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Journal of Business Research 192 (2025) 115285

Contents lists available at ScienceDirect

Journal of Business Research

journal homepage: www.elsevier.com/locate/jbusres

Exploring the role of product attributes in 9-ending pricing strategies: A study on online retailing

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ARTICLE INFO

Keywords:
E-commerce
Psychological prices
Odd prices
Just-below prices
Price strategy

ABSTRACT

This study investigates the use of 9-ending pricing strategies in e-commerce by analyzing over 50,000 shoe prices. Using web scraping and a logit model from a German online retailer, the research assesses how product attributes influence the adoption of 9-ending prices. Key findings reveal that 9-ending prices are predominantly used for female and newly introduced products, as well as for items with lower and standard prices. The study also explores the effects of exclusivity and sustainability on pricing strategies, showing that their impact varies with different 9-ending price categories. Overall, this research demonstrates the complex nature of 9-ending pricing strategies, with the 9-zero removal model supporting all hypotheses, whereas the 99c and 95c models show differential effects. This extends our understanding of pricing tactics in online retail and highlights the significance of product attributes for marketing and sales strategies.

1. Introduction

The 9-ending pricing strategy (also known as psychological, odd, or just-below pricing) employs prices just below a round number (e.g., ending with 9 cents or 99 cents instead of a whole unit – either euro, dollar or other reference currency) as a persuasion technique in consumer decision-making. The 9-ending pricing strategy has been consistently adopted for several decades (Strulov-Shlain, 2023; Troll et al., 2023) and is a common practice in both retail (Fraccaro et al., 2021) and e-commerce settings (Hillen, 2021; Jeong & Crompton, 2017; Snir & Levy, 2021). Extant literature highlights an over-representation of 9-ending prices compared to even prices (i.e., ending with one or more zeros) and precise prices (i.e., those that do not follow an ending pattern). Some estimates suggest that 9-endings may account for between 30 and 95 percent of all retail prices (Snir & Levy, 2021). The popularity of 9-ending prices is generally attributed to their expected impact on consumer behavior and the consequent effects on business performance, particularly on sales. Strategies involving 9-ending prices are expected to foster sales (Anderson & Simester, 2003; Kim et al., 2022; Lopez-Pastor et al., 2020; Troll et al., 2023) due to their positive influence on price perceptions (Chen, 2023; Kim et al., 2022; Snir & Levy, 2021) and consumer attitudes (Ortega & Tabares, 2023). Furthermore, the literature indicates that the beneficial impacts of 9-ending strategies (or 9-endings) extend beyond end-consumers, affecting traders in global markets (Chen, 2018). In a recent study, Troll et al. (2023) performed a *meta*-analysis of findings in the literature, confirming that the use of 9-endings generally leads consumers to underestimate prices without harming the quality image of the products. This creates a price perception advantage and contributes positively to the purchase decision. However, the authors caution against a high presence of non-significant effects, the heterogeneity of results, and the moderating effect of price and product characteristics.

Our study addresses two main inconsistencies identified in the literature on 9-endings. First, there is a significant gap in the research into 9-endings as a pricing strategy associated with the type of product characteristics or attributes. Although the body of literature on 9-endings is expanding, most studies focus on the effects on consumer perceptions and purchase behaviors (e.g., Hodges et al., 2022; Laurent et al., 2023; Sokolova et al., 2020; Troll et al., 2023). Research exploring managers' use of 9-endings remains limited, with very few exceptions (e.

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https://doi.org/10.1016/j.jbusres.2025.115285
Received 22 September 2023; Received in revised form 27 February 2025; Accepted 2 March 2025
Available online 8 March 2025

g., Aalto-Setälä & Halonen, 2004; Hillen, 2021; Jeong & Crompton, 2017; Snir & Levy, 2021). Recent literature calls for further investigation into 9-endings as a pricing strategy (e.g., Ortega & Tabares, 2023; Snir & Levy, 2021). For example, Strulov-Shlain (2023) stressed that, besides popularity, little is known about the 9-ending strategies and practices of companies. Indeed, the literature mostly evaluates the adoption of 9-endings by several businesses, such as luxury fashion brands (Aiello et al., 2018; Fraccaro et al., 2021; Parguel et al., 2021), hotels (Boyol Ngan et al., 2021), tourism services (Dang et al., 2024; Jeong & Crompton, 2017), automotive retail (Aalto-Setälä & Halonen, 2004), gasoline retail (Huck et al., 2021), supermarkets (Aalto-Setälä & Halonen, 2004; Snir & Levy, 2021; Strulov-Shlain, 2023), and online food retail (Hillen, 2021). Likewise, the literature suggests that the prevalence of 9-ending prices varies according to product attributes. Based on a *meta*-analysis of the behavioral literature, Troll et al. (2023) emphasized that product characteristics and price levels moderate the impacts of 9-endings on consumers. More than one decade ago, Macé (2012) stressed the need to consider a wide range of variables in studying 9-ending price strategies. However, this gap has not yet been adequately addressed.

Snir et al. (2022) highlight the diversity of outcomes reported in the literature, suggesting that the use of 9-endings varies with both product attributes and retailers themselves. In line with this, Ortega and Tabares (2023) recommend that managers consider diverse product attributes when defining 9-ending strategies, including category, price level, brand type, and consumer product involvement. Interestingly, Hillen (2021) found that, in online food retail, 9-endings are more common in low-price and "want" products compared to high-price and "should" products. Additionally, 9-endings are believed to be less adequate for luxury and high-quality products (Aiello et al., 2018; Fraccaro et al., 2021; Parguel et al., 2021). Overall, investigations into product attributes in the 9-ending literature, beyond price and category, are scarce and fragmented. This highlights the need for a more holistic approach to analyzing retailers' pricing strategies, one that considers a wider range of product characteristics.

The second major area identified in the literature is the inconsistent definition of 9-endings. Empirical studies employ various interpretations of 9-endings, including prices with 9 in the cents position (Boyol Ngan et al., 2021; Hillen, 2021; Jeong & Crompton, 2017; Snir et al., 2022; Snir & Levy, 2021) and in the thousandths position (e.g., Huck et al., 2021), prices ending in 99 cents (e.g., Aparicio & Simester, 2022; Hodges et al., 2022; Schindler, 2001; Strulov-Shlain, 2023), prices with a 9 as the last dollar digit (e.g., Anderson & Simester, 2003), and prices having 9 as the first non-zero digit to the right (e.g., Aalto-Setälä & Halonen, 2004; Jeong & Crompton, 2017; Schindler, 2009), namely in the tens position (Fraccaro et al., 2021; Parguel et al., 2021). Snir and Levy (2021) note that some typologies overlap (e.g., 99 cents is a subset of prices ending in 9 cents). How this inconsistency may bias results and contribute to mixed findings in the literature is yet to be known. Aiello et al. (2018) attempted a broad approach, identifying a price as 9-ending if it featured a 9 in any position, except the most significant digit to the left. However, their aggregate analysis did not account for the possibility of prices being classified differently across typologies, leaving a gap in understanding the full implications of 9-ending diversity. This gap is significant and recent studies show that consumer responses to 9-endings differ as they are influenced by factors such as numeracy skills (Hodges et al., 2022) and price simplification strategies (Laurent et al., 2023). As 9-ending typologies vary in complexity, it can be inferred that consumers process them differently, thus affecting their perceptions and decision-making. Strulov-Shlain (2023) recommends finer digit discrimination in future 9-ending research due to the significant implications on business profitability. In line with these contributions, we argue for an extended analysis of 9-ending strategies to better inform business pricing tactics.

Building on the inconsistencies found in the literature, this article aims to delve deeper into e-commerce 9-ending pricing strategies by exploring those product attributes (e.g., sustainability, exclusiveness, novelty, price level) associated with alternative 9-ending prices, particularly in a footwear e-commerce setting. Although the literature provides contributions on the use of 9-ending prices in e-commerce (Hackl et al., 2014; Hillen, 2021; Lee et al., 2009), studies in the online context are still scarce (especially in the fashion sector). Currently, fashion is the largest e-commerce segment, accounting for almost 27 % of all e-commerce sales (Statista, 2021a). Within the fashion sector, footwear is an ideal industry to study pricing strategies as it has established a strong online presence, with online retail sales accounting for 31.5 % of global footwear sales in 2021 (Statista, 2021b) – despite shoes being considered an experience good, which potentially limits online sales (Zhang et al., 2018).

This article makes several contributions to the field of marketing management, specifically in relation to the concept of 9-ending prices. First, this work adds to the ongoing scholarly debate surrounding 9-endings by exploring the various typologies present in the literature. To the best of the authors' knowledge, this is the first article that studies and compares alternative 9-ending price typologies that have been adopted in retail (e.g., 9 cents, 99 cents, 9 as the first non-zero digit to the right), thus providing a more comprehensive understanding of this phenomenon. Second, this study further contributes to the clarification of the adoption of 9-endings as a marketing strategy, by considering the attributes of products from an analytical perspective. In particular, this study combines attributes that have been frequently explored by extant literature – namely price level – with other important characteristics of the products, providing a novel and more comprehensive explanation of the factors behind 9-ending strategies. Third, by testing a set of attributes for alternative price endings offers additional validation to the findings and this helps address previous inconsistencies in the literature.

The organization of this article is as follows. The following section highlights the primary contributions in the literature relating to 9-ending price strategies and their association with product attributes. The methodology section describes the data collection and the analysis procedures employed. Then, the results are presented and discussed. The final section provides conclusions, including theoretical contributions, implications for managers, and future research directions.

2. Literature review and hypothesis development

2.1. Psychological pricing

Psychological pricing strategies are employed to make products more appealing to customers (Jošić & Žmuk, 2020), reduce the level of guilt that might be associated with purchases (Fraccaro et al., 2021; Parguel et al., 2021), and exert an influence on their buying decisions (Anderson & Simester, 2003; Kim et al., 2022; Lopez-Pastor et al., 2020; Troll et al., 2023). One common strategy is the use of just-below round numbers, particularly nines on the right-hand side of prices.

Two theoretical underpinnings guide the extant literature aiming to explain why consumers tend to associate 9-endings with low prices: 1.) the prospect theory provides an explanation identified as "image effect" and, 2.) the underestimation mechanism or left-digit bias that introduces the "level effect". According to the "image effect", 9-endings can convey information about a product's price level and quality, and are associated with lower quality, lower prices, and products that are "on sale" (Fraccaro et al., 2021; Hillen, 2021; Schindler, 2001, 2006; Schindler & Kibarian, 2001). On the other hand, the "level effect" posits that consumers tend to overlook or undervalue the rightmost digits of a price due to the cognitive costs of processing this specific information (Bizer & Schindler, 2005; Macé, 2012; Schindler & Kirby, 1997) and because they scan prices from left to right, with differences in units having a greater impact on perceptions than differences in cents (Chen, 2023; Manning & Sprott, 2009; Sokolova et al., 2020; Thomas & Morwitz, 2005). Consequently, the left-digit bias means consumers perceive a 9-ending price as significantly lower than the just-above round price (Strulov-Shlain,

2023).

More recently, Laurent et al. (2023) proposed a "Reading and Verbal Encoding Theory" that questions the left-digit bias. This theory demonstrates that consumers look at both the cents and the units part of a price to help them encode the price effectively. However, they confirmed that consumers tend to adopt simplification strategies to encode and memorize a price. Hodges et al. (2022) further stress that consumers' characteristics, especially numeracy skills, also affect their responses to odd prices, particularly 9-endings. In line with these contributions, 0-endings (also known as "even prices") are sometimes used by high-end retailers as a way to reinforce the high quality of their products (Fraccaro et al., 2021; Parguel et al., 2021).

In addition, 5-ending prices are easily processed by consumers, leading some authors to classify 5-endings as round numbers (Huck et al., 2021; Macé, 2012; Naipaul & Parsa, 2001). As noted by extant literature, prices ending in 5 are extensively adopted (Jošić & Žmuk, 2020), particularly those ending in 95 cents (Naipaul & Parsa, 2001). However, opinions in the literature on 5-ending prices are not unanimous, and some authors stress that they should also be considered odd prices (e.g., Gendall et al., 1998; Tripathi & Pandey, 2017; Wagner & Beinke, 2006). This can be explained by the fact that these prices are seen as "just-below-round" prices (Choi et al., 2014; Gendall et al., 1998; Jošić & Žmuk, 2020; Schindler, 1984; Wagner & Beinke, 2006), distinguishing them from "even prices" and, consequently, having a consumer impact similar to that observed for 9-endings (Tripathi & Pandey, 2017).

2.2. Product attributes and price endings

Previous research has established that the prevalence of 9-ending prices cannot be generalized across all products and is, instead, contingent upon specific product characteristics (Hillen, 2021; Lee et al., 2009; Macé, 2012; Ortega & Tabares, 2023; Troll et al., 2023). Based on this understanding, this section explores the attributes of shoes that are relevant in the context of 9-ending pricing strategies in online retail, and from this, we propose a set of research hypotheses.

The impact of 9-endings on sales is contingent upon the product's price level and is usually stronger for less expensive products. Indeed, the use of 9-endings is often associated with lower-quality products, which contrasts with the high-quality message conveyed by higher prices (Diamantopoulos et al., 2021; Schindler, 2001, 2006; Schindler & Kibarian, 2001; Stiving, 2000). As a result, 9-ending pricing is less common in higher-priced items so as to signal their high quality (Fraccaro et al., 2021; Hackl et al., 2014; Hillen, 2021; Lee et al., 2009; Parguel et al., 2021). This perception is further analyzed by consumer psychology, which asserts that higher prices often denote superior quality and exclusivity, factors that are diminished when prices end in 9 (Lee, 2013). Additionally, premium brands and retailers frequently opt for rounded price endings to align with a more upscale and polished brand image, further deterring the use of 9-endings in this segment. Also, the low-quality association with 9-endings is even stronger in product categories where buyers are unable to determine the actual quality of the product before purchasing (Stiving, 2000), as with experience goods bought online (such as footwear). Thus, as fewer 9-ending prices are expected as the price level of shoes increases, it is hypothesized that:

H1: The use of 9-ending prices is negatively associated with the price of shoes.

The literature on consumer behavior has consistently explored the influence of gender on purchasing decisions and the responsiveness to different pricing strategies. While several studies on price endings have chosen the women segment as the main focus (e.g., Fraccaro et al., 2021), gender is typically restricted to sample characterization and not emphasized as an explanatory variable. However, recent consumer studies stress the importance of gender, particularly when looking at price sensitivity (Gao et al., 2020). The literature reports evidence of a gender-based differential in responsiveness to 9-endings, with female shoppers exhibiting greater sensitivity compared to male shoppers (Baumgartner & Steiner, 2007; Harris & Bray, 2007; Lepeyko et al., 2019). This differential response is particularly notable in markets where gender roles and expectations significantly influence consumer behavior, with women often perceived as more value-conscious and attentive to cost, which may make them more receptive to pricing cues like 9-endings (Harris & Bray, 2007; Lepeyko et al., 2019). Therefore, it is anticipated that this pricing strategy is predominantly utilized in products specifically targeted at a female consumer base. As a result, it is hypothesized that:

H2: 9-ending prices are more frequently utilized in shoes targeted toward women compared to shoes targeting men.

Product novelty is another attribute that is frequently emphasized in online retail footwear. Consumers experience a higher level of uncertainty when purchasing newly introduced products, as the performance of such items is yet to be determined. Therefore, price ending may serve as a valuable cue for guiding consumer decision-making (Anderson & Simester, 2003; Fraccaro et al., 2021; Macé, 2012). As a result, 9-endings are expected to be a particularly useful pricing strategy for newly launched shoes, as consumers are more likely to rely on the economic signal conveyed by such a price ending (i.e., a stronger price-image effect). Furthermore, the strategic use of 9-endings in new releases may serve to capture initial consumer interest and competitiveness in a saturated market, where standing out with attractive pricing can significantly influence early product adoption (Dogerlioglu-Demir et al., 2022; Ortega & Tabares, 2023). Hence, the third research hypothesis is:

H3: 9-ending prices are more frequently utilized in shoes labeled as "new releases" than in other shoes.

A popular strategy for differentiating from competitors has been the sale of retailer-exclusive products (Mehra et al., 2018; Song et al., 2020). Consumers who seek exclusivity are believed to be less sensitive to price (Kupiec & Revell, 2001), as they are often willing to pay higher prices for intangible benefits. Although many luxury consumers prefer prices just below the round number (Fraccaro et al., 2021), when a product is only available on a specific retailer's website, it creates a "customer lock-in" situation. As a result, retailers do not need to convey a message of "low-price" or "good deal" when pricing such products. This differentiation strategy reinforces the perception of premium value and uniqueness, discouraging the association with more common pricing tactics like 9-endings that might undermine the exclusive appeal (Holmes & Otero, 2023). Thus, the proposed hypothesis is:

H4: The use of 9-ending prices is less prevalent in shoes classified as "exclusive" compared to shoes without such labeling.

Product design is often associated with luxury and with consumers' willingness to pay a premium price (Hemonnet-Goujot & Valette-Florence, 2022). The widespread association between 9-endings and low quality (Schindler & Kibarian, 2001; Stiving, 2000) is a major factor that prompts luxury products, such as those offered by designer brands, to adopt 0-endings (Royne et al., 2012; Stiving, 2000). This shift is aimed at conveying a message of high quality to consumers (Wagner & Beinke, 2006), as 0-endings for pricing helps to further reinforce the high-quality image and appeal of the products. Moreover, designer brands frequently seek to position themselves above typical market pricing strategies, utilizing price as a tool to enhance brand prestige and exclusivity, thus avoiding the common perception of discounting associated with 9-endings (Dogerlioglu-Demir et al., 2022). Consequently, the following hypothesis is defined:

H5: The utilization of 9-ending prices is less frequent in shoes of designer brands compared to shoes from other brands without a similar classification.

A product attribute that has gained prominence in the fashion industry, particularly in online retail, is sustainability. Green products are expected to benefit from 0-ending prices to send a positive message about performance and quality (Royne et al., 2012; Tripathi & Pandey, 2017, 2018). This is especially important for online purchases of

experience goods, where buyers may have difficulty determining product quality before purchasing (Stiving, 2000). Additionally, the growing consumer awareness around environmental and ethical practices increases the expectation for transparency and quality in sustainable products (Jaffry et al., 2004). Consumers interested in sustainability are often more discerning and may view 9-ending prices as misaligned with the values of environmental and social responsibility (de Medeiros & Ribeiro, 2017). Moreover, the market for sustainable goods often involves a higher-educated and more affluent consumer base that values integrity and authenticity over mere cost savings (Duber-Smith and Rubin, 2013). These consumers are likely to respond better to pricing that reflects the quality and ethical commitment of the product rather than to traditional psychological pricing tactics. Hence, it is hypothesized that:

H6: 9-ending prices are used less in shoes classified as "sustainable" than in other shoes without such classification.

3. Method

This research adopts a theory-driven web scraping approach (Landers et al., 2016), where the choice of method and data source was guided by the research hypotheses previously defined (Hofstetter, 2021). Web scraping involves automatic software-enabled data collection from online platforms (Boegershausen et al., 2022; George et al., 2016; Hofstetter, 2021). Although web scraping is considered a relatively new technique (Hillen, 2019), its popularity is growing among researchers (Boegershausen et al., 2022), who take advantage of the large amounts of data available online (Boegershausen et al., 2022; George et al., 2016; Hillen, 2019; Hofstetter, 2021). Web scraping is characterized by its low cost (Guyt et al., 2024; Hillen, 2019), customization (Hillen, 2019), and non-intrusiveness (Boegershausen et al., 2022; Guyt et al., 2024). It can be performed without direct participation from the data provider, therefore granting researchers full control (Prentice & Pawlicz, 2023). Consequently, web scraping has the potential to yield more accurate responses to those research questions that require large datasets (George et al., 2016; Guyt et al., 2024; Hofstetter, 2021), including those related to retail. Web scraping has previously been adopted by psychological pricing research, including when studying price endings (e.g., Boyol Ngan et al., 2021; Fraccaro et al., 2021; Hillen, 2021; Parguel et al., 2021). The extant literature recommends that web scraping should respect the terms of use of the data source platform (Hillen, 2019; Prentice & Pawlicz, 2023), ensure data accuracy by considering geographical context, avoid missing data bias (Prentice & Pawlicz, 2023), and confirm the overall validity of the data and findings (Hofstetter, 2021; Landers et al., 2016). As Boegershausen et al. (2022) noted, enhancing data validity involves careful selection of the data source selection, data collection design, and data extraction. The procedures adopted in this study are detailed below.

3.1. Source selection and data collection

A leading footwear e-commerce website operating in Germany was selected as the data source for this study. As Germany is the world's fifth-largest e-commerce market – with a revenue of $109 billion (E-Commerce DB, 2021) and as it is a leading importer of apparel in the European apparel market (Smith, 2022), it is an appropriate empirical location for this study. The use of a single data source for web scraping is prevalent in existing literature (Guyt et al., 2024) and mitigates potential biases arising from potential differences in quality, stability, and retrievability across various online platforms (Boegershausen et al., 2022). Despite limiting the generalization of findings, this option ensures data consistency and reduces bias associated with cleaning and normalization of data from different sources, prevents missing data, and enhances control over data quality. After a careful analysis, the selected data source was considered adequate for the research objectives and hypotheses. Relevant metrics, especially the shoe attributes considered in the research hypotheses, were freely available in the selected data source. Additionally, data retrieval did not require an authentication procedure, thereby avoiding any biases that could result from website algorithms. The six explanatory variables considered in this study are presented in Table 1.

3.2. Data extraction procedures

This study employed a self-scraping approach (Prentice & Pawlicz, 2023), as the authors designed and developed a web scraping program, written in Python, to extract data from the focal online store. The web scraper was designed to gather information on all men's and women's shoes sold on the website, which were then used as variables in the study. This information included: unique identifier code, name, brand, and the product characteristics indicated in Table 1. Data was extracted on a randomly selected day in April 2022 (10 April).

To ensure a representative and bias-free sample, certain measures were taken, such as excluding some shoe model variants (e.g., color, size) and removing duplicates of unisex shoes listed on both the women's and men's pages. This resulted in a final dataset of 58,006 shoe prices.

3.3. Model specification

Logit models were employed following authors such as Hosmer et al. (2013) and Hilbe (2015) to examine the factors affecting the probability of observing 9-endings in the sample of shoes (Muñoz-Izquierdo et al., 2019). The prices were classified as dummy variables, either 9-endings or not-9-endings. Given the lack of agreement in the literature about the definition of 9-endings, this study considered the most widely used 9-ending classifications from previous research, while also striving for the best fit of the data. Hence, to estimate the probability of observing a 9-ending price for each product I, five logit models were considered, each with a different 9-ending dummy variable, as detailed in Table 2.

The full form of the binary logit models is as follows:

$$P(NineEnding_i = 1) = \beta 0 + \beta 1*Female_i + \beta 2*Novelty_i + \beta 3*Exclusiveness_i + \beta 4*DesignerBrand_i + \beta 5*Sustainability_i + \beta 6*PriceLevel_i + \varepsilon_i.$$

3.4. Data analysis procedures

Maximum likelihood estimates (MLEs) were utilized to adjust the coefficient estimates. This approach is particularly useful for overcoming the possible heteroskedasticity of the disturbance terms in the logit model (Gujarati, 2003; Verbeek, 2017). The results were validated with likelihood ratio statistics and concordant pairs analysis (Tan et al., 2022). The likelihood ratio statistics evaluated the goodness of fit by

Table 1
Explanatory variables.

Code	Variable	Description
$Female_i$	Female	A binary dummy variable indicating the target audience of the product as either woman or other (i.e., man, unisex, kids) shoes
$Novelty_i$	New Release	A binary dummy variable indicating whether the product was coded as a new release or no.
$Exclusiveness_i$	Exclusive	A binary dummy variable indicating whether the product was exclusively sold on the e-commerce website or made available by several retailers
$DesignerBrand_i$	Designer Brand	A binary dummy variable indicating whether the product was from a designer brand or from regular brands
$Sustainability_i$	Sustainable	A binary dummy variable indicating whether the shoes were coded as sustainable products, or not
$PriceLevel_i$	Price Level	A continuous variable indicating the price of the product

Source: The authors.

Table 2
9-ending variables coded for this study.

Code NineEnding$_i$	Type of 9-ending	Supporting extant literature
9c	Dummy variable coded as 1 for prices ending in 9 cents, and 0 for all other prices	This definition of 9-ending is frequently considered in the literature (e.g., Hillen, 2021; Macé, 2012; Schindler & Kirby, 1997; Snir & Levy, 2021; Thomas & Morwitz, 2005)
9-ZeroRemoval	Dummy variable coded as 1 for prices where 9 is the first non-zero digit from right to left (e.g., x.90, x9.00, 90,00), and 0 for all other prices	This 9-ending is commonly suggested in the literature (e.g., Aalto-Setälä & Halonen, 2004; Aiello et al., 2018; Hackl et al., 2014; Schindler, 2009), especially for analyzing high-priced products
0x.9x	dummy variable coded as 1 for prices that feature the digit 9 in the decimal position of cents, and 0 for all other prices	This classification of 9-endings takes into account the impact of other just-below-round prices and has been used in previous literature (e.g., Mitra & Fay, 2010; Ngobo et al., 2010; Wagner & Beinke, 2006) as a more comprehensive classification of 9-endings compared to the 9c typology
95c	Dummy variable coded as 1 for prices ending in 95 cents, and 0 for all other prices	This is a specific instance of the x.9x pricing strategy, which has received extensive attention in the academic literature as a common form of odd pricing, particularly because it ends with the digit 5 (e.g., Gendall et al., 1998; Ngobo et al., 2010)
99c	Dummy variable coded as 1 for prices ending in 99 cents, and 0 for all other prices	It is a well-established and widely studied type of 9-ending pricing strategy (e.g., Hackl et al., 2014; Hodges et al., 2022; Lee et al., 2009; Schindler, 2001, 2006; Schindler & Kibarian, 2001)

comparing the significance of the specified model with a model without explanatory variables (Glover & Dixon, 2004), with a 99 % confidence level. Regarding the concordant pairs analysis, the count R2 was calculated by dividing the number of correct predictions by the total observations, with a threshold of 0.5 (Agresti, 2003; Gujarati, 2003; Hosmer et al., 2013; Long & Freese, 2001). Sensitivity (proportion of correctly specified events) and specificity (proportion of correctly specified non-events) were also analyzed, considering a threshold value of 1 (Henriksson & Merton, 1981). Some models had unbalanced data, with more non-events than events (Salas-Eljatib et al., 2018), leading to near 0 % sensitivity values regardless of the potentially high overall fit of the model (Hosmer et al., 2013). In such cases, undersampling was used to balance the data and improve the models' classification and predictive power (Islam et al., 2022).

To analyze whether the results of the regressions were statistically significant, a 99 % confidence level was considered (Urbano et al., 2021). Variance inflation factors (VIFs) were calculated to detect multicollinearity among independent variables. All VIFs were only slightly above 1, far beneath the threshold value of 5 used by conservative scholars (Hair et al., 2006; James et al., 2021; Menard, 1995), which suggests the absence of multicollinearity issues. Sample characteristics are summarized in Table 3.

Table 4 displays the distribution of price digits by ascending unit levels. The most frequently used digit in the decimal, unit, and tens positions is 9. However, the digit 5 is the most prevalent in the cents position.

Considering the price endings by the last two digits, more than half of all prices in the sample end in 95 cents (53.72 %), followed by the next most popular endings of 99 cents (19.13 %), 00 cents (16.69 %), 90 cents (7.30 %), and 94 cents (1.06 %), respectively. The prevalence of 95 cent prices has been highlighted by previous studies (Naipaul & Parsa, 2001), being accepted as psychological pricing, as they are a "just-below-round" classification, meaning they are just five cents less than a rounded price (Choi et al., 2014; Jošić & Žmuk, 2020; Schindler, 1984; Wagner & Beinke, 2006).

Table 3
Descriptive characterization of the sample.

Shoes' characteristics		N	%
Gender	Female	33,264	57.35
	MenAll	19,867	34.25
	(unisex)	4744	8.18
	Kids	131	0.23
Novelty	New	9746	16.80
	Not-new	48,260	83.20
Exclusiveness	Exclusive	233	0.40
	Non-exclusive	57,773	99.60
Brand	Designer Brand	1828	3.15
	Other Brands	56,178	96.85
Sustainability	Sustainable	7990	13.77
	Not-sustainable	50,016	86.23
Price	Minimum	4.95€	
	Maximum	1095.00€	
	Average	109.02€	

Table 4
Distribution of endings by ascending units level.

Digit	Unit Cents	Decimal Cents	Euro Unit	Tens of Euro
0	24.4 %	16.8 %	7.4 %	5.3 %
1	0.2 %	0.4 %	0.9 %	8.2 %
2	0.0 %	0.0 %	1.2 %	9.9 %
3	0.1 %	0.1 %	0.7 %	10.2 %
4	1.2 %	0.2 %	14.1 %	12.1 %
5	53.9 %	0.3 %	6.3 %	11.0 %
6	0.2 %	0.2 %	0.7 %	10.7 %
7	0.2 %	0.1 %	1.0 %	9.6 %
8	0.1 %	0.3 %	0.6 %	9.6 %
9	19.6 %	81.7 %	67.1 %	13.4 %
Total	**100 %**	**100 %**	**100 %**	**100 %**

4. Results

4.1. Goodness of fit

The Likelihood Ratio (LR) statistics indicate that all five logit models are globally significant: $\chi2(6) = 3513.547$, $p < 0.001$ in the *9c* model; $\chi2(6) = 1213.88$, $p < 0.001$ in the *9-ZeroRemoval* model; $\chi2(6) = 4430.723$, $p < 0.001$ in the *x.9x* model; $\chi2(6) = 783.126$, $p < 0.001$ in the *95c* model; and $\chi2(6) = 3416.818$, $p < 0.001$ in the *99c* model. Regarding the concordant pairs analysis, the count R^2 value should be above the 50 % threshold (Agresti, 2003; Gujarati, 2003; Hosmer et al., 2013; Long & Freese, 2001) and the sum of the sensitivity and specificity values should exceed 100 % (Henriksson & Merton, 1981). The count R^2 is 64.35 % in the *9c* model, 55.04 % in the *9-ZeroRemoval* model, 82.73 % in the *x.9x* model, 54.30 % in the *95c* model, and 64.04 % in the *99c* model. This means that in all the logit models presented, between nearly 54 % and 83 % of the values are correctly predicted by the model, which is above the defined threshold (Hilbe, 2015; Hosmer et al., 2013). Moreover, the sensitivity value added to the specificity value is 128,70 % in the *9c* model, 110,09 % in the *9-ZeroRemoval* model, 109.59 % in the *x.9x* model, 102.35 % in the *95c* model, and 128.07 % in the *99c* model, therefore above the suggested threshold. Hence, these results suggest the good fit of the models used in this research.

4.2. Determinants of the use of psychological pricing

Table 5 displays the coefficients and standard errors for the five logit models estimated based on five different dependent variables (i.e., 9-endings). For the models 9c, 99c, and 9-ZeroRemoval, undersampling was performed to achieve balanced data (i.e., an equal number of 0 s and 1 s). As a result, the number of observations is smaller in these models compared to the 95c and x.9x models.

As shown in Table 5, the effects of *Price Level* were significant and negative for all 9-ending classifications (B = –.015 in 9c model; B = –.004 in *9-ZeroRemoval* model; B = –.007 in *x.9x* model; B = –.001 in *95c* model; and B = –.015 in *99c* model), supporting hypothesis **H1**. The results of this study suggest that the use of 9-endings decreases as the price of the shoes increases. This finding is consistent with the literature, which suggests that consumers are more engaged in the purchasing process when considering high-priced products, resulting in a weaker price level effect (Macé, 2012). Additionally, previous research has indicated that 9-endings are often associated with low quality, which may conflict with the message of high quality conveyed by a high price point (Fraccaro et al., 2021; Hackl et al., 2014; Hillen, 2021; Lee et al., 2009; Parguel et al., 2021).

The effects of *Female* on 9-ending price were significant and positive for all the classifications considered (B = 0.234 in *9c* model; B = 0.112 in *9-ZeroRemoval* model; B = 0.277 in *x.9x* model; B = 0.102 in *95c* model; and B = 0.261 in *99c* model), providing support to hypothesis **H2**. The results of this study indicate that, all else being equal, shoes marketed to women are more likely to have prices ending in 9 than shoes marketed to unisex, men, or children. These findings are consistent with previous research suggesting that female shoppers are more receptive to prices ending in 9, leading to increased demand for products marketed to women using this pricing strategy (Baumgartner & Steiner, 2007; Harris & Bray, 2007; Lepeyko et al., 2019).

The results of this study were mixed regarding hypothesis **H3**, as the effects of *Novelty* on price endings varied across different models. Specifically, the coefficients for *Novelty* were positive but not significant in the *9c* (B = 0.047), *95c* (B = 0.007), and *99c* (B = 0.058) models, indicating that these models did not support the hypothesis. However, in the *9-ZeroRemoval* (B = 0.095) and *x.9x* (B = 0.084) models, the coefficients for *Novelty* were positive and significant, providing support for hypothesis **H3**. Taken together, the findings suggest that, all else being equal, new shoes are more likely to have prices ending in 9 when a zero-removal criterion or decimal cents digits are used, compared to non-new release shoes. This may be because consumers face greater uncertainty when purchasing new items, making prices ending in 9 a more effective signal of low prices (Fraccaro & Macé, 2020) and potentially increasing demand (Anderson & Simester, 2003; Macé, 2012).

The findings for the effects of *Exclusiveness* and *Sustainability* also varied depending on the use of 9-endings but led to similar conclusions. Specifically, the *Exclusiveness* effects were found to be significant and negative in the *9c* (B = –.776), *9-ZeroRemoval* (B = –1.158), and *99c* (B = –.77) models, which supports hypothesis **H4**. Similarly, the *Sustainability* effects were found to be significant and negative in the *9c* (B = –.173), *9-ZeroRemoval* (B = –.146), and *99c* (B = –.164) models, providing support for hypothesis **H6**. However, unexpected results were obtained in the *x.9x* and in the *95c* models, where both the *Exclusiveness* effects (B = 2.957 in the *x.9x* model and B = 1.655 in the *95c* model) and the *Sustainability* effects (B = 0.651 in the *x.9x* model and B = 0.427 in the *95c* model) were significant and positive. These findings do not support hypotheses **H4** and **H6**, respectively.

Similar findings for *Sustainability* and *Exclusiveness* may be explained by the unique characteristics of these product types. For example, consumers often perceive sustainable products as more expensive, which can discourage their purchase (Barbarossa & Pastore, 2015). However, many luxury consumers prefer odd prices (Fraccaro et al., 2021). To address this, retailers may use 9-endings to signal lower prices, as consumers are willing to pay a premium for sustainability products. Similarly, *Exclusiveness* can help differentiate from competitors (Mehra et al., 2018; Song et al., 2020) and mitigate price comparison. Using 9-endings may be a strategy to stimulate sales of exclusive shoes. The use of 95c instead of the more common 9c or 99c is notable, as 9-endings are often associated with low quality (Macé, 2012; Tripathi & Pandey, 2017) and viewed as a deceptive marketing tactic (Bray & Harris, 2006; Schindler, 2001, 2006). This may have influenced the use of 95c to avoid such negative perceptions.

Finally, the effects of *Designer Brand* were consistently found to be significant and negative across all 9-ending classifications (B = –4.276 in the *9c* model; B = –1.85 in the *9-ZeroRemoval* model; B = –.798 in the *x.9x* model; B = –.643 in the *95c* model; and B = –4.273 in the *99c* model). These findings support hypothesis **H5** and are consistent with the literature, which suggests that the purchase of premium products is often influenced by factors beyond price (Pauwels et al., 2007) and the use of 0-endings is typically associated with signaling high quality (Wagner & Beinke, 2006).

Previous studies have examined various types of 9-endings, which may explain the divergent findings in the literature. As demonstrated in this study, the support for the research hypotheses is not consistent across all the models that were defined. Table 6 shows that the support for the hypotheses in the *9c* and *99c* models are similar, with the *9c*

Table 5
Logit regressions.

	(1)	(2)	(3)	(4)	(5)
	9c	9-ZeroRemoval	0x.9x	95c	99c
Sustainability	**0–.173*****	**0–.146*****	0.651***	0.427***	**0–.164*****
	(0.042)	(0.032)	(0.038)	(0.025)	(0.042)
Exclusiveness	**0–.776*****	**–1.158*****	2.957***	1.655***	**0–.77*****
	(0.246)	(0.215)	(0.574)	(0.189)	(0.246)
Novelty	***0.047***	**0.095*****	**0.084*****	***0.007***	***0.058***
	(0.038)	(0.029)	(0.031)	*(0.023)*	*(0.039)*
Designer Brand	**–4.276*****	**–1.85*****	**0–.798*****	**0–.643*****	**–4.273*****
	(1.006)	(0.143)	(0.064)	(0.06)	(1.005)
Female	**0.234*****	**0.112*****	**0.277*****	**0.102*****	**0.261*****
	(0.029)	(0.022)	(0.023)	(0.017)	(0.029)
Price Level	**0–.015*****	**0–.004*****	**0–.007*****	**0–.001*****	**0–.015*****
	(0)	(0)	(0)	(0)	(0)
_cons	1.289***	0.351***	2.12***	0.131***	1.251***
	(0.037)	(0.027)	(0.026)	(0.019)	(0.038)
Observations	22,736	34,708	58,006	58,006	22,406
LR Chi^2	3513.547	1213.88	4430.723	783.126	3416.818
Prob > Chi^2	0	0	0	0	0
Pseudo R^2	0.111	0.025	0.08	0.01	0.11

Note: Standard errors are reported in parentheses.

Table 6
Summary of hypothesis test.

Hypotheses supported in this study	(1) 9c	(2) 9-Zero Removal	(3) x,9x	(4) 95c	(5) 99c
H1: The use of 9-ending prices is negatively associated with the price of shoes	Yes	Yes	Yes	Yes	Yes
H2: 9-ending prices are more frequently utilized in shoes targeted towards women as compared to other shoes	Yes	Yes	Yes	Yes	Yes
H3: 9-ending prices are more frequently utilized in shoes labeled as "new releases" than in the other shoes	–	Yes	Yes	–	–
H4: The use of 9-ending prices is less prevalent in shoes classified as "exclusive" compared to shoes without such labeling	Yes	Yes	–	–	Yes
H5: The utilization of 9-ending prices is less frequent in shoes of designer brands compared to shoes from other brands without a similar classification	Yes	Yes	Yes	Yes	Yes
H6: 9-ending prices are less used in shoes classified as "sustainable" than in the other shoes without such classification	Yes	Yes	–	–	Yes

model being a specific case of the *99c* model. The *9-Zero-Removal* model is the most versatile 9-ending, demonstrating good adaptability to any type of shoe, including those marked by exclusivity, sustainability, and designer brands. Indeed, the *9-Zero-Removal* model provides support for all research hypotheses. Interestingly, the most common 9-ending observed in the sample, 95 cents, showed the most contradictory results, with three out of six hypotheses not being confirmed by the *95c* model. It is worth noting that the *99c* and *95c* models present different results, with the *99c* model supporting **H4** and **H6**, while the *95c* model does not. These are two variations of the *x.9x* model – given that the two variations show distinct findings, it is suggested that the analysis of the *99c* and *95c* models is preferable and that the *x.9x* model should be considered with caution.

5. Discussion

First, the results support H1, confirming that the use of 9-ending prices decreases as the price of shoes increases across all models tested (See Table 6) (9c, 9-Zero Removal, x.9x, 95c, and 99c). This finding is consistent with previous literature (Stiving, 2000), which suggests that consumers associate 9-endings with lower-quality goods, making this strategy less effective for higher-priced items (Mitra & Fay, 2010). Retailers of premium products may avoid 9-endings to signal higher value and quality, aligning with consumer expectations in the high-end market segment, as stated by extant literature (Dogerlioglu-Demir et al., 2022; Liang & Kanetkar, 2006).

Additionally, the present study provides positive evidence for H2, showing that 9-ending prices are more frequently used in shoes marketed to women (9c, 9-Zero Removal, x.9x, 95c, and 99c). This trend supports existing research indicating that female consumers are more sensitive to price endings, particularly to those ending in 9 (Lepeyko et al., 2019). Retailers may leverage this preference to position their products as more attractive or offering better value to female shoppers, thereby influencing purchase decisions more effectively (Harris & Bray, 2007; Siraj et al., 2024).

In contrast, the findings related to H3, which explores the link between novelty and 9-ending pricing, are mixed. The results show that new products are more likely to have 9-ending prices only in the 9-Zero Removal and x.9x models (in Table 6: 9-Zero Removal, x.9x), while this effect is not significant in the other models. This suggests that certain types of 9-ending prices are more suitable for signaling lower prices or better deals on newly released products, especially in contexts where consumers face higher uncertainty about the value of new items (Snir et al., 2017). However, this pattern does not hold consistently across all price formats.

The relationship between exclusiveness and 9-ending prices, as stated in H4, also presents varied results. While exclusivity is negatively associated with the use of 9-endings in the 9c, 9-Zero Removal, and 99c models (9c, 9-Zero Removal, 99c), this relationship is not significant in the x.9x and 95c models. This discrepancy can be explained by the different perceptions of exclusivity in the market (Wang et al., 2022). In some segments, 9-endings may undermine the exclusive appeal of a product by associating it with lower prices or discounting, while in other cases, particularly in more competitive markets, retailers might still employ 9-endings to enhance product appeal without diluting the exclusive image (Dertwinkel-Kalt and Köster, 2022; Wang et al., 2024).

Regarding H5, the results demonstrate that 9-ending prices are less frequently used in designer brand shoes across all models (9c, 9-Zero Removal, x.9x, 95c, and 99c). This finding is in line with the literature, which suggests that designer brands tend to avoid psychological pricing tactics like 9-endings (Fuentes et al., 2023; Nagle & Müller, 2017). Such brands typically prioritize maintaining an image of luxury and high quality, and using rounded prices helps reinforce this perception (Singh, 2023). The consistent avoidance of 9-endings by designer brands further emphasizes their focus on exclusivity and premium branding (Ko et al., 2019).

Finally, the results related to H6 predict that 9-ending prices are less commonly used in sustainable products, and are supported in the 9c, 9-Zero Removal, and 99c models (9c, 9-Zero Removal, 99c) but not in the x.9x or 95c models. This mixed result suggests that while consumers may expect transparency and quality from sustainable products (Ariffin et al., 2016; Shen et al., 2020), making 9-endings seem misaligned with these values, in certain pricing formats, retailers might still opt to use 9-endings to signal a better deal or lower price for green products (Kamboj & Matharu, 2021).

6. Conclusion

This research complements the literature on 9-ending price strategies by providing a comprehensive study on 9-ending price strategies in the context of footwear in e-commerce. Guided by the two main inconsistencies found in the literature, this article explored the product attributes associated with 9-ending prices. The resulting six hypotheses were tested using pricing data from a footwear e-commerce website obtained by web scraping. Given the variation in the classification of 9-ending prices in the literature, this study tested the hypotheses for the most widely used 9-ending classifications from previous research, while also striving for the best fit of the data. As such, logistic regression models were used to identify the factors that influence the likelihood of using each of the five 9-ending price point variations: 9 cents, 99 cents, 95 cents, 9 decimal cents, and 9 after zero removal. This study provides both theoretical and managerial contributions, which are detailed below.

6.1. Theoretical contributions

This article contributes to the ongoing discussion on the use of 9-ending prices by retailers, especially in the e-commerce domain. Previous literature has studied different types of psychological pricing but not provided a precise definition of 9-endings. In this study, alternative 9-ending concepts were tested, revealing inconsistencies in the findings that may help explain the divergent results in extant literature.

As found by Stiving (2000) for a physical footwear store, results suggest that in footwear e-commerce most prices end in 95c, indicating that psychological pricing continues to play a crucial role in e-commerce, namely in the footwear industry. The lower frequency of 9c and

99c endings may be explained by typical 9-endings conveying a message of low quality. The digit 5 is frequently perceived as a salient threshold for consumers due to its easy interpretation. Therefore, it can be used to signal quality, leading to increased demand, as suggested by Gendall et al. (1998). By combining the benefits of both 9 and 5 digits, the 95c-ending creates just-below-round prices, contributing to the image and level effects to convey the message of "good deal" and "low price", while simultaneously avoiding some of the disadvantages of 9c or 99c, such as a low-quality image. However, in competitive contexts, such as footwear e-commerce, other typologies of 9-endings may be more adaptive. This study provides a comprehensive understanding of the phenomenon by comparing several 9-ending models, demonstrating that variations of one 9-ending model (i.e., 95 cents and 99 cents as particular cases of the 9-cents ending) provided contradictory findings. Additionally, less commonly studied 9-endings, (particularly the zero-removal model) showed a better fit to the hypotheses derived from the literature.

In conclusion, this article highlights the complexity of 9-endings pricing attributes, such as the "image effect" and the "level effect" as suggested by the prospect theory and the left-digit bias mechanism. It aligns with recent theoretical advancements in behavioral studies on 9-endings, which suggest consumers' sophistication in interpreting and encoding prices (Hodges et al., 2022; Laurent et al., 2023). Utilizing prices ending in 5, especially 95 cents, may enhance the appeal of just-below-round prices while mitigating the negative connotations associated with traditional 9-cent and 99-cent endings. This contribution enriches the ongoing scholarly debate surrounding pricing strategy and emphasizes the need for further theoretical exploration in this domain. The study demonstrates the complexity of the topic by incorporating a broad range of product characteristics that may determine the adoption of 9-ending prices and compares the findings. Existing literature often overlooks the specific reasoning behind choosing particular 9-ending pricing strategies. Typically, studies tend to follow precedents established by previous research on similar product categories, with few exceptions. This research elucidates how different conceptualizations of 9-endings can lead to distinct findings, even though supporting at least some of the predefined hypotheses. By delving into the diversity of 9-endings, the results shed light on a complex and nuanced subject area, providing a valuable analytical perspective for future research.

6.2. Implications for managers

The findings suggest that psychological pricing remains a prevalent strategy in a market as transparent and competitive as e-commerce. Although 9-endings are often associated with low prices and good deals, it is important to recognize that there are different types of 9-endings, each with varying levels of perceived aggressiveness that require careful consideration. The study reveals that the online retailer employed distinct pricing strategies based on price levels, utilizing the digit 9 to communicate lower prices and the digit 0 to signify a higher-quality image (Hillen, 2021; Lee et al., 2009; Lopez-Pastor et al., 2020; Macé, 2012; Ngobo et al., 2010).

Additionally, the study reveals differences in the frequency of use of 9-endings according to the different shoes' characteristics. Five different 9-ending classifications were considered: *9c*, *9-ZeroRemoval*, *x.9x*, *95c*, and *99c*. Results suggest that:

- 9-endings are used more in women's shoes than in men's, unisex or kid's shoes.
- 9-endings are used more in shoes labeled as "new releases" than in other shoes (although results were not statistically significant for *9c*, *95c*, and *99c* endings).
- The price of shoes is negatively associated with the use of 9-endings.
- 9-endings are used less in shoes of a "designer brand" than in other brand shoes.
- Typical 9-endings, such as 9c, 99c, or 9-ZeroRemoval, are used less in shoes classified as "exclusive" than in other shoes without such labeling, while the x.9x-ending and 95c-ending are used more in "exclusive" shoes. Since online retailers may have a higher profit margin on the sale of "exclusive" shoes (as they face no competition) (Gielens et al., 2014), then it might be rational to apply these non-typical 9-endings to promote the sale of such shoes instead of all others offered on the website.
- Typical 9-endings, such as 9c, 99c, or 9-ZeroRemoval, are used less in shoes classified as "sustainable" than in other shoes without such classification, while the x.9x and the 95c endings are used more in "sustainable" shoes. This may be because consumers perceive sustainable products as more expensive (Barbarossa & Pastore, 2015), thus non-typical 9-endings may be applied to convey the message of low price and "good deal" without conveying the low-quality image.

The challenge for retailers is to find a pricing strategy that balances the desire to convey an image of low cost with one of high quality so as to maintain a strong market position. Based on the results of this study, managers should consider using 9-endings that are less common or straightforward, such as the 9 digit in decimal cents (i.e., *x.9x*), as well as other approaches to 9-endings, such as zero-removal. For a company with low prices, this approach appears to be an effective way to convey a softer message while maintaining a high-quality image.

To optimize sales and profitability, it is important that managers do not apply 9-endings uniformly to all products. Instead, they should consider the specific characteristics of each product when defining their pricing strategy, recognizing that a particular ending may be effective for some products but not for others. By tailoring the pricing strategy to each product, managers can achieve better results and improve their overall competitiveness.

6.3. Limitations and future research directions

This study has some limitations that need to be considered. First, it only analyzed data from one e-tailer and prices were collected for a single day, 10 April 2022. Therefore, the generalization of the findings should be made with caution. Further research is needed to validate the results, including the comparison of different time periods, such as seasons or sales periods, and the analysis of multiple footwear online stores, including non-European retailers. An additional avenue for future research is to investigate other zero-removal endings, particularly in prices where the first two non-zero digits from the right are 95 (e.g., $95.00 or $195.00). Given that this study indicates both 95-cent endings and prices with 9 as the first non-zero digit to the right are relevant pricing strategies, future studies should examine the prevalence of other odd endings after zero removal. This approach can provide valuable new insights into the use of psychological prices.

Second, the study does not directly address the impact of 9-ending prices on sales, as sales data was not publicly available to be collected. Therefore, future research should explore sales data, costs, and pricing policies to gain a more comprehensive understanding of the relationship between 9-ending pricing strategies and sales performance.

Finally, the study does not provide information about customers' perceptions of psychological pricing in e-commerce. Future research could employ experimental designs or questionnaires to investigate how consumers process online price information and their attitudes towards psychological pricing in e-commerce.

CRediT authorship contribution statement

Mariana Gaspar Gonçalves: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation. **Belem Barbosa:** Investigation, Formal analysis, Data curation, Conceptualization. **Jose Ramon Saura:** Writing – review & editing, Validation, Supervision, Conceptualization. **Marcello Mariani:** Validation, Supervision, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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