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Effect of wood attributes on the price persistence of acoustic guitars

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Abstract

Wood attributes are important, because they directly affect the price persistence of wood products. Consumers consider the “aesthetic,” “traditionality,” “decay resistance,” and “scarcity” attributes important when evaluating wood. This study analyzed the impact of these four attributes on the price persistence of acoustic guitars. We obtained data from a Japanese internet auction platform and winning-bid data for two representative brands, Martin and Yamaha. We performed a quantitative analysis using the winning bid price as the dependent variable and the adoption of various wood attributes in each part of the guitar corresponding to the four attributes as explanatory variables. We found that rosewood, mahogany, palisander, and ebony have a significant impact on price persistence, and that all of them fit the four attributes of traditionality, decay resistance, scarcity, and aesthetics. We also found that traditionality was the key attribute among the four. Using wood in luxury brands without traditionality was not effective, even if other attributes were present. For mass-market brands, scarcity and decay resistance had positive effects on price persistence. The finding that scarcity and decay resistance were important only for mass-market brands can help companies understand market demand, determine product attributes, and achieve product–market fit.

Keywords: Wood product, Price persistence, Aesthetic attribute, Traditionality, Decay resistance, Scarcity, Winning bid price, Internet auction, Multiple regression analysis

Introduction

Background and purpose

Despite recent advances in materials science, wood remains the preferred material in musical instrument manufacturing owing to its unique acoustic and aesthetic attributes [1]. Pakarinen and Asikainen [2] confirmed that “aesthetic attributes” are important for consumers when evaluating wood products. In addition, because wood is often used in musical instruments, its “traditionality,” “decay resistance,” and “scarcity” attributes have been emphasized [3]. Thus, this study proposes hypotheses regarding the relationship among the aesthetics, traditionality, decay resistance, scarcity, and price persistence of musical instruments. Wood choice is the most important parameter in the design of stringed

instruments, such as guitars [4]. In instrument design, different parts require different wood attributes, particularly in stringed instruments [4]. Thus, the manufacturing of musical instruments is significantly influenced by wood attributes [5].

The sources of competition for wood products are the “development of the material itself” and the “design and appearance” [6]. The choice of material is important for industrial design processes [6]. Wood is an important material used in musical instruments [7]. However, the increasing competition in international markets requires the wood product industry to adapt flexibly to the economic conditions and dynamic customer needs in these markets [8, 9]. According to Andreessen, “product/market fit means being in a good market with a product that can satisfy that market” [10]. Companies usually do not understand why they cannot meet customer needs. One major problem is product–market fit. Therefore, companies must identify market needs and define product goals.

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Customers find it important that the purchasing price of durable wood products be maintained; thus, identifying important wood quality characteristics and quantifying their achievable returns are crucial [11]. A comprehensive picture of the competitive situation regarding wood requires information on its performance and relative substitutes [11]. This information is necessary for determining which customer needs require attention in terms of quality improvement and product development, and thus optimally satisfying customers [12]. Providing customers with high-quality value-added materials is an important component of competitiveness [13, 14]. Thus, price persistence has a significant impact on consumer willingness to purchase.

A range of materials must be considered for use, understanding, and adaptability to existing products [15]. Commercial studies on consumer perceptions and attitudes toward wood are extensive [15]. However, the research has not fully explored the impact of wood choice on the price persistence of musical instruments. Thus, this study investigates how these four wood attributes influence the price persistence of musical instruments. This study contributes to the wood industry and wood product companies specializing in musical instruments by identifying the priority attributes in product design as well as the attributes that are detrimental to price persistence.

Our analysis focuses on the acoustic guitar industry. Acoustic guitars are among the most popular musical instruments worldwide [5] and are used by both musicians and consumers. Therefore, the acoustic guitar industry is an appropriate setting in which to pursue the objectives of this study. It should be mentioned, however, that the results of this study flow from observations on a single industry.

Wood attributes are important, because they directly impact market opportunities and consumer acceptance of wood products [16]. Consumer preferences and purchase intentions are strongly related to wood attributes [17, 18]. Product design has the greatest influence on consumers' willingness to pay (WTP) [19]. Aesthetics, traditionality, decay resistance, and scarcity were considered important attributes for assessing consumers' wood evaluations in this study. In the following sections, we explore hypotheses regarding the relationship between these attributes and the price persistence of musical instruments.

Hypotheses

Aesthetics is one of the main factors in the choice of wood materials for certain products [20]. In appearance-based evaluations of wood products, the choice of wood species and its influence on product aesthetics and consumer preferences should be considered [10]. In a survey of wood manufacturers, Nicholls and Roos [21] confirmed the importance of appearance in the marketing of

wood products. [21]. Broman [17] derived rich features from visual perception. Wood species are generally considered important and include attributes related to their design or appearance [21]. Evaluations based on wood design or appearance tend to be based on wood color [21]. Dark-colored wood (e.g., mahogany and walnut) is often considered expensive and grand [10]. Lindberg et al. [22] corroborated these results, finding that dark colors were negatively correlated with affordability and positively correlated with exclusivity. Liu et al. [23] found that wood surface color should be black, dark brown, or dark purple–brown to satisfy traditional aesthetics. Aesthetics is a valuable factor that provides products, values, and knowledge to customers [24]. Attitudes toward appearance directly affect consumers' perceptions of quality and brand preference and indirectly affect the value of a product [25]. The relationship between aesthetics and value has been previously discussed [10]. However, guitars are durable products, and consumers consider price persistence to be an important influencing factor when purchasing such products. Few studies have discussed the relationship between price persistence and dark wood.

Dark wood exhibits positive results in terms of value (here referring to the value of a guitar body during purchase, while "price persistence" refers to its future value). Dark wood is assumed to have a positive impact on both value and price persistence. The rationale for this is that dark wood is often regarded as expensive and grand; hence, guitars with dark wood should maintain the price persistence of guitar products. Therefore, we propose the following hypothesis:

Hypothesis 1 Dark wood has a positive effect on the price persistence of acoustic guitars.

Several species of wood are used in the production of musical instruments [3, 5]. Advances in musical instruments have resulted from advances in the use of wood [26]. A wide variety of wood species has been used in acoustic guitars [27]. Producers of stringed instruments have been conservative in their wood choices for guitars [5]. The soundboard (top) of the guitar is usually made of American or European spruce. Rosewood, mahogany, maple, and koa are commonly used on the backs and sides of guitars. Spruce and mahogany wood are used for the neck, whereas ebony and rosewood are used for fingerboards [5]. However, a wide range of wood species, plywood, and composite laminates are now used for the backs and sides of guitars [28]. Visual, cost, and sustainability factors are prioritized regardless of the choice of wood species used [28]. However, acoustic guitars made from these alternative materials are considered artificial

products of low value [29]. Therefore, strummers and retailers generally remain skeptical about them [29].

As wood choice for guitars is conservative, instrument makers and musicians prefer traditional wood. We verified this using relevant data. Traditional wood is thought to have a positive impact on value and permanence, as the initial value of a commodity forms the basis for its future value. Therefore, we propose the following hypothesis:

Hypothesis 2 Wood with traditionality has a positive impact on the price persistence of acoustic guitars.

Wood deteriorates over time due to a variety of environmental factors (e.g., mold, insects, rainwater). Therefore, using high-quality wood that is resistant to decay increases the functionality of wood products [3]. Guitars are wood products with both structural (i.e., the shape of a product and the way it is manufactured) and acoustic specifications [28]. The selected wood should be durable, allow fluid vibration, and should not deform excessively over time [28]. The perceived value of wood products is related to product quality [8]. The ability to offer high quality and value to customers is an important competitive factor [14]. Thus, the functionality associated with decay resistance in the production of acoustic guitars is related to the quality and value of the instrument. The relationship between decay resistance and value has been examined in previous studies but not in terms of price persistence. Therefore, this study used related data to verify this relationship.

The studies mentioned above indicate that customers must be sure of the quality and value of a product. Hence, wood products must have a high decay resistance. A good decay resistance has a positive impact on the value of guitar products. Wood with good decay resistance can thus be assumed to have a positive impact on value and price persistence, since decay resistance can guarantee long-term instrument functionality. Therefore, we propose the following hypothesis:

Hypothesis 3 Wood with decay resistance has a positive impact on the price persistence of acoustic guitar.

For centuries, guitar players and makers have sought wood that can produce superior tones in the production of acoustic guitars [30]. However, owing to deforestation, various species are almost extinct and are subject to trade protection under international environmental laws [30]. Thus, environmental and musical sensibilities are at odds [30]. Furthermore, as the retail price of guitars sold in the United States approaches \$1 billion per year, the demand for their materials will not decline in the short term [3]. Owing to the scarcity of wood, guitar makers have been searching for reliable color-substituting wood composites [29]. Several well-known stringed instrument makers use low-quality composite wood and

non-wood products to emphasize the importance of designing guitars in ways that utilize available materials rather than premium wood [30]. In addition, the choice of materials is extremely important for the guitar industry. As the global environment changes, new materials have been developed. Composite resins and carbon fibers are commonly used, and an increasing number of guitars made of new materials are available. This implies that consumers' product preferences are influenced by a diversity of wood attributes. Pedgley and Norman demonstrated that wood species can be replaced with unconventional wood varieties or new materials without affecting the acoustics of stringed instruments [28]. However, consumers demand scarce natural wood [5]. The combination of precious and rare wood provides high-value instrumentation [5]. In addition, this study used and validated the data, because scarcity and price persistence have not been discussed in previous studies.

Wood scarcity has a positive impact on the value of a guitar. High-value wood is thus more difficult to obtain. Therefore, scarcity has a positive effect on price persistence. Accordingly, we formulate the following hypothesis:

Hypothesis 4 Wood scarcity has a positive impact on the price persistence of acoustic guitars.

Methods

We chose acoustic guitars as the research object and focused on the auction market of used goods. The AucFan media service, which enables the comparison, search, and analysis of products and price information, was used with permission from the platform owner. AucFan allows users to search for data related to product transactions on Yahoo Auctions, the largest Internet auction platform in Japan. Therefore, this service is suitable for this study, which focuses on the persistence of product prices [31].

The research indicates that Fender, Martin, Taylor, Ibanez, and Yamaha are the most prominent acoustic brands [32]. However, this study considers only two of them, Martin¹ and Yamaha,² because AucFan has

¹ Martin (formally known as the "C.F. Martin Company") is a world-renowned manufacturer of high-quality acoustic guitars and acoustic guitar strings [33]. Martin guitars have been known for decades because of their high-quality design and materials [33]. Martin's reputation is as a maker of high-quality sounding and playable guitars that are extremely resistant to decay, even with frequent use [33]. Martin, as a luxury brand of guitars, is extremely strict in its choice of materials and material development process [33].

² Nippon Gakki Co., Ltd., currently Yamaha Corporation, was established in 1897 with capital of 100,000 yen [35]. Yamaha believes in the importance of producing advanced high-quality equipment at a reasonable and affordable price [34]. Yamaha, being a large company with a long history, is extremely strict in selecting materials for their guitars and has focused on providing quality guitars for beginners and professionals for many decades [35].



Fig. 1 Example of a Martin guitar (D-28, 146 samples in analysis). Photograph taken with permission of store staff

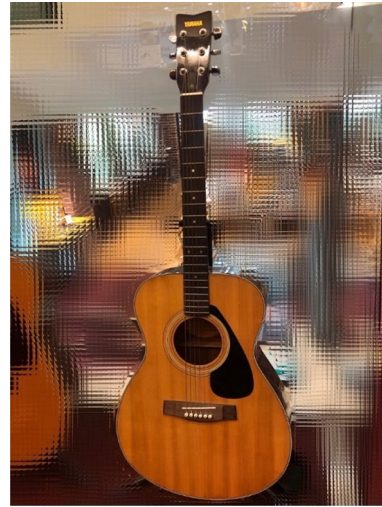


Fig. 2 Example of Yamaha guitar (FG-122, 5 samples in analysis). Photograph taken with permission of store staff

abundant data on them. We considered these to be the representative brands in the Japanese acoustic guitar market. Although both Martin and Yamaha are well-known acoustic guitar brands, we regard them as different: Martin is a luxury brand, whereas Yamaha is a mass-market brand. Martin's price is high [33], and Yamaha believes in the importance of producing advanced high-quality equipment at a reasonable and affordable price [34]. Therefore, by analyzing these two brands, we can also analyze the different markets in the acoustic guitar industry. Figures 1 and 2 show examples of Martin and Yamaha guitars, respectively.

Different parts of the guitar have different effects on tone, so different species of wood are needed for each part. For example, the wood used in fingerboards is generally more expensive. Therefore, this study analyzed the combination of parts, wood species, and wood attributes. We used two analyses to verify the effects of wood attributes on price persistence. One analysis directly used the combination of guitar and wood species as explanatory variables to identify the wood species and specific attributes that had a significant impact on price persistence. Another analysis used a combination of guitar and wood attributes as explanatory variables to determine which attribute played a role in price persistence.

Analysis 1 used a combination of wood species and guitar parts as the explanatory variables. Because each brand uses a different species of wood, we analyzed the two brands in the first analysis. In this study, the guitar parts consist of "fingerboard," "neck," "top," and "side back" (as shown in Fig. 3). In our data set, the wood used for sides and backs was the same for most guitars. Therefore, this

study set the variable as "side back," instead of separating them. This analysis determined the wood species and their specific attributes that have a significant effect on price persistence. However, we could not determine which attribute played a role in price persistence in Analysis 1. Therefore, to observe the effects of the attributes individually, Analysis 2 used the combination of the guitar part and wood attributes (i.e., traditionality, aesthetics, scarcity, and decay resistance) as the descriptive variables. As with Analysis 1, we analyzed the data for the two brands. In addition, we set the explanatory and control variables as dummy variables. Additional explanations are provided in Sects. "Explanatory variables" and "Control variables".

We conducted multiple regression analysis using the R programming language. The stepwise method was used to test for more appropriate models that could estimate the dependent variable. We used bidirectional elimination, because it combines the advantages of the forward selection and backward elimination methods. We input or removed variables by selecting the smallest AIC statistic. Bidirectional elimination started with no predictors, and then we sequentially added the predictors that contributed the most. After each new variable was added, any variables that no longer provided an improvement in the model fit were removed.

Sample collection

We collected product data for 2000 transactions containing product models and winning bid prices from Aucfan (1000 transactions each for Yamaha and Martin). The data acquisition period for the 1000 Yamaha

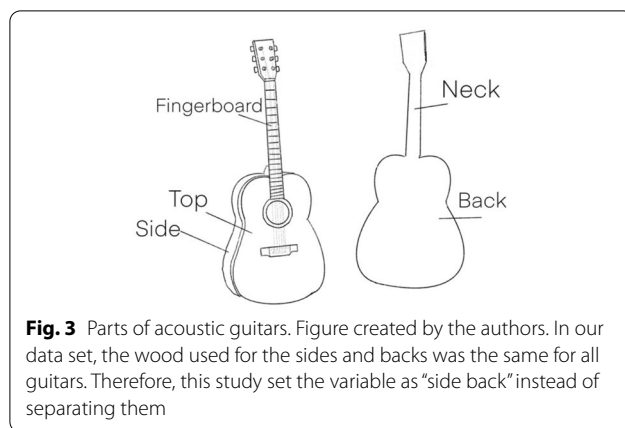


Fig. 3 Parts of acoustic guitars. Figure created by the authors. In our data set, the wood used for the sides and backs was the same for all guitars. Therefore, this study set the variable as “side back” instead of separating them

samples spanned from May 1, 2021, to August 15, 2021. The Martin sample in Aucfan is smaller than Yamaha’s; therefore, the data acquisition period for the 1000 Martin samples spanned from August 17, 2020, to May 1, 2021. Only used goods were included in the analysis. Aucfan provided information on whether a product was new. After collecting the 2000 transactions, we collected more information, including on the wood species used for each part of the guitar model, the age of the guitar model, and whether the wood was natural, for each guitar. We confirmed the Yamaha old model data from the list provided by the website (this list is the official one provided by Yamaha) [36]. In addition, some sample data were not provided in the list; hence, we confirmed this information using Yamaha’s official website and the Yamaha guitar product manual [37–40]. We confirmed that the Martin guitar data mainly relied on official websites and Martin product manuals provided by other websites [41–43]. We also collected data on the characteristics of wood attributes. The criteria for organizing the attribute-specific characteristics of wood are as follows. First, dark color was determined by referring to the Wood Database [44] and Wood Museum [45]. The wood used for acoustic guitar color can be divided into (1) black, (2) brown, (3) white, and (4) yellow. Here, we considered black and brown as “dark” colors and white and yellow as “bright” colors. The decision regarding traditionality was made by considering Bennett’s wood arrangement, in which he identified the main species of traditional wood used to make guitars [5]. Third, decay resistance was determined based on the description of decay resistance in the Wood database [44]. “Durable” to “very durable” was considered satisfactory, and decay resistance was regarded as unsatisfactory. For the last item, scarcity, we also referred to the Wood Database [44] and determined that the wood included in the International Union for Conservation of

Nature (IUCN) was scarce and that the wood excluded from the IUCN was not scarce [36].

We removed inadequate samples using the following process. First, we confirmed that some samples showed winning bid prices that were either too high or too low. We removed these samples, because such outliers could have produced a non-negligible bias in the analysis. (This procedure is explained in “Dependent variables” below.) Second, as mentioned, because the species of wood used for the side and back are almost the same, we set the variable as “side back” instead of separating them. However, the Yamaha sample included a few cases in which different woods were used for the back and side; therefore, we removed such data to eliminate potential bias in the analysis. Fourteen samples were removed from the Yamaha data set. Third, we removed colored guitar samples, because some guitars were painted, which would interfere with the observation of aesthetic characteristics. After we removed these unsuitable observations, the sample quantity was reduced from 1000 to 779 for Martin and 949 for Yamaha.

Dependent variables

Owing to the large differences between the winning bid prices, we converted the prices to natural logarithms for analysis. After taking the natural logarithm, we used the three-sigma rule to remove outliers [46].

After removing the outliers, we found that the data contained samples with the same model number but different winning bid prices, which may have caused bias in the analysis results. Therefore, we took the average of the winning bid price (calculated after the natural logarithmic transformation of the winning bid price) for the same guitar model and aggregated the data of the same model numbers. We used 188 samples of data for Yamaha and 159 samples of data for Martin. In the analysis, we set the dependent variables as “ γ Price Persistence.” In addition, the models had different numbers of samples. In the Martin data, the maximum number of samples for the same model was 146, with a minimum of two, a mean of 11, and a median of five. In the Yamaha data, the maximum number of samples was 41, the minimum was two, the mean was seven, and the median was four.

Explanatory variables

In Analysis 1, the explanatory variables were the combination of wood species and guitar parts. The explanatory variable was the wood species used in the guitar. Specifically, the species of wood used in each guitar part—fingerboard, neck, top, and side back—was set as 1 if that wood was employed in that part of the guitar and 0 otherwise. As explained above, we removed the samples from different wood species. We collected 21 combinations from Martin and 25 combinations from Yamaha as the explanatory

Table 1 Species of wood used in acoustic guitar parts (Martin/Yamaha)

Part	Wood species
Fingerboard	Ebony, Rosewood, Palisander, Bubinga, Ovangkol, Richlite, Morado, Select hardwood, Katalox, Black Micarta
Neck	Mahogany, Select hardwood, Nato, Maple, Rosewood, Strata bond, Spanish cedar
Top	Sitka Spruce, Spruce, Yezo-Spruce, Cedar, Palisander, Mahogany, Sapele, Bamboo, HPL (High Pressure Laminate)
Side back	Mahogany, Rosewood, Sapele, Nato, Toog, Palisander, Meranti, Calantas, Walnut, Maple, Agathis, Ovangkol, Sycamore, Jacaranda, Koa, Siris, HPL, Resin, Bamboo

variables. The number of explanatory variables differed between the two brands, because different wood species were used. Details on the wood used and information on its attributes are provided in Tables 1 and 2. Table 1 summarizes the wood species used for each part of the guitar for both Martin and Yamaha. Four attributes corresponding to the hypotheses were defined for each species. Table 2 shows the correspondence between the characteristics of each wood sample and the attributes discussed in the hypothesis section. For the Martin sample, we set these 21 explanatory variables as follows: “ $x_{\text{Fingerboard-Rosewood}}$ ” “ $x_{\text{Fingerboard-Ebony}}$ ” “ $x_{\text{Fingerboard-Richlite}}$ ” “ $x_{\text{Fingerboard-Morado}}$ ” “ $x_{\text{Fingerboard-SelectHardwood}}$ ” “ $x_{\text{Fingerboard-Katalox}}$ ” “ $x_{\text{Fingerboard-BlackMicarta}}$ ” “ $x_{\text{Neck-Mahogany}}$ ” “ $x_{\text{Neck-SelectHardwood}}$ ” “ $x_{\text{Neck-Stratabond}}$ ” “ $x_{\text{Neck-Spanishcedar}}$ ” “ $x_{\text{Top-Sitkaspruce}}$ ” “ $x_{\text{Top-Sapele}}$ ” “ $x_{\text{Top-HPL}}$ ” “ $x_{\text{Top-Mahogany}}$ ” “ $x_{\text{Sideback-Mahogany}}$ ” “ $x_{\text{Sideback-Rosewood}}$ ” “ $x_{\text{Sideback-Sapele}}$ ” “ $x_{\text{Sideback-HPL}}$ ” “ $x_{\text{Sideback-Koa}}$ ” “ $x_{\text{Sideback-Siris}}$ ”. In Yamaha, we named these 25 explanatory variables as, “ $x_{\text{Fingerboard-Rosewood}}$ ” “ $x_{\text{Fingerboard-Ebony}}$ ” “ $x_{\text{Fingerboard-Palisander}}$ ” “ $x_{\text{Fingerboard-Bubinga}}$ ” “ $x_{\text{Fingerboard-Ovangkol}}$ ” “ $x_{\text{Neck-Mahogany}}$ ” “ $x_{\text{Neck-Nato}}$ ” “ $x_{\text{Neck-Maple}}$ ” “ $x_{\text{Neck-Rosewood}}$ ” “ $x_{\text{Top-Spruce}}$ ” “ $x_{\text{Top-YezoSpruce}}$ ” “ $x_{\text{Top-Palisander}}$ ” “ $x_{\text{Sideback-Toog}}$ ” “ $x_{\text{Sideback-Nato}}$ ” “ $x_{\text{Sideback-Mahogany}}$ ” “ $x_{\text{Sideback-Palisander}}$ ” “ $x_{\text{Sideback-Rosewood}}$ ” “ $x_{\text{Sideback-Meranti}}$ ” “ $x_{\text{Sideback-Clantus}}$ ” “ $x_{\text{Sideback-Walnut}}$ ” “ $x_{\text{Sideback-Maple}}$ ” “ $x_{\text{Sideback-Agathis}}$ ” “ $x_{\text{Sideback-Sapele}}$ ” “ $x_{\text{Sideback-Ovangkol}}$ ” “ $x_{\text{Sideback-Jacaranda}}$ ”.

In the Martin sample, multicollinearity occurred in Fingerboard-Richlite, Fingerboard-Ebony, and Fingerboard-Rosewood. Among these three variables, Fingerboard-Richlite is a synthetic material that meets only two attributes, and is thus less important. Therefore, we removed this information. In the Yamaha sample, we removed four variables because of multicollinearity. Fingerboard-Ovangkol was highly correlated with all of the fingerboard variables, and the number of samples was small; therefore, it was removed. Nato was viewed as a substitute wood for Mahogany; therefore, Neck-Nato and Side Back-Nato were removed when multicollinearity was generated.

In the analysis, we identified and interpreted wood as statistically significant for the winning bid price.

In Analysis 2, the explanatory variables were a combination of wood attributes and guitar parts. Analysis 2 used

a combination of guitar and wood attributes as explanatory variables to determine which attribute played a role in price persistence. In Analysis 2, we identified whether each wood species conformed to the attribute and labelled it as “1” for conformity and “0” for non-conformity. For example, if a sample’s fingerboard used rosewood, we could check the attributes of rosewood shown in Table 2. We could then determine that rosewood matched all the four attributes, so this sample’s Fingerboard-Dark, Fingerboard-Traditionality, Fingerboard-Decay resistant, and Fingerboard-Scarcity are all scored 1. We then set the explanatory variables directly for the wood attributes and guitar parts [47]. In Analysis 2, we set 16 explanatory variables (i.e., “ $x_{\text{Fingerboard-Dark}}$ ” “ $x_{\text{Fingerboard-Traditionality}}$ ” “ $x_{\text{Fingerboard-Decayresistant}}$ ” “ $x_{\text{Fingerboard-Scarcity}}$ ” “ $x_{\text{Neck-Dark}}$ ” “ $x_{\text{Neck-Traditionality}}$ ” “ $x_{\text{Neck-Decayresistant}}$ ” “ $x_{\text{Neck-Scarcity}}$ ” “ $x_{\text{Top-Dark}}$ ” “ $x_{\text{Top-Traditionality}}$ ” “ $x_{\text{Top-Decayresistant}}$ ” “ $x_{\text{Top-Scarcity}}$ ” “ $x_{\text{Sideback-Dark}}$ ” “ $x_{\text{Sideback-Traditionality}}$ ” “ $x_{\text{Sideback-Decayresistant}}$ ” “ $x_{\text{Sideback-Scarcity}}$ ”).

For Martin, more woods satisfy decay resistance, because decay resistance and dark are multicollinearity-generated in parts of the fingerboard, neck, and top. Thus, we removed decay resistance to observe the difference in the dark, meaning that fingerboard-decay resistant, neck-decay resistant, and top-decay resistant were removed. Top-Scarcity and Top-Traditionality have a strong correlation. Therefore, we removed Top-Scarcity. In addition, in the neck part, any two of Neck-Dark, Neck-Traditionality, and Neck-Scarcity will produce multicollinearity, so we are left with only one variable observation. The attribute analysis was divided according to the properties of wood. Four types of wood are used by Yamaha for the neck. The other attributes of these four types are similar, and only their scarcity is different. Two kinds of wood are scarce, and two are not; thus, we retained Neck-Scarcity.

In the Yamaha sample, we removed five variables because of multicollinearity. We also found that, in all of the parts, dark and decay resistance have a strong correlation, and more wood satisfies decay resistance; therefore, we removed decay resistance in three parts (fingerboard, neck, top), which means that fingerboard-decay resistance, neck-decay resistance, and top-decay resistance were removed, leaving the decay resistance observed in the side back part. Therefore, we removed the dark back side. In addition, traditionality and scarcity were

Table 2 Characteristics of wood used for acoustic guitars by attribute

Name of wood	H1 Dark color	H2 Traditionality	H3 Decay resistant	H4 Scarcity
Agathis	0	0	0	1
Bamboo	0	0	0	0
Black Micarta	1	0	1	0
Bubinga	1	0	1	0
Calantas	0	0	1	0
Cedar	0	0	1	1
Ebony	1	1	1	1
HPL	1	0	1	0
Jacaranda	0	0	0	0
Katalox	1	0	1	0
Koa	1	1	0	1
Mahogany	1	1	1	1
Maple	0	1	0	0
Meranti	0	0	0	0
Morado	1	0	1	0
Nato (Mora)	1	0	1	0
Ovangkol	1	0	1	0
Palisander	1	1	1	1
Resin	1	0	1	0
Rosewood	1	1	1	1
Sapele	1	0	1	1
Select hardwood	Not available	Not available	Not available	Not available
Siris	1	0	0	0
Sitka Spruce	0	1	0	0
Spanish cedar	0	0	1	1
Spruce	0	1	0	0
Strata bond	1	0	1	0
Sycamore	0	0	0	0
Toog	1	0	1	1
Walnut	1	0	1	1
Yezo-Spruce	0	0	0	0

Table 2 shows the correspondence between the characteristics of each wood sample and the attributes discussed in the hypotheses. We marked woods with matching attributes as “1” (pink) and woods with mismatched attributes as “0” (green). “Select Hardwoods” is the term Martin is using, we cannot know the wood species or wood attributes of “Select Hardwoods”, and we marked it as “Not Available”. The criteria used to organize the attribute-specific characteristics of wood are described in “Sample collection” above

highly correlated in the neck and top parts; therefore, as with the Martin sample, we retained traditionality to be observed in the top part and removed Neck-Scarcity and Top-Scarcity.

Control variables

First, we controlled for the effect of the age of the acoustic guitar, calculated from the year in which it was initially released. Given that the price persistence of a product may be affected by age, we analyzed the age of the acoustic guitar as a control variable. Age was measured from the 1920s to the 2020s in decadal units and was set to “1” if the year the product was first released fell into this category and “0” if it did not [47]. We named these 10 variables “ x_{1920s} ,” “ x_{1930s} ,” “ x_{1940s} ,” “ x_{1950s} ,” “ x_{1960s} ,” “ x_{1970s} ,” “ x_{1980s} ,” “ x_{1990s} ,” “ x_{2000s} ,” “ x_{2010s} ,” and “ x_{2020s} .”

Second, we controlled for the influence of natural and artificial woods. The wood used in guitars can be divided into two types: solid and plywood. Solid wood is natural wood, whereas plywood is synthetic wood. Artificial synthetic materials are cheaper and more resistant to decay than are natural materials; however, consumers often prefer their general value [22]. Natural wood products are considered more stable, rot-resistant, natural, modern, and luxurious than laminates [48]. Therefore, naturalness (solid) was analyzed as a control variable, because product value can be affected by the naturalness of wood. Specifically, the value was set to “1” if the product was natural wood and “0” otherwise. This control variable can be used for both the top and side backs. We set these variables as “ $x_{Solid-Top}$ ” and “ $x_{Solid-Sideback}$.” However, the control variable for the side back had a high correlation with its explanatory variables, causing a multicollinearity problem. Therefore, only the top portion was included in this analysis.

Empirical specifications

We regarded a p value less than 0.05 (typically ≤ 0.05) as statistically significant. We used this criterion to identify the significant variables. We provide confirmation results for any statistical problems in the four models as follows. In Analysis 1, Martin’s mean variance inflation factor (VIF) was 1.64, and the maximum VIF was 2.48; Yamaha’s mean VIF was 1.87, and the maximum VIF was 4.33. In Analysis 2, Martin’s mean VIF was 1.35, and the maximum VIF was 2.26; Yamaha’s mean VIF was 1.51, and the maximum VIF was 2.19. We ultimately confirmed that there was no multicollinearity problem, as they were all below 5 (as a rule of thumb, VIF values above 5 or 10 indicate multicollinearity [49]).

To verify the presence or absence of heteroskedasticity, the Breusch–Pagan test was conducted. In Analysis 1, Martin’s p value in the Bruch–Pagan test was 0.04, and Yamaha’s p value in the Bruch–Pagan test was 0.02. In Analysis 2, Martin’s p value in the Bruch–Pagan test was 0.07, and Yamaha’s p value was 0.006. The Bruch–Pagan test result was typically > 0.05 ; hence, we used the Newey–West test to provide

an estimate of the covariance matrix of the parameters of a regression-type model, except for Martin in Analysis 2.

The complete model of the four models is as follows: where β is the coefficient of each variable, C is a constant, and ε is an error term.

Model 1: Analysis 1 (the explanatory variables were the combination of wood species and guitar part [Martin])

$$\begin{aligned} y_{Price}^{Martin1} = & \beta_1 x_{Fingerboard-Rosewood}^{Martin1} + \beta_2 x_{Fingerboard-Ebony}^{Martin1} \\ & + \beta_3 x_{Fingerboard-Richlite}^{Martin1} + \beta_4 x_{Fingerboard-Morado}^{Martin1} \\ & + \beta_5 x_{Fingerboard-SelectHardwood}^{Martin1} + \beta_6 x_{Fingerboard-Katalox}^{Martin1} \\ & + \beta_7 x_{Fingerboard-BlackMicarta}^{Martin1} + \beta_8 x_{Neck-Mahogany}^{Martin1} \\ & + \beta_9 x_{Neck-SelectHardwood}^{Martin1} + \beta_{10} x_{Neck-Stratabond}^{Martin1} \\ & + \beta_{11} x_{Neck-Spanishcedar}^{Martin1} + \beta_{12} x_{Top-Sitkaspruce}^{Martin1} \\ & + \beta_{13} x_{Top-Sapele}^{Martin1} + \beta_{14} x_{Top-HPL}^{Martin1} \\ & + \beta_{15} x_{Top-Mahogany}^{Martin1} + \beta_{16} x_{Sideback-Mahogany}^{Martin1} \\ & + \beta_{17} x_{Sideback-Rosewood}^{Martin1} + \beta_{18} x_{Sideback-Sapele}^{Martin1} \\ & + \beta_{19} x_{Sideback-HPL}^{Martin1} + \beta_{20} x_{Sideback-Koa}^{Martin1} \\ & + \beta_{21} x_{Sideback-Siris}^{Martin1} + \beta_{22} x_{1920s}^{Martin1} \\ & + \beta_{23} x_{1930s}^{Martin1} + \beta_{24} x_{1940s}^{Martin1} \\ & + \beta_{25} x_{1950s}^{Martin1} + \beta_{26} x_{1960s}^{Martin1} \\ & + \beta_{27} x_{1970s}^{Martin1} + \beta_{28} x_{1980s}^{Martin1} \\ & + \beta_{29} x_{1990s}^{Martin1} + \beta_{30} x_{2000s}^{Martin1} \\ & + \beta_{31} x_{2010s}^{Martin1} + \beta_{32} x_{2020s}^{Martin1} \\ & + \beta_{33} x_{Solid-Top}^{Martin1} + \beta_{34} x_{Solid-Sideback}^{Martin1} \\ & + C + \varepsilon. \end{aligned}$$

Model 2: Analysis 1 (the explanatory variables were the combination of wood species and guitar part [Yamaha]).

$$\begin{aligned} y_{Price}^{Yamaha1} = & \beta_1 x_{Fingerboard-Rosewood}^{Yamaha1} + \beta_2 x_{Fingerboard-Ebony}^{Yamaha1} \\ & + \beta_3 x_{Fingerboard-Palisander}^{Yamaha1} + \beta_4 x_{Fingerboard-Bubinga}^{Yamaha1} \\ & + \beta_5 x_{Fingerboard-Ovankol}^{Yamaha1} + \beta_6 x_{Neck-Mahogany}^{Yamaha1} \\ & + \beta_7 x_{Neck-Nato}^{Yamaha1} + \beta_8 x_{Neck-Maple}^{Yamaha1} + \beta_9 x_{Neck-Rosewood}^{Yamaha1} \\ & + \beta_{10} x_{Top-Spruce}^{Yamaha1} + \beta_{11} x_{Top-Yezospruce}^{Yamaha1} \\ & + \beta_{12} x_{Top-Palisander}^{Yamaha1} + \beta_{13} x_{Sideback-Toog}^{Yamaha1} \\ & + \beta_{14} x_{Sideback-Nato}^{Yamaha1} + \beta_{15} x_{Sideback-Mahogany}^{Yamaha1} \\ & + \beta_{16} x_{Sideback-Palisander}^{Yamaha1} + \beta_{17} x_{Sideback-Rosewood}^{Yamaha1} \\ & + \beta_{18} x_{Sideback-Meranty}^{Yamaha1} + \beta_{19} x_{Sideback-Clantus}^{Yamaha1} \\ & + \beta_{20} x_{Sideback-Walnut}^{Yamaha1} + \beta_{21} x_{Sideback-Maple}^{Yamaha1} \\ & + \beta_{22} x_{Sideback-Agathis}^{Yamaha1} + \beta_{23} x_{Sideback-Sapele}^{Yamaha1} \\ & + \beta_{24} x_{Sideback-Ovankol}^{Yamaha1} + \beta_{25} x_{Sideback-Jacaranda}^{Yamaha1} \\ & + \beta_{26} x_{1970s}^{Yamaha1} + \beta_{27} x_{1980s}^{Yamaha1} + \beta_{28} x_{1990s}^{Yamaha1} \\ & + \beta_{29} x_{2000s}^{Yamaha1} + \beta_{30} x_{2010s}^{Yamaha1} + \beta_{31} x_{Solid-Top}^{Yamaha1} \\ & + \beta_{32} x_{Solid-Sideback}^{Yamaha1} + C + \varepsilon. \end{aligned}$$

Model 3: Analysis 2 (The explanatory variables were a combination of wood attributes and guitar part [Martin])

$$\begin{aligned}
 y_{\text{Price}}^{\text{Martin2}} = & \beta_1 x_{\text{Fingerboard-Dark}}^{\text{Martin2}} + \beta_2 x_{\text{Fingerboard-Traditionality}}^{\text{Martin2}} \\
 & + \beta_3 x_{\text{Fingerboard-Decayresistant}}^{\text{Martin2}} + \beta_4 x_{\text{Fingerboard-Scarcity}}^{\text{Martin2}} \\
 & + \beta_5 x_{\text{Neck-Dark}}^{\text{Martin2}} + \beta_6 x_{\text{Neck-Traditionality}}^{\text{Martin2}} \\
 & + \beta_7 x_{\text{Neck-Decayresistant}}^{\text{Martin2}} + \beta_8 x_{\text{Neck-Scarcity}}^{\text{Martin2}} \\
 & + \beta_9 x_{\text{Top-Dark}}^{\text{Martin2}} + \beta_{10} x_{\text{Top-Traditionality}}^{\text{Martin2}} \\
 & + \beta_{11} x_{\text{Top-Decayresistant}}^{\text{Martin2}} + \beta_{12} x_{\text{Top-Scarcity}}^{\text{Martin2}} \\
 & + \beta_{13} x_{\text{Sideback-Dark}}^{\text{Martin2}} + \beta_{14} x_{\text{Sideback-Traditionality}}^{\text{Martin2}} \\
 & + \beta_{15} x_{\text{Sideback-Decayresistant}}^{\text{Martin2}} + \beta_{16} x_{\text{Sideback-Scarcity}}^{\text{Martin2}} \\
 & + \beta_{17} x_{1920s}^{\text{Martin2}} + \beta_{18} x_{1930s}^{\text{Martin2}} + \beta_{19} x_{1940s}^{\text{Martin2}} \\
 & + \beta_{20} x_{1950s}^{\text{Martin2}} + \beta_{21} x_{1960s}^{\text{Martin2}} + \beta_{22} x_{1970s}^{\text{Martin2}} \\
 & + \beta_{23} x_{1980s}^{\text{Martin2}} + \beta_{24} x_{1990s}^{\text{Martin2}} + \beta_{25} x_{2000s}^{\text{Martin2}} \\
 & + \beta_{26} x_{2010s}^{\text{Martin2}} + \beta_{27} x_{2020s}^{\text{Martin2}} + \beta_{28} x_{\text{Solid-Top}}^{\text{Martin2}} \\
 & + \beta_{29} x_{\text{Solid-Sideback}}^{\text{Martin2}} + C + \varepsilon.
 \end{aligned}$$

Model 4: Analysis 2 (The explanatory variables were a combination of wood attributes and guitar part [Yamaha]).

$$\begin{aligned}
 y_{\text{Price}}^{\text{Yamaha2}} = & \beta_1 x_{\text{Fingerboard-Dark}}^{\text{Yamaha2}} + \beta_2 x_{\text{Fingerboard-Traditionality}}^{\text{Yamaha2}} \\
 & + \beta_3 x_{\text{Fingerboard-Decayresistant}}^{\text{Yamaha2}} + \beta_4 x_{\text{Fingerboard-Scarcity}}^{\text{Yamaha2}} \\
 & + \beta_5 x_{\text{Neck-Dark}}^{\text{Yamaha2}} + \beta_6 x_{\text{Neck-Traditionality}}^{\text{Yamaha2}} \\
 & + \beta_7 x_{\text{Neck-Decayresistant}}^{\text{Yamaha2}} + \beta_8 x_{\text{Neck-Scarcity}}^{\text{Yamaha2}} \\
 & + \beta_9 x_{\text{Top-Dark}}^{\text{Yamaha2}} + \beta_{10} x_{\text{Top-Traditionality}}^{\text{Yamaha2}} \\
 & + \beta_{11} x_{\text{Top-Decayresistant}}^{\text{Yamaha2}} + \beta_{12} x_{\text{Top-Scarcity}}^{\text{Yamaha2}} \\
 & + \beta_{13} x_{\text{Sideback-Dark}}^{\text{Yamaha2}} + \beta_{14} x_{\text{Sideback-Traditionality}}^{\text{Yamaha2}} \\
 & + \beta_{15} x_{\text{Sideback-Decayresistant}}^{\text{Yamaha2}} + \beta_{16} x_{\text{Sideback-Scarcity}}^{\text{Yamaha2}} \\
 & + \beta_{17} x_{1970s}^{\text{Yamaha2}} + \beta_{18} x_{1980s}^{\text{Yamaha2}} + \beta_{19} x_{1990s}^{\text{Yamaha2}} \\
 & + \beta_{20} x_{2000s}^{\text{Yamaha2}} + \beta_{21} x_{2010s}^{\text{Yamaha2}} \\
 & + \beta_{22} x_{\text{Solid-Top}}^{\text{Yamaha2}} + \beta_{23} x_{\text{Solid-Sideback}}^{\text{Yamaha2}} + C + \varepsilon
 \end{aligned}$$

Results

The results of Analyses 1 and 2 are presented below. Two brands were used in each analysis. Tables 3 and 4 present the results of Analysis 1. We performed separate analyses for the two brands. Tables 5 and 6 present the results of Analysis 2. In addition, Figs. 4, 5, 6, and 7 show the four regression analyses performed in our study. For ease of visualization, separate scatter plots of the observed and predicted values were created. Although some of the samples were less predictive, the overall results showed a strong positive correlation.

Table 3 Multiple regression analysis results for Martin guitars

	Coefficient	Standard error
Fingerboard-Ebony	0.60**	0.11
Neck-Mahogany	0.14	0.13
Side back-Rosewood	0.27*	0.13
Side back-Sapele	− 0.33**	0.11
Side back-HPL	− 0.55**	0.09
Year 1950s	0.51**	0.10
Year 1990s	− 0.48**	0.10
Year 2000s	− 0.29**	0.09
Constant	11.42**	0.09
Adjusted R-squared	0.70	

The explanatory variables were the combination of wood species and guitar parts

** $p < 0.01$, * $p < 0.05$, † $p < 0.10$

The results presented in this table are the results of stepwise regression analysis

Table 4 Results of multiple regression analysis for Yamaha guitars

	Coefficient	Standard error
Fingerboard-Rosewood	0.58**	0.15
Fingerboard-Ebony	1.44**	0.20
Fingerboard-Palisander	0.31**	0.11
Neck-Mahogany	0.34**	0.12
Neck-Rosewood	− 0.54	0.38
Side back-Palisander	0.52**	0.12
Side back-Rosewood	0.36	0.11
Side back-Meranti	− 0.48*	0.20
Side back-Maple	0.51†	0.26
Side back-Agathis	− 0.37†	0.20
Solid-Top	0.42**	0.13
Year 1970s	− 0.20†	0.11
Year 2010s	0.37*	0.18
Constant	8.50**	0.17
Adjusted R-squared	0.61	

The explanatory variables were the combination of wood species and guitar parts

** $p < 0.01$, * $p < 0.05$, † $p < 0.10$

The results presented in this table are the results of stepwise regression analysis

Analysis 1: The explanatory variables were the combination of wood species and guitar parts.

Tables 3 and 4 present the results of the multiple regression analysis (in which the explanatory variables were a combination of wood species and guitar parts) for each product category. The adjusted coefficients of determination, confirmed using the stepwise method, were 0.70 and 0.61 for Martin and Yamaha, respectively. We confirmed that the following eight factors had positive

Table 5 Multiple regression analysis results for Martin guitars

	Coefficient	Standard error
Fingerboard-Traditionality	0.41**	0.11
Top-Dark	− 0.38**	0.12
Side back-Traditionality	0.76**	0.11
Side back-Decay resistance	− 0.41	0.28
Year 1940s	− 0.59*	0.28
Year 1950s	0.60*	0.28
Year 1990s	− 0.64**	0.11
Year 2000s	− 0.41**	0.11
Constant	11.42**	0.27
Adjusted R-squared	0.61	

The explanatory variables were the combination of guitar parts and wood attributes

** $p < 0.01$, * $p < 0.05$, † $p < 0.10$

The results presented in this table are the results of stepwise regression analysis

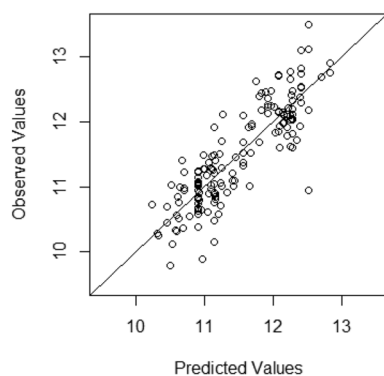
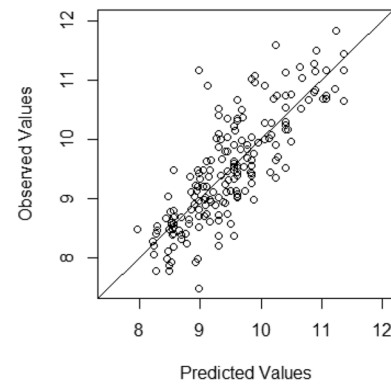
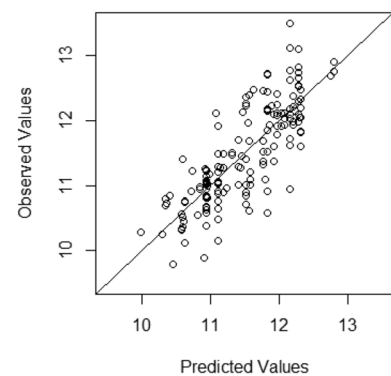
Table 6 Multiple regression analysis for Yamaha guitars

	Coefficient	Standard error
Fingerboard-Scarcity	0.44**	0.16
Neck-Traditionality	0.51**	0.17
Side back-Traditionality	0.51*	0.20
Side back-Decay resistance	0.39**	0.15
Side back-Scarcity	− 0.33	0.24
Solid-Top	0.66**	0.20
Year 1980s	0.32 †	0.18
Constant	8.13**	0.22
Adjusted R-squared	0.51	

The explanatory variables were the combination of guitar parts and wood attributes

** $p < 0.01$, * $p < 0.05$, † $p < 0.10$

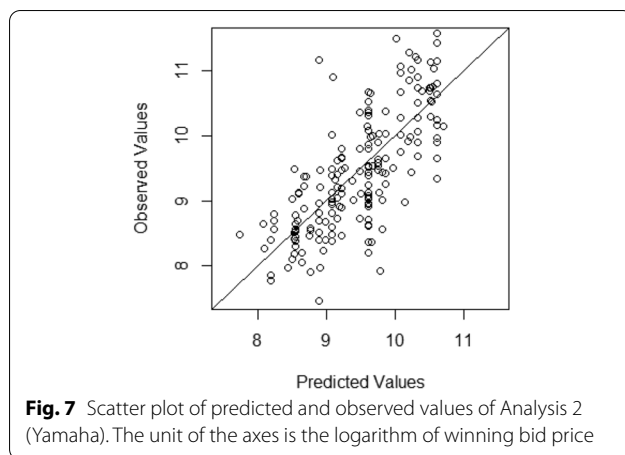
The results presented in this table are the results of stepwise regression analysis

**Fig. 4** Scatter plot of predicted and observed values of Analysis 1 (Martin). The unit of the axes is the logarithm of winning bid price**Fig. 5** Scatter plot of predicted and observed values of Analysis 1 (Yamaha). The unit of the axes is the logarithm of winning bid price**Fig. 6** Scatter plot of predicted and observed values of Analysis 2 (Martin). The unit of the axes is the logarithm of winning bid price

effects on the explanatory variables identified using the stepwise method. For Martin, two factors had significantly positive effects: fingerboard-bony ($p < 0.01$) and side-back-Rosewood ($p < 0.05$). For Yamaha, five factors had positive effects: Fingerboard-Rosewood ($p < 0.01$), Fingerboard-Ebony ($p < 0.01$), Fingerboard-Palisander ($p < 0.01$), Neck-Mahogany ($p < 0.01$), and Side Back-Palisander ($p < 0.01$). Using the stepwise method, we confirmed that the following four factors had negative effects on the explanatory variables identified. For Martin, Side Back-Sapele ($p < 0.01$) and Side Back-HPL ($p < 0.01$) had significantly negative effects. For Yamaha, Side Back-Meranti ($p < 0.05$) had negative effects.

Analysis 2: The explanatory variables were the combination of guitar parts and wood attributes.

Tables 5 and 6 present the results of multiple regression analysis for each product category. The adjusted coefficients of determination, confirmed using the



stepwise method, were 0.61 and 0.51 for Martin and Yamaha, respectively. We confirmed that four factors had significantly positive effects on the explanatory variables identified using the stepwise method. For Martin, Fingerboard-Traditionality ($p < 0.01$) and Side back-Traditionality ($p < 0.01$) had positive effects. Top-dark conditions ($p < 0.05$) were found to have a negative effect. For Yamaha, four factors had positive effects: Fingerboard-Scarcity ($p < 0.01$), Neck-Traditionality ($p < 0.01$), Side

back-Traditionality ($p < 0.05$), and Side back-Decay resistance ($p < 0.01$).

Discussion

Tables 7 and 8 summarize the results regarding the significance of the variables and the evaluation of the hypotheses in Analysis 1 (with the combination of wood species and guitar parts used as explanatory variables). In these tables, only the significant explanatory variables ($p < 0.05$) are organized along with their wood characteristics. This study examined the influence of wood species on the price persistence of acoustic guitars by considering four attributes. Among the wood species that were statistically significant, only the traditional attributes matched all wood species. The other three attributes included not only the wood species that met the criteria but also those that did not. In addition, among the wood species that were statistically significant, some wood species conformed only to the traditional attributes. However, among the other three attributes, a wood species that conformed to one attribute also conformed to other attributes. Therefore, the traditional attribute is a key attribute of price persistence, while the other three attributes are important only in some cases, which we explain in detail in Sects. “Results interpretation for Hypothesis 1” to “Results interpretation for Hypothesis 4”.

Table 7 Results of stepwise method for Martin (Analysis 1)

Wood	Statistic significance	H1: Dark color	H2: Traditionality	H3: Decay resistance	H4: Scarcity
Ebony	Positively	Match	Match	Match	Match
Rosewood	Positively	Match	Match	Match	Match
Sapele	Negatively	Does not match	Match	Does not match	Does not match
HPL	Negatively	Does not match	Match	Does not match	Match

Table 8 Results of stepwise method for Yamaha (Analysis 1)

Wood	Statistic significance	H1: Dark color	H2: Traditionality	H3: Decay resistance	H4: Scarcity
Ebony	Positively	Match	Match	Match	Match
Rosewood	Positively	Match	Match	Match	Match
Mahogany	Positively	Match	Match	Match	Match
Palisander	Positively	Match	Match	Match	Match
Meranti	Negatively	Match	Match	Match	Match

1. If the wood is positively significant and matches the attribute, it is determined to be a “Match.” If the wood is positively significant and does not match the attribute, it is a “Does not match”

If the wood is negatively significant and the wood’s attributes match the attributes, it is a “Does not match”

If the wood is negatively significant and does not match the attribute, it is a “Match”

2. The criteria for matching in this table are derived from the criteria for specific characteristics described in “Dependent variables”. If the color is black, the dark color is determined to be a “Match.” The decision regarding traditionality was made by considering Bennett’s wood arrangement, in which he identified the main types of traditional wood used to make guitars [5]. Decay resistance is considered a “Match” if the wood species are identified as good. Scarcity was regarded as a “Match” if it was an endangered species

Table 9 Results of stepwise method for both brands (Analysis 2)

Brand	H1: Dark color	H2: Traditionality	H3: Decay resistance	H4: Scarcity
Martin	Negatively significant	Positively significant	–	–
Yamaha	–	Positively significant	Positively significant	Positively significant

Table 9 summarizes the significance of the variables and the evaluation of the hypotheses in Analysis 2 (combination of wood attributes and guitar parts as explanatory variables). In Analysis 2, we confirmed that the most important of these four attributes is traditionality, while scarcity and decay resistance, when appearing in mass-market brands, such as Yamaha, also influence price persistence.

In summary, Analysis 1 shows that rosewood and ebony have positive impacts on guitar price persistence in both brands, and that all of them match the four attributes. For Yamaha, mahogany and palisander had positive impacts on price persistence, with mahogany and palisander conforming to the four attributes. However, in Analysis 2, the only positive influence on guitar price is traditionality, which is directly reflected by the four variables. Traditionality plays a key role in the price persistence of guitars, and all other attributes depend on traditionality to have an impact on persistence. However, for mass-market brands, scarcity and decay resistance positively influence price persistence. Contrary to prior research findings, dark color does not appear to have a positive effect, perhaps because people are more interested in musical instruments' practicality than in their color.

Results interpretation for Hypothesis 1

In Analysis 1, we confirmed the effects of seven wood species (ebony, rosewood, sapele, HPL, mahogany, palisander, and meranti) in terms of dark color (aesthetic attributes). In the Martin sample, the results for ebony and rosewood support Hypothesis 1; however, HPL and sapele, although dark in color, still have a negative effect on price persistence and do not support this hypothesis. We speculate that this result is obtained, because HPL and sapele match traditionality, which has more weight in terms of price persistence. Hence, we deduce that this attribute is not a key attribute in luxury brands. In the Yamaha sample, five wood species (ebony, rosewood, mahogany, palisander, and meranti) supported Hypothesis 1. Rosewood, mahogany, ebony, and palisander, all dark-colored, have a positive effect on the price persistence of guitars. Meranti is brightly colored and has a negative effect on the price persistence of guitars, supporting the hypothesis. Thus, we found that color is an important attribute of wood. However, most of the woods that support Hypothesis 1 also conform to other attributes in addition to aesthetic ones.

In Analysis 2, top-dark has a negative effect on price persistence. Spruce, which is used heavily on guitar tops, is white or cream in color and does not conform to the conventional dark color. However, spruce conforms to traditionality. Here, the two characteristics create a conflict. Therefore, a negative impact occurs when spruce, which does not conform to traditional characteristics, is used at the top, which also indirectly confirms the positive impact of traditionality on guitar price persistence.

Thus, we conclude that dark color is not a key factor in price persistence, which is inconsistent with Hypothesis 1.

Results interpretation for Hypothesis 2

In Analysis 1, we used wood species and guitar parts as explanatory variables. We confirmed the effects of seven wood species in terms of traditionality. Ebony, rosewood, mahogany, and palisander were in accordance with traditionality characteristics and had a positive effect on the price persistence of guitars. Sapele, HPL, and meranti do not have traditionality and have a negative effect on price persistence, consistent with our assumptions. Thus, we confirmed that traditionality attributes are important. In Analysis 2, we used wood species and attributes as the explanatory variables. Traditionality has a highly significant effect on the dependent variables, which is directly reflected by the four variables.

Overall, the results demonstrate that traditionality attributes have a significant effect on price persistence. Therefore, Hypothesis 2, which states that traditionality has a positive impact on product value persistence, is supported. Thus, we confirmed that traditionality is important.

Results interpretation for Hypothesis 3

In Analysis 1, we confirmed the effects of the seven wood species in terms of decay resistance. In this analysis, five species (ebony, rosewood, mahogany, palisander, and meranti) supported Hypothesis 3, while sapele and HPL did not.

For Martin, ebony and rosewood support the hypothesis; however, HPL and sapele, although they have decay resistance, still have a negative effect on price persistence and do not support this hypothesis. We speculate that this happens, because HPL and sapele do not have traditionality, which has more weight in terms of price persistence. Hence, we deduce that this attribute is not a key one in luxury brands.

For Yamaha, five species (ebony, rosewood, mahogany, palisander, and meranti) support this hypothesis. Rosewood, mahogany, ebony, and palisander have decay resistance and positive effects on the price persistence of guitars. Meranti lacks decay resistance and has a negative effect on guitar price persistence, supporting this hypothesis. Thus, we find that decay resistance is important for price persistence in mass-market brands.

Analysis 2 reveals that, for Martin, decay resistance does not appear to have a positive influence on price persistence, but decay resistance has a positive significant effect for Yamaha. Yamaha is a mass-market brand; therefore, we can deduce that decay resistance has a critical impact on price persistence only for mass-market brands.

Thus, we find that decay resistance is not a key attribute for luxury brands, while it has a critical impact on price persistence for mass-market brands.

Results interpretation for Hypothesis 4

We confirmed the effects of the seven wood species in terms of scarcity. The timber market occupies a special economic position [50]. Trade in commodities such as valuable timber is strongly constrained by the loading capacity of forest ecosystems and the potential for afforestation [50]. Rosewood, mahogany, ebony, and palisander are scarce and thus have a positive effect on the price persistence of guitars.

For Martin, ebony, rosewood, and HPL support Hypothesis 4; however, sapele, though scarce, has a negative effect on price persistence and does not support this hypothesis. We speculate that this happens, because sapeles do not have traditionality, which accounts for their greater weight in terms of price persistence. Hence, we deduce that scarcity is not a key attribute for luxury brands.

For Yamaha, five species (ebony, rosewood, mahogany, palisander, and meranti) supported this hypothesis. Ebony, rosewood, mahogany, and palisander have positive effects on guitar price persistence. Meranti is not scarce and has a negative effect on guitar price persistence, supporting the hypothesis. Thus, we find that scarcity is important for price persistence in mass-market brands.

Further attribute analysis reveals that scarcity does not appear to have a positive influence on price persistence for Martin guitars but does have a significantly positive effect for Yamaha guitars. The difference here is that scarcity alone does not maintain the price of luxury instruments; it requires a combination of other attributes. However, in a mass-market brand, simply using wood with a scarcity attribute positively affects price persistence.

Thus, we find that scarcity is not a key attribute for luxury brands but has a critical impact on price persistence for mass-market brands.

Implications

This study expands the literature on consumer purchase motivation in terms of price persistence. Previous studies have not conducted empirical research on the current market; thus, we collected and verified relevant market data. The price persistence of guitar products is an important factor influencing purchase decisions. We confirmed that the attributes of different woods have different effects on price persistence.

Due to environmental degradation, species that have been used by the guitar industry for over 200 years are almost extinct and no longer commercially viable. The guitar industry thus uses wood alternatives. However, we confirmed that wood conforming to traditionality has a positive impact on the price persistence of acoustic guitars, which is negatively affected if traditionality is absent. Therefore, guitar companies using new materials in their guitars should not use the new materials in all parts of the guitar but instead use them in combination with traditional wood. In addition, we confirm that scarcity and decay resistance can play a positive role in price persistence for mass-market brands. Thus, guitar companies must choose guitar woods based on the nature of the market.

Limitations and future research

This study has several limitations, which future research endeavors can address. First, our data were drawn only from the Japanese second-hand goods market. As cultures and senses of value vary among countries, future research should collect market data from other countries and compare it with those used in this study. A comparison between different markets can provide additional findings and useful suggestions for future research.

Second, this study focused on acoustic guitars. The scope of instruments examined should be expanded. Market data for wooden instruments, such as electric guitars and violins, could be collected and studied by comparing between instruments. Such comparisons will provide additional findings and fruitful directions for future research.

Finally, musical instruments have existed as cultural products for many years. We collected data from an actual second-hand market and conducted a quantitative research. However, we excluded qualitative information such as on history from the analysis. The implications of such qualitative analysis, in addition to the four investigated wood attributes, would improve our understanding of the influence of materials on musical instruments. Thus, future research could extend the results of this study by conducting qualitative analysis.

Conclusions

Wood attributes are important, because they directly impact market opportunities and consumer acceptance of wood products [16]. Previous studies have found a strong relationship between customers' preference and willingness to pay (WTP) for wood attributes [17, 18]. Based on the notion that wood attributes contribute to the price persistence of guitar products, this study analyzes the market for used products and contributes to the study of price persistence.

We analyze the effect of wood attributes on the price persistence of acoustic guitars. First, we find that the dark color attribute has no impact on the price persistence of either mass-market or luxury brand guitars. Second, in the overall market, we find that the traditionality attribute is the most critical for the price persistence of guitars. Third, we find that both decay resistance and scarcity are important for the price persistence of mass-market guitars, whereas decay resistance and scarcity are not key attributes for luxury guitars, which need only the traditionality attribute for price persistence.

Given the continuously increasing competition in international markets, the wood product industry should flexibly adapt to economic conditions and dynamic customer needs [8, 9]. This study can help companies understand the needs of the market, define objectives for their products, and choose guitar wood attributes according to the market. For both mass-market and luxury brands, woods with traditionality attributes are key for the price persistence of a guitar. For mass-market brands, decay resistance and scarcity also have positive impacts on price persistence, so preference should be given to woods with these two attributes.

Abbreviations

IUCN: International Union for Conservation of Nature; HPL: High Pressure Laminated; VIF: Variance inflation factor; WTP: Willingness to pay.

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Author contributions

Conceptualization, XZ, RM and YI; methodology, XZ, RM and YI; software, XZ and RM; validation, XZ, RM and YI; formal analysis, XZ, RM and YI; investigation, XZ; resources, XZ; data curation, XZ, RM and YI; writing—original draft preparation, XZ, RM and YI; writing—review and editing, XZ, RM and YI; visualization, XZ, RM and YI; supervision, YI; project administration, YI; funding acquisition, YI. All authors have read and agreed to the published version of the manuscript.

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Availability of data and materials

The data presented in this study are available upon request from the corresponding author.

Declarations

Competing interests

The authors declare no competing interest.

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References

- Wegst UG (2006) Wood for sound. *Am J Bot* 93(10):1439–1448. <https://doi.org/10.3732/ajb.93.10.1439>
- Pakarinen TJ, Asikainen AT (2001) Consumer segments for wooden household furniture. *Holz als Roh- und Werkstoff* 59(3):217–227. <https://doi.org/10.1007/s001070100187>
- French M, Handy R, Jackson MJ (2009) Manufacturing sustainability and life cycle management in the production of acoustic guitars. *IJCMSE* 2(1/2):41–53. <https://doi.org/10.1504/IJCMSE.2009.024922>
- Yoshikawa S, Waltham C (2014) Wood for wooden musical instruments. *Proceedings of the International Symposium on Musical Acoustics, ISMA, Le Mans, France, 7–12 July 2014*, pp 281–286. <https://doi.org/10.13140/2.1.5067.1369>
- Bennett BC (2016) The sound of trees: wood selection in guitars and other chordophones. *Econ Bot* 70(1):49–63. <https://doi.org/10.1007/s12231-016-9336-0>
- Ashby M, Johnson K (2003) *Materials and design: the art and science of material selection in product design*. England, Oxford
- Kretschmann DE (2010) Mechanical properties of wood. In: *Wood Handbook—Wood as an Engineering Material*, Forest Products Laboratory, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory: Madison, WI America, pp 4–14
- Toivonen RM (2012) Product quality and value from consumer perspective—an application to wooden products. *J For Econ* 18(2):157–173. <https://doi.org/10.1016/j.jfe.2011.12.004>
- Nicholls D, Bumgardner M (2018) Challenges and opportunities for North American hardwood manufacturers to adopt customization strategies in an era of increased competition. *Forests* 9(4):186. <https://doi.org/10.3390/f9040186>
- Andreessen M (2017) 12 Things about product–market fit. <https://a16z.com/2017/02/18/12-things-about-product-market-fit/>. Accessed 11 Feb 2022.
- Olsen PF, Smith T, Schnell J, Vos T (1997) Breeding trait gains and economic worth. In: Burdon RD, Moore JM (Eds) "IUFRO '97 Genetics of Radiata Pine" *Proceedings of the NZ FRI-IUFRO, Rotorua, New Zealand, 1–4 December 1997*
- Jonsson R (2006) Increasing the competitiveness of wood in material substitution: a method for assessing and prioritizing customer needs. *J Wood Sci* 52(2):154–162. <https://doi.org/10.1007/s10086-005-0741-8>
- Sweeney JC, Soutar GN (2001) Consumer perceived value: the development of a multiple item scale. *J Retail* 77(2):203–220. [https://doi.org/10.1016/S0022-4359\(01\)00041-0](https://doi.org/10.1016/S0022-4359(01)00041-0)
- Lindgreen A, Wynstra F (2005) Value in business markets: what do we know? Where are we going? *Ind Mark Manag* 34(7):732–748. <https://doi.org/10.1016/j.indmarman.2005.01.001>
- Fisher TH (2004) What we touch, touches us: materials, affects, and affordances. *Des Issues* 20(4):20–31. <https://doi.org/10.1162/0747936042312066>
- Briggs D, Bialozynski L (1995) Use of wood raw materials by the U.S. millwork industry in 1990. *For Prod J* 45(2):27–34
- Broman NO (2000) Means to measure the aesthetic properties of wood. Doctoral Thesis, Division of Wood Technology, Luleå University of Technology, Luleå.
- Brinberg D, Bumgardner M, Danilovsky K (2007) Understanding perception of wood household furniture: application of a policy capturing approach. *For Prod J* 57(7/8):21–26
- Spetic W, Kozak R, Cohen D (2005) Willingness to pay and preferences for healthy home attributes in Canada. *For Prod J* 55(10):19–24
- Rametsteiner E, Oberwimmer R, Gschwandt I (2007) Europeans and wood. What do Europeans think about wood and its uses? A review of consumer and business surveys in Europe. In: *Proceedings of the*

Ministerial Conference on the Protection of Forests in Europe, Warsaw, Poland, 5 NOV, 2007

21. Nicholls DL, Roos J (2006) Lumber attributes, characteristics, and species preferences as indicated by secondary wood products firms in the continental United States. *Holz Roh Werkst* 64(4):253–259. <https://doi.org/10.1007/s00107-005-0071-y>
22. Lindberg S, Roos A, Kihlstedt A (2013) A product semantic study of the influence of vision on wood evaluation. *Wood Sci Technol* 45(4):353–362
23. Liu M, Peng L, Lyu S, Lyu J (2020) Properties of common tropical hardwoods for fretboard of string instruments. *J Wood Sci* 66(1):14. <https://doi.org/10.1186/s10086-020-01862-7>
24. Workman JE, Caldwell LF (2007) Centrality of visual product aesthetics, tactile and uniqueness needs of fashion consumers. *Int J Cons Stud* 31(6):589–596. <https://doi.org/10.1111/j.1470-6431.2007>
25. Wang E (2007) The influence of visual packaging design on perceived food product quality, value, and brand preference. *Int J Retail Distrib* 41(10):805–816. <https://doi.org/10.1108/JRDM-12-2012-0113>
26. Richardson BE (1994) The acoustical development of the guitar. *J Catgut Acoust Soc* 25(Series L1):1–10
27. Data Source T (2021) <http://tonewooddatasource.weebly.com>. Accessed 11 July 2021.
28. Gore T (2011) Wood for guitars. *J Acoust Soc Am* 129(4):2519
29. Pedgley O, Norman E (2012) Materials innovation in acoustic guitars: challenging the tonal superiority of wood. *Leonardo Music J* 22:17–24. https://doi.org/10.1162/LMJ_a_00087
30. Black L (2013) Tonewood: an environmental perspective. Dissertation, California State University.
31. Aucfan.com. <https://aucfan.com>. Accessed 13 Sept 2021.
32. Music strive (2021). Guitar sales stat. <https://musicstrive.com/guitar-sales-statistics/>. Accessed 22 Aug 2021.
33. Kushner RJ (2019) Building, leading, and sustaining a cultural enterprise: Martin Guitar in 2019. *Cases J* 15(4):306–336. <https://doi.org/10.1108/TJ-07-2018-0086>
34. Six string acoustic (2021) <https://sixstringacoustic.com/the-story-of-Yamaha-acoustic-guitars-history>. Accessed 22 Aug 2021.
35. Yamaha.com (2021) <https://www.Yamaha.com/en/about/history/>. Accessed 1 Oct 2021.
36. Yamaha Vintage FG Acoustic Guitars (2022) <http://yamahavintagefg.com/yamaha-acoustic-guitar-archive>. Accessed 16 Feb 2022.
37. Jp.yamaha.com (2022) https://jp.yamaha.com/products/musical_instruments/guitars_basses/ac_guitars/index.html. Accessed 16 Feb 2022.
38. No.yamaha.com (2022) https://no.yamaha.com/files/download/brochure/9/324029/2011_ACOUSTIC.pdf. Accessed 16 Feb 2022.
39. Brochures.yokochou.com (2022) https://brochures.yokochou.com/en_index_ag.html#YAMAHA. Accessed 16 Feb 2022.
40. Jp.yamaha.com (2022) https://jp.yamaha.com/products/contents/guitars_basses/downloads/brochures/index.html?k=&c=guitars_basses. Accessed 16 Feb 2022.
41. Martinguitar.com (2022) <https://www.martinguitar.com/guitars/>. Accessed 16 Feb 2022.
42. Guitar-catalogs.com (2022) <http://www.guitar-catalogs.com/535/en/1.html>. Accessed 16 Feb 2022.
43. Acoustic Music (2022) <https://acousticmusic.org/research/guitar-information/catalogs/>. Accessed 16 Feb 2022.
44. Wood Database (2021) <https://www.wood-database.com>. Accessed 22 Aug 2021.
45. Wood Museum (2021) <https://wood-museum.net/>. Accessed 11 Jul 2021.
46. Lehmann R (2013) 3sigma-rule for outlier detection from the viewpoint of geodetic adjustment. *J Surv Eng* 139(4):157–165. [https://doi.org/10.1061/\(ASCE\)SU.1943-5428.0000112](https://doi.org/10.1061/(ASCE)SU.1943-5428.0000112)
47. Inoue Y (2019) Winner-takes-all or co-evolution among platform ecosystems: a look at the competitive and symbiotic actions of complementors. *Sustainability* 11(3):726. <https://doi.org/10.3390/su11030726>
48. Jiménez P, Dunkl A, Eibel K, Denk E, Grote V, Kelz C, Moser M (2016) Wood or laminate?—Psychological research of customer expectations. *Forests* 7(12):275. <https://doi.org/10.3390/f7110275>
49. James G, Witten D, Hastie T, Tibshirani R (2014) An introduction to statistical learning: with applications in R, 1st edn. Springer, Heidelberg, p112
50. Zastocki D, Oktaba J, Lachowicz H (2021) Changes in the market of precious wood: a case study of submission system in Poland. *Forests* 12(4):421. <https://doi.org/10.3390/f12040421>

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