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The impact of coffee quality attributes and ratings on specialty coffee bean prices

Mohammed Al-Mahish* and Reem Alfayadh

Department of Agribusiness & Consumer Science, College of Agriculture & Food Science, King Faisal University, Al-Hofuf, Saudi Arabia 31982

* Corresponding author, E-mail: malmahish@kfu.edu.sa

Abstract

The relationship between roast level and coffee quality indicators has been widely examined in the food science literature. However, published studies in the economics and business fields have not yet explored the effects of this relationship on the price of specialty coffee beans. Therefore, this paper aims to explore the factors that influence the retail prices of specialty coffee beans. Specifically, this paper examines the impact of the size of coffee bean bag, and the aroma, acidity, body, flavor and aftertaste rating of the coffee on the retail price of coffee beans. The sample of this study consisted of 1601 observations collected from expert sensory evaluators as well as customer ratings. The results show that the selling price is reduced when the size of the coffee bean bag increases. Coffee beans originating from Asia, Central and South America are, on average, more highly priced than those from Africa. Furthermore, this study demonstrates the existence of a significant interaction between quality attributes and roasting level, which ultimately affects the sale price of specialty coffee beans. This study recommends that, in order to ensure their coffee is accurately priced, sellers of specialty coffee beans should attempt to collect as much feedback from consumers as possible, including aftertaste and flavor ratings, which exert the strongest influence on the selling price.

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Introduction

With a growing interest worldwide, coffee is one of the most significant agribusiness commodities, coming only after oil as a traded economic good in the global market. Indeed, it is widely acknowledged as a crucial driver of the global economy. In 2021, coffee exports were estimated to be worth a substantial USD $36.3 billion.[1] Brazil and Vietnam are the leading coffee-producing and exporting countries globally. Brazil contributes approximately 33% of the world's coffee production, while Vietnam's share is approximately 14%[2]. Although more than 124 coffee species have been identified around the world[3], Coffea arabica and Coffea canephora are the most commercially and economically utilized[4], accounting for 70% and 30% of the overall commercial production of coffee, respectively. Arabica and robusta coffees are diverse in several aspects, including optimal growing climate, physical properties, chemical identities, and the characteristics of the beverage resulting from the roasting of their seeds[5]. Coffee beans with unique flavor profiles that are produced in special geographical microclimates are known as specialty coffees. Specialty coffees have high niche markets and fetch premium prices due to the great care taken over the growth and preparation of the beans; they also differ from commercial coffee in terms of taste, quality, and cultivation methods. Currently, specialty coffee represents one of the fastest growing sectors. Specialty coffee beans are graded based on a 100-point scale to assess their quality, with beans scoring 80-100 points being recognized as specialty grades and those scoring below 80 points being categorized as commercial varieties[6].

This study aims to explore the factors affecting the prices of specialty coffee beans. Furthermore, this study investigates the way in which the relationship between coffee bean quality indicators and roast degree influences coffee bean prices. The results of this study will be important to both customers and producers alike because they will guide consumers in their purchasing decisions, while assisting sellers in establishing data-driven pricing decisions. The following section presents an overview of the previous studies that have investigated coffee prices with regard to price volatility, international trade, agricultural cooperatives, and coffee quality.

Coffee price volatility

Coffee is a popular beverage and is consumed in various forms. A limited number of countries in Africa, Asia, and Latin America produce most of the coffee traded internationally. A study conducted in Ethiopia measured and compared the price risks facing producers, wholesalers, and exporters in order to identify the groups most affected by price volatility over the past three decades, along with the Ethiopian coffee value chain. It was revealed that the producers' prices were found to be the most volatile, followed by wholesale prices and export prices, respectively[7]. However, the welfare effects of coffee price volatility for Ethiopian coffee producers were estimated, following the elimination of coffee price volatility, with the results revealing that the welfare gain from eliminating coffee price volatility was limited and that the gain per producer came to a meager US $0.76 per year[8]. An experimental approach was used to examine the patterns and underlying causes of the excessive price volatility of coffee and cocoa – two soft commodities of critical importance to many of the poorest commodity-dependent developing countries – in the Nether-

lands. In terms of historical coffee and cocoa prices, coffee price volatility has a different or heterogeneous impact, depending on the nature of the market shock. The indirect effects of oil prices on the coffee and cocoa markets were also assessed, using co-integration and error correction models. The findings demonstrated that there is a long-run causal relationship between oil prices and coffee and cocoa prices[9]. Also, a study in Uganda indicated that there is a long-term causal relationship between oil prices and the price of coffee[10]. A descriptive analytical approach was used to create a data set involving two series of future coffee prices and crop reports, which were the daily closing prices for arabica and robusta coffee from Close Futures reported by Intercontinental Exchange (ICE) between January 2004 and December 2014 in the USA and Brazil. The study indicated that crop reports generally affect price fluctuations. This effect is particularly strong when the reports provide information following boom periods in Colombia, Brazil, and Vietnam, which are the world's main producers[11]. Additionally, the effects of climate change and commodity price volatility in Nigeria on the coffee output were analyzed. The findings confirmed that the coffee output in Nigeria is influenced by both climate change and the international commodity price of coffee[12].

International trade and coffee prices

The price setting mechanism is largely determined by availability of buyers and the existing market forces in the importing and exporting markets, respectively[13]. The coffee sector was analyzed as a potentially important source of export diversification in Zambia[14]. The results show that Zambian coffee exhibits asymmetric short-run supply adjustments related to a long-run equilibrium, whereby production rises significantly after prices rise, while changing little after prices fall. Production, exchange rates, and prices have significant positive impacts on the export volume of coffee. Production variables, exchange rates, and prices positively and significantly affect coffee exports in South Sulawesi in Indonesia[15]. The clear gap in the transmission of international coffee prices in the Mexican coffee market was studied, using a descriptive-analytical approach. The Conditional Error Correction Model (ECM) was used to analyze the relationship between the Mexican and international coffee markets by modeling the price of coffee in the Mexican market (the dependent variable) related to Mexican coffee production and the international price of coffee (independent variables). Time series data were analyzed for a period of 16 years using monthly observations, reaching a total of 192 observations. The following findings were the most important of this study: a 1% increase in the international price of coffee was 0.9% higher than the Mexican price; Mexican production has no impact on its local price; and the collapse started in 2015 and caused a loss of statistical significance in the long-run relationship among prices until 2017[16]. Using a descriptive-analytical approach, an analysis of the world's largest coffee producers was conducted in Varna, Bulgaria[17], to identify the challenges in accessing and producing coffee, as well as international coffee prices and the dynamics of their changes. The most notable findings of this study were that the coffee trade of four multinational companies – Nestlé, Kraft Foods, Procter & Gamble, and Sarah Lee – has led to a reduction in economic growth in the last two years due to a crisis related to the negative effects of climate change, which affects the production of coffee. The current adverse conditions in the global coffee industry are associated with the availability of cheap labor and high labor costs in coffee-producing countries. From an economic point of view, the crisis also reveals the failure of export-oriented models, wherein significant financial resources are allocated to countries processing coffee but not to countries producing this specific type of crop.

Agricultural Cooperatives and Coffee Prices

The effect of the pricing mechanisms of coffee on the sustainability of Agricultural Marketing Cooperatives (AMCOS) in the coffee-growing districts of Rombo in Kilimanjaro and Mbozi in Tanzania were assessed. The results showed that unfavorable coffee prices, access to extension services, pests, coffee diseases, unreliable coffee markets, shortages, and untimely accessibility of farm inputs were the main challenges related to changes in the price of coffee as well as the sustainability of AMCOS[18]. Cooperative direct export is one of the institutions involved in the coffee value chain in Indonesia. Compared to exporting through exporters, this route is more beneficial since acceptable price is charged and higher value-added coffee is sold[19].

Coffee quality and prices

The factors affecting the sales price of arabica coffee include the quality of the coffee and the technology used in post-harvest processing[20]. The main quality indicator used as a criterion to determine the price of coffee is the quality grade of the coffee. Based on the scores of green bean physical and cup qualities (0–100) and according to the Specialty Coffee Association (SCA) of America, coffee that scores 80 points or more out of 100 is classified as specialty coffee[21]. Taiwanese consumers' evaluations of various attributes of local specialty coffees were assessed to help coffee retailers develop strategies for increasing sales in the secondary market[22]. In terms of intrinsic quality, atypically, as shown by the empirical results of the analysis, Taiwanese consumers do not prefer coffee attributes such as extra aroma and a strong sour taste. A study undertaken in Mexico involved the survey method to extend the framework used in previous research to understand specialty coffee purchasing behavior. Simple and multilevel mixed-effects logistic models were tested. Most notably, the study found that the probability of buying specialty coffee increased when consumers inhaled the coffee aroma, when the coffee shop had a value-added business model and had diversified into sales of ground coffee and coffee drinks, and when the coffee shop was located in a city with a high education index. In contrast, the probability of buying specialty coffee decreased when a coffee professional tasted the coffee before purchasing, when coffee shops did not provide the option to roast the coffee, and when coffee shops were in large cities[23].

Materials and methods

The data for this research were obtained from the Coffee Review[24,25], a website that specializes in reporting specialty coffee bean prices and evaluating specialty coffee bean quality to guide coffee consumers worldwide in their purchasing decisions. A 100-point scale evaluation system is used according to the following interpretation, shown in Table 1[26].

After removing any missing or incomplete observations, the total number of observations reached 1,601. Table 2 shows a

Table 1. Coffee Rating Interpretation

Score	Implication
95–100	Exceptional
90–94	Very Good
85–89	Good
80–84	Fair
Less than 80	Poor

Source: Coffeereview.com

summary of the statistics of the collected data, indicating that the average score for acidity and aftertaste is fair while aroma and body aroma were good. Surprisingly, the average score for flavor is within the very good range.

Furthermore, the results show that the average retail price of specialty coffee beans is $24, while the average size is 10.8 ounces. The internal consistency for the coffee attribute ratings was examined using Cronbach's Alpha. The obtained score was within the acceptable range (0.76) with a 95% bootstrap confidence interval ranging from 0.73 to 0.79.

The reported consumer ratings for coffee attributes reached as low as 60 for acidity, body, and aftertaste. The attributes that achieved the maximum ratings were acidity, aroma, and body. The roasting levels obtained from the original data consisted of light, medium, dark, medium-light, and medium-dark. However, we merged medium-dark with dark and medium-light with light for the sake of organization and brevity. Also, the coffee beans' origins were classified according to their continent rather than their country of origin to reduce the data dimensions and reduce the degrees of freedom in the subsequent analysis. We noticed that the majority of coffee beans originated from Africa, followed by Central and South America, respectively. Coffee beans produced in Hawaii, Papua New Guinea, Haiti, Dominican Republic and elsewhere were labeled as Other.

To examine how the factors influence coffee bean prices, we used the following model (also known as the hedonic pricing model):

$$P_i = \beta_0 + \beta_1 Size_i + \beta_2 Quality_i + \beta_3 R_i + \beta_4 O_i + \varepsilon_i \quad (1)$$

where P denotes the specialty coffee bean retail prices, size is the weight of a sold bag in ounces, Quality reflects the variables of the quality attributes and consumer ratings, and R and O are the dummy variables, representing roasting level and country of origin.

Results

The results of the estimating model (1) are reported in Table 3, along with the goodness of fit measures (r-square, adjusted r-square, and regression standard error).

The results for goodness of fit, as measured by regression standard error, r-squared, and adjusted r-squared, show that the log-log model is a better fit than the first model with no logs. Consequently, the results of model 2 will be the main focus of our analysis. The results of the Breusch-Pagan heteroskedasticity test show that the null hypothesis of constant error variance (homoskedasticity) is rejected. Thus, the reported standard errors in Table 3 are heteroskedasticity robust standard errors.

Discussion

The sign of the size coefficient in both models confirms the economic theory of inverse demand, which states that there is a negative relationship between quantity and the retail price of specialty beans, in this case. In other words, an increase in the quantity of specialty coffee beans offered for sale reduces the retail price that the customer pays per gram. This aligns with the findings of Donnet et al. (2008), Traore et al. (2018), Teuber and Herrmann (2012) and Wilson and Wilson (2014)[27–30] who found that quantity (the size of a bag of coffee) negatively influences the selling price of specialty coffee. Thus, buying specialty coffee beans in larger bags, whether in pounds or kilograms, will result in greater savings for the consumer. Specifically, the results showed that a 1% increase in the size of the coffee bag offered for sale reduces the retail price by 0.13% on average, when all of the other factors remain constant.

All of the control variables representing coffee quality attributes (aroma, acidity, body, flavor, and aftertaste rating) were found to have a positive effect on the retail price of coffee beans. This result confirms the findings of prior research[31], which found that the quality score positively affects the price of specialty coffee. Aroma and coffee flavors (such as sweet, floral, and fruity) as well as acidity were found to have a positive impact on specialty coffee prices[28]. Conversely, our results differ from other findings[28], which reported that the aftertaste score does not affect the price of specialty coffee. Nonetheless, our findings show that flavor rating and aftertaste rating have the largest impact. Thus, decision-makers in the specialty bean industry should seek advice from expert sensory evaluators and

Table 2. Summary Statistics

Variable	Mean	Minimum	Maximum	SD	Variable	N (%)
Price USD	23.629	4.65	206	16.375	Roasting	
Size (Ounce)	10.773	2.00	8.818	2.869	Dark	4 (0.25)
Acidity	84.85	60.00	10.00	0.566	Medium	205 (12.80)
Aroma	88.21	70.00	10.00	0.440	Light	203 (12.68)
Body	85.95	60.00	10.00	0.516	Medium-Dark	25 (1.56)
Flavor	89.53	70.00	90.00	0.368	Medium-Light	1164 (72.70)
Aftertaste score	80.83	60.00	90.00	0.494	Coffee Origin	
					Africa	552 (34.48%)
					Asia	98 (6.12%)
					Central America	356 (22.24%)
					South America	299 (18.68%)
					Mixed	126 (7.87%)
					Other	170 (10.62%)

Table 3. Estimated Parameters of the Linear Regression Models

	Model 1	Model 2 (Log-log Model)	Model 3 Interaction Terms
Variable	Coefficients	Coefficients	Coefficients
Intercept	−105.463*** (15.635)	−6.493*** (0.772)	−4.843*** (0.862)
Size	−0.816*** (0.271)	−0.126*** (0.048)	−0.108** (0.047)
Light roast	−12.457** (5.454)	−0.223 (0.200)	−1.055 (1.679)
Medium roast	−12.053** (5.329)	−0.284 (0.199)	−1.933 (1.822)
Medium-dark roast	−7.402 (5.738)	−0.219 (0.231)	7.047** (2.869)
Medium-light roast	−12.710** (5.336)	−0.257 (0.199)	−3.241** (1.395)
Aroma	2.072* (1.108)	0.682*** (0.262)	3.041*** (0.328)
Acidity	1.029 (0.999)	0.667*** (0.177)	1.229*** (0.303)
Body	2.867*** (0.635)	0.828*** (0.155)	−3.267*** (0.312)
Flavor	5.892*** (1.769)	1.260*** (0.366)	1.635*** (0.457)
Aftertaste	5.338*** (1.083)	1.214*** (0.215)	1.251*** (0.253)
Continent Asia	1.090 (1.560)	0.103** (0.042)	0.115*** (0.042)
Continent Central America	5.380*** (1.367)	0.150*** (0.030)	0.154*** (0.030)
Continent Mixed	1.024 (1.463)	0.048 (0.039)	0.037 (0.036)
Continent Other	10.839*** (2.045)	0.429*** (0.047)	0.439*** (0.047)
Continent South America	2.509** (1.152)	0.111*** (0.026)	0.115*** (0.026)
Light roast *aroma	–	–	−3.652*** (0.884)
Medium roast*aroma	–	–	−1.978** (0.777)
Medium-dark * aroma	–	–	−5.219*** (1.683)
Medium-light*aroma	–	–	−2.231*** (0.412)
Light roast *acid	–	–	−0.894* (0.516)
Medium roast*acid	–	–	0.163 (0.678)
Medium-dark*acid	–	–	2.617 (1.696)
Medium-light*acid	–	–	−0.592 (0.366)
Light roast*body	–	–	3.660*** (0.483)
Medium roast*body	–	–	4.106*** (1.491)
Medium-dark*body	–	–	8.076*** (1.491)
Medium-light*body	–	–	4.177*** (0.334)
Light roast*flavor	–	–	0.969 (1.149)
Medium*flavor	–	–	−1.360 (1.030)
Medium-dark*flavor	–	–	−6.799*** (2.477)
Light roast*aftertaste	–	–	0.286 (0.606)
Medium roast*aftertaste	–	–	−0.162 (0.648)
Medium-dark* aftertaste	–	–	−2.050* (1.053)
R-Squared	0.195	0.295	0.314
Adj R-Squared	0.186	0.288	0.298
Residual Standard Error	15.176	0.371	0.368

Note: ***,** and * denote significance at the 1%, 5% and 10% levels, respectively. The values in parentheses are standard errors.

collect consumer feedback since highly rated coffee beans will enable them to charge a higher price for their beans. On the other hand, the results of the first model show that light, medium, medium-dark and medium-light roasted coffee beans are, on average, priced lower than dark roast coffee beans. This result contrasts with the findings of previous studies[28], which found that roasted coffee flavor does not affect the coffee price. Furthermore, coffee beans originating from Central America, South America, and countries such as Hawaii, Papua New Guinea, Haiti, Dominican Republic are priced higher, on average, than those from Africa. This result is consistent with prior studies[28,29] which found that the country of origin is a significant determinant of specialty coffee pricing.

In the third model, we extended the log-log model (model 2) by adding interaction terms between roast level and quality attributes, as shown below:

$$\ln P_i = \beta_0 + \beta_1 \ln Size_i + \beta_2 \ln Quality_i + \beta_3 R_i + \beta_4 O_i + \beta_5 R_i * \ln Quality_i + \varepsilon_i \quad (2)$$

The interaction between buyer location and quality score has been previously investigated[30]. In this paper, we are interested in exploring the existence of potential interaction between the specialty coffee bean quality attributes and roast level, and the effects of such interaction on pricing. The impact of a change in quality attributes can be found by taking the partial derivatives of $\ln P_i$ with respect to $\ln Quality_i$:

$$\frac{\partial \ln P_i}{\partial \ln Quality_i} = \beta_2 + \beta_5 R_i \quad (3)$$

Equation (3) shows that the impact of a change in quality variables on price varies, based on the roast level. Thus, when the roast level is (R=1), as in the case of light and medium roasts, we use equation (3). However, when the roast level is dark (R=0), the effect of a change in the quality variables on the price is simply β_2.

The results in Table 3 reveal a statistically significant interaction between aroma and roast levels, which confirms that the roasting level is a critical factor in coffee aroma formation[32]. The sign of the interaction terms between the acidity and roast level was negative, confirming the negative association between overall coffee acidity and roasted coffee quality[33]. Furthermore, all other quality attributes interact significantly with roast level. A significant interaction was found between acidity and light roasted coffee beans. Also, all roasting levels

significantly interact with coffee body, resulting in a strong positive influence on price, which is consistent with previous findings[34] that showed that the influence of roasting degree is more pronounced on body and acidity, respectively.

Furthermore, when the coffee roast is light, a 1% increase in aroma, acidity, flavor, and aftertaste rating increases the selling price by more than one percent, with other factors remaining constant. Moreover, the results did not show a significant interaction between acidity and medium roast coffee beans that may influence the selling price.

Thus, we recommend that decision-makers in the specialty coffee bean industry study coffee flavor rating scores and consumers' aftertaste ratings since they have the strongest influence on the retail price of specialty coffee. Moreover, sellers are recommended to sell the finest specialty coffee beans in small-sized bags only in order to maximize their revenue.

The main limitation of our model is that it does not include variables representing coffee processing (such as natural, washed, and honey processed) or altitude, which can influence the retail price, because data on these variables were not available. Thus, we recommend that future researchers could study these and other variables such as store type (online or physical location) to gain further understanding of the factors that affect the retail price of specialty coffee.

Conclusions

Coffee is a favorite beverage of many people worldwide, and its popularity has led consumers to search for the finest coffee beans. Specialty coffee beans are sought by consumers worldwide due to their unique flavor and pleasant smell. Specialty coffee retail prices, whether sold online or in stores, vary significantly. Therefore, this study attempted to identify the factors that affect specialty coffee bean prices in order to help consumers save money on their purchases and to provide producers with recommendations for identifying the most important attributes that influence the selling price of their beans. This study used 1601 observations regarding price, size, origin, and the sensory evaluation of specialty coffee bean attributes (aroma, acidity, body, flavor, and aftertaste rating). The results for Cronbach's Alpha showed an acceptable internal consistency for the coffee attribute ratings. The results of the linear regression models show that as the size of coffee bean bags (in ounces) increased, the further the retail selling price is expected to be reduced. This study recommends that consumers interested in cost savings should buy their favorite coffee beans in larger quantities and only purchase smaller quantities when they want to taste new brands, flavors, roasteries and so on. Conversely, the sellers of specialty coffee beans are recommended to sell the finest high quality beans in small bag lots to obtain higher revenue. Also, the results show that specialty coffee beans originating from Asia, Central and South America are, on average, priced higher than those from Africa. Aroma, acidity, body, flavor, and aftertaste ratings were all found to have a positive influence on specialty coffee bean prices. Also, this paper found a significant interaction between roasting level and coffee quality score, represented by acidity, body, flavor, and aftertaste ratings. Thus, the impacts of quality attributes on price were demonstrated as varying, based on the roasting level. This study recommends that producers and sellers of specialty coffee beans should regularly seek feedback from consumers on flavor and aftertaste ratings, since this information will help them to charge higher prices for their beans. Furthermore, we recommend that future researchers should collect data directly from coffee consumers using surveys in order to investigate the impact of consumers' socio-demographics characteristics (such as race, gender, household size, education level, etc.) on the quantity of specialty coffee beans consumed. This would help to estimate the price elasticity of demand for specialty coffee beans, which will, in turn, help to determine the responsiveness of quantity demands to changes in specialty coffee bean prices.

Authors' contributions

The authors confirm their contributions to the paper as follows: study conception and design: Al-Mahish MA, Alfayadh RA; data collection: Al-Mahish MA; analysis and interpretation of results: Al-Mahish MA, Alfayadh RA; draft manuscript preparation: Al-Mahish MA, Alfayadh RA. All of the authors reviewed the results and approved the final version of the manuscript.

Data availability

The data that support the findings of this study are available on the kaggle.com website repository[24]. These data were derived from the following resources, available in the public domain: www.kaggle.com/datasets/hanifalirsyad/coffee-scrap-coffeereview, www.coffeereview.com/review/

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Conflict of interest

The authors declare that they have no conflict of interest.

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