retailer type

Source: own illustration based on estimation results

5 Discussion, Limitations, and Conclusions

The areas under organic farming keep expanding to meet the continuously growing demand for organic foods. The perilous ecological situation and fairness, health, and food safety concerns that gained prominence during the COVID-19 pandemic drive sales and amplify the importance of understanding the links between the willingness to pay for organic attributes and the capacity to convert it into organic price premiums. Although consumer attitudes toward organic products and their resulting willingness to pay have been the subject of numerous empirical studies, information regarding price premiums, especially in online retailing, is more scattered. In this study, we sought to examine the average price difference between organic and conventional products (RQ1) in German grocery retailing using price information collected from major online-only and multichannel German grocery retailers for their entire food and beverage assortments.

Our estimates fit reasonably well into the existing body of empirical findings and are within the range of what consumers are found to be typically willing to pay for organic labels, although, with an estimated price premium of about 5%, we are rather on the left of the (positive) price premium distribution. The positive average price difference for organic products indicates that even when the entire grocery assortment is concerned, organic prices are higher than prices for conventional products, corroborating consumers' willingness to pay for organic attributes.

Average grocery prices declined somewhat due to pandemics, although this decline was less pronounced for organic goods (RQ2), with some heterogeneity of organic product price developments across store types. No clear-cut difference could be found in the price difference between organic and conventional products across retailer types (RQ3). If anything, the price differentials are slightly lower for online-only retailers.

When evaluating the results, one should consider our analysis's limitations. The coefficients we report are not price premiums for the organic price attribute from a hedonic price model, in which all product-related features are known and quantified. Our estimates are differences in average prices of organic and conventional products within product groups, defined at the retailer level's most disaggregated level. The product IDs and individual product groups in the data are not matched across retailers. We treat each product as an individual item and incorporate dummy variables representing its division into 14 categories provided in the dataset when calculating average price differences. Product groups, especially for online products, have been the subject of heated debates over recent years, and there seems to be no uniquely available way to assign products across product groups.

To estimate the organic price differences in a dataset of many million observations, we had to adjust the raw data. Although we applied a standard tool for eliminating extreme values (interquartile range method), an alternative method would potentially result in a different sample size. The same applies to threshold choices in selecting the product categories in the empirical sample. To test the sensitivity of the results to these sample choices, we provide the estimation results for Equations 1-5 for both raw data and the sample following the outlier elimination. The robustness of our results suggests that the empirical sample we chose is a good enough representation of the raw data. Yet, the arbitrariness of sample selection choices should be considered when interpreting the results.

Data availability with respect to several characteristics of the products is also a limitation of our study. Organic attribute correlates with several product characteristics (e.g. packaging size, brand, origin, labeling standards), but in light of data limitations, we assume these are uncorrelated. This might lead to over- or underestimation of the organic effect depending on how this unaccounted correlation runs. In many cases, however, there is no clear-cut evidence as to why some attributes should affect prices differently for organic vs conventional products. Importantly, the size information is not included in the dataset and is not easily extractable on the product pages within and across retailers after a time gap. Ex-post extracting such information would require item-tailored scrapping efforts and detailed matching information that is not revealed in the data openly available. Nonetheless, the data we used was the first effort of large-scale food price data collection undertaken around the first Covid wave time. Up to date, we are not aware of existing efforts to consider the uncovered research needs for more detailed data in agricultural and food empirics that are common in related fields. Accordingly, our study that includes this broader range of products compared to the literature comes at the cost of less accurate estimation of the price differences between organic and conventional products. For this reason, the estimated coefficients better be interpreted as an average price difference between the population of conventional and organic products rather than price premiums.

Finally, our data includes the six largest German online grocery retailers. Although these sellers are major market participants in both online-only and offline food retailing, the results we record are for these sellers only and cannot be easily generalized to other sellers or markers.

Analysing and plausibly explaining the possible heterogeneity in organic price differences across product categories requires more detailed data on product-specific attributes within each product group, which we do not possess. Although ex-ante data collection might technically be feasible for the products that respective retailers still offer under constant IDs, such data effort needs a lot of planning and time investment and is outside the scope of our study.

It is straightforward to assume that looking into product categories or groups of related categories across retailers with detailed information on product attributes at hand would provide results more precisely than we can obtain given the data limitations. That is, there is much potential for hedonic price analysis using online data.

Data

Fedoseeva, S. (2023): Grocery prices in German e-commerce [Data set]. Zenodo https://doi.org/10.5281/zenodo.8028017.

Statements and Declarations

There are no conflicts of interest to declare.

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Appendix

Table A1. Summary statistics for the truncated data across product categories

	Conventional			Organic			Share organic
	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	
Baby food	10.91	9.81	1,154,897	7.11	8.92	544,100	0.32
Non-alcoholic bevs.	15.84	12.32	10,036,214	14.67	11.50	1,665,364	0.14
Alcoholic beverages	24.56	13.57	12,648,948	20.76	15.28	242,046	0.02
Instant meals	9.65	10.20	4,842,983	10.11	10.60	555,717	0.10
Cooking ingredients	10.90	9.63	12,402,464	12.38	10.13	2,148,225	0.15
Jams and spreads	13.14	10.75	2,824,184	11.54	9.98	642,348	0.19
Muesli and cereals	10.66	10.52	1,050,374	10.46	9.64	441,918	0.30
Pantry products	11.90	10.72	2,726,203	13.83	10.87	752,495	0.22
Oil, vinegar and dips	13.01	10.69	6,571,938	13.89	10.28	1,282,910	0.16
Snacks and Sweets	12.87	11.07	17,028,778	14.34	11.20	1,502,595	0.08
Dairy products	7.22	9.87	1,953,616	8.10	10.40	460,332	0.19
Fruits and vegetables	19.98	17.03	679,895	7.33	9.09	109,854	0.14
Fresh and chilled products	10.63	11.62	1,650,851	7.05	9.06	185,432	0.10
Frozen products	6.26	6.87	1,277,855	5.50	6.46	135,613	0.10

Source: own calculations based on Fedoseeva (2023)

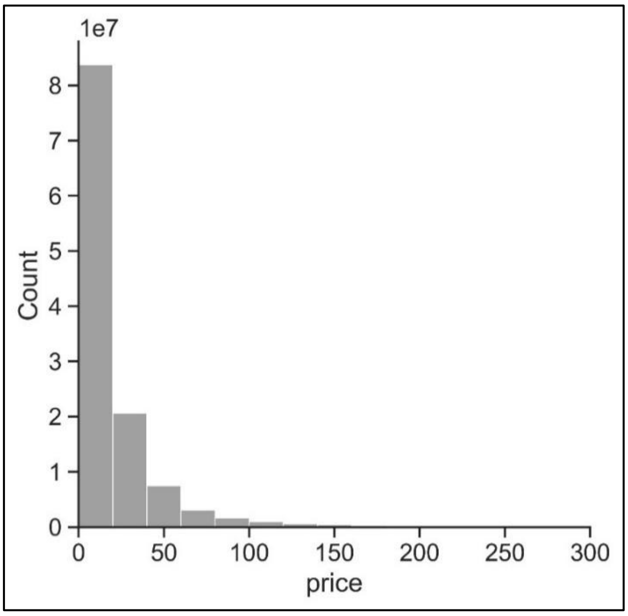

Figure A1. Price distribution (total sample truncated at 300 euro)

Notes: prices above 300 euro are truncated to enhance the visualization
Source: own calculations based on Fedoseeva (2023)

Table A2. Price differences between organic and conventional products (raw data)

	(1)	(2)	(3)	(4)	(5)
Organic	0.042***	0.042***	0.054***	0.086***	0.055***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Covid		-0.0004***	-0.0004***	-0.0004***	-0.0004***
		(0.00)	(0.00)	(0.00)	(0.00)
Organic x Covid			-0.0005***	-0.0005***	0.0004***
			(0.00)	(0.00)	(0.00)
Organic x online				-0.035***	-0.0001
				(0.00)	(0.01)
Organic x Covid x online					-0.0012***
					(0.00)
Constant	2.370***	2.381***	2.380***	2.380***	2.380***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Adj. R-squared	0.50	0.50	0.50	0.50	0.50
Retailer-product group FEs	Yes	Yes	Yes	Yes	Yes
Retailer-day of the week FEs	Yes	Yes	Yes	Yes	Yes
Month-product category FEs	Yes	Yes	Yes	Yes	Yes
Number of observations	120,141,109	120,141,109	120,141,109	120,141,109	120,141,109
Number of products	910,505	910,505	910,505	910,505	910,505

Notes: ***p < 0.001, **p < 0.01, *p < 0.05. All equations are estimated in Stata 15 with a reghdfe estimator (Correia, 2017). Robust standard errors (in parentheses) are adjusted for 910,505 clusters in product ID.
Source: estimation results

Table A3. Price differences between organic and conventional products (raw data with outliers removed)

	(1)	(2)	(3)	(4)	(5)
Organic	0.046***	0.046***	0.054***	0.084***	0.058***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Covid		-0.0006***	-0.0006***	-0.0006***	-0.0006***
		(0.00)	(0.00)	(0.00)	(0.00)
Organic x Covid			-0.0003	-0.0004***	0.0004***
			(0.00)	(0.00)	(0.00)
Organic x online				-0.034***	-0.004
				(0.00)	(0.01)
Organic x Covid x online					-0.001***
					(0.00)
Constant	2.164***	2.180***	2.180***	2.179***	2.179***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Retailer-product group FEs	Yes	Yes	Yes	Yes	Yes
Retailer-day of the week FEs	Yes	Yes	Yes	Yes	Yes
Month-product category FEs	Yes	Yes	Yes	Yes	Yes
Adj. R-squared	0.48	0.48	0.48	0.48	0.48
Number of observations	109,925,608	109,925,608	109,925,608	109,925,608	109,925,608
Number of products	812,188	812,188	812,188	812,188	812,188

Notes: ***p < 0.001, **p < 0.01, *p < 0.05. All equations are estimated in Stata 15 with a reghdfe estimator (Correia, 2017). Robust standard errors (in parentheses) are adjusted for 812,188 clusters in product ID.
Source: estimation results