



Research article

An hedonic evaluation of the impacts of vertical coordination on business performance amongst apple producers in Morocco

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ABSTRACT

We present an econometric analysis of the marketing of apples in Morocco that investigates the relationship between vertical coordination arrangements and the prices of apples for farmers. In this study, the hedonic method is used to evaluate the vertical coordination of apple fruit chains by analyzing the marginal implicit price of different product characteristics. We examine the variables influencing apple prices for farmers, comprising intrinsic factors related to the farm's characteristics and quality attributes such as fruit variety and fruit diameter. Additionally, we consider extrinsic variables associated with marketing factors, including vertical coordination systems, payment terms, seasonality of sale, cold storage, and geographical origin. Based on a nationally representative survey of 190 apple growers in the southeast of Morocco, an empirical analysis is conducted. Results highlight the pivotal role of apple growers' experience in elevating farm-level prices, indicating a deeper understanding of market dynamics. Significant price variations are tied to quality attributes, notably a 19.2% premium for larger apples (75–85 mm diameter), indicating market preference. The economic analysis underscores the influence of apple varieties, with Golden commanding a 16.4% higher price, indicating heightened consumer demand. Additionally, the study found that marketing factors, vertical coordination models, payment terms, seasonality of sale, cold storage, and geographical origin also have a positive impact on apple prices. Furthermore, vertical coordination models positively impact apple and prices provide producers with guidance for effective supply chain coordination. These insights, extending beyond theory, serve as a roadmap for policymakers to support the agricultural sector. Equipped with knowledge of business performance, farmers can implement targeted measures to enhance the marketing value of their agricultural products, fostering resilience and profitability in the Moroccan apple sector.

Abbreviations: Ag, Aggregated; AG, Aggregator; AAP, Agricultural Aggregation Project; GG, Generation Green; GMP, Green Morocco Plan; HPM, Hedonic Price Method; MIP, Marginal Implicit Price; ONCA, National Agricultural Advisory Board; INRA, National Institute for Agricultural Research; TCT, Transaction Cost Theory; VC, Vertical Coordination.

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1. Introduction

The analysis of fruit markets has always attracted the attention of researchers and professionals. The main reason for this is that the fruit markets are very complex and characterized by a high degree of uncertainty. Fruit trees, on the other hand, are a key component of the economic development of rural Morocco [1]. After almond trees, the *ROSACEAE* fruit tree that covers the most land in Morocco is the apple tree. Morocco is the 18th-biggest apple-producing country [1]. Apple production in Morocco has been growing at a year-on-year rate of 6.5 percentage points higher since 2014 [1]. It is suggested that the apple industry has achieved remarkable growth over the past several years thanks to the initiatives and finances of the Ministry of Agriculture and the Green Morocco Plan (GMP). According to MAPM, on a national scale, apple trees account for 20% of the growing area. In addition, the area under apple trees that was being cultivated expanded from 26.752 ha in 2008 to 51.871 ha in 2020 [1]. The apple yield per unit of land area ranges between 8 and 18 t ha⁻¹. Increasing yields is crucial for the success of the apple sector, but ensuring effective market access and robust value chains are crucial. The export of apples from Morocco began in 2009, accounting for a meager 0.03% of the national production. These exports are predominantly directed towards the French and Senegalese markets. Consequently, the bulk of apple production is channeled to the domestic market [2].

In a situation where the European market, especially Poland, faces an annual surplus of at least 1 million tons of apples due to Russia's ban on imports from the Western world (Canada, Europe, etc.), farmers seek reliable markets, fair prices, and appropriate infrastructure for the storage, processing, and transportation of their products. Developing strong market links, promoting value addition, and improving post-harvest handling practices are crucial areas that must be addressed to maximize the benefits of rising yields. However, compared to farmers in other countries with significant apple production, the number of vertical coordination (VC) systems utilized by Moroccan apple farmers for marketing apples has remained relatively low. For instance, in China, apple producers predominantly engage in transactional arrangements with small retailers, wholesalers, and cooperatives [3]. In Canada, a variety of VC systems are employed, including the market pricing system, vertical integration, the contracting system, and co-operation, with the flexibility to apply these systems separately or in combination [4]. Regarding production, there was a notable 21.8% increase in global apple production from 2009 to 2019, reaching a total of 87.2 million tons. Noteworthy achievements were observed in countries such as France, Spain, and Germany, which recorded impressive yields of 40 tons per hectare during this period. Furthermore, these nations implemented varied VC methods, encompassing the spot market, contract farming, and vertical integration, as highlighted in a study by Juillion et al. [5]. Historically, intermediaries, through VC strategies in spot markets, set apple-pricing policies in Morocco. Since 2012, a mode of VC has been developed, and the Moroccan government has implemented the legal and institutional framework associated with Agricultural Aggregation Projects (AAP: <https://www.ada.gov.ma/fr/cadre-reglementaire>).

The goal of agricultural aggregation is to determine the appropriate method that should be used to establish contractual ties between a farmer (aggregated, Ag) and a firm (aggregator, AG) for the purpose of implementing the AAP. This will ensure that all transactions involving the various stakeholders, particularly commercial ones, go off without a hitch. This model of contracting, which was revised in 2021, pushed marketing arrangements even further since it was intended to boost the competitiveness of agricultural markets and improve the productivity of agricultural output. Actually, one of the most significant challenges facing small and medium farmers throughout the transition period in the Moroccan agricultural sector and commercial relationships was the difficulty of gaining access to markets. One may make the case that the transitional disruptions and the number of intermediaries have been even more severe in the spot markets than they have been in other VC systems (for example, AAP). Furthermore, the apple producers in Morocco are confronted with significant challenges stemming from the absence of a dedicated commercial policy and limited VC. These issues create formidable obstacles to the development of the agricultural product value chain. Additionally, the impact of fluctuating international commodity prices and heightened competition underscores the need for improved marketing strategies. To address these challenges, it is crucial to implement policies and initiatives that strengthen the agricultural marketing chain in Morocco. In this context, our main research question is: How can agricultural aggregation (AAP) be leveraged as a practical solution to address the marketing challenges faced by apple producers? Through an in-depth analysis of VC in the apple sector, the study aims to offer valuable insights that can enhance the efficiency and sustainability of agricultural production in Morocco, ultimately contributing to increased farm profitability, rural development, and food security. The hedonic method serves as a robust framework to comprehend market preferences, establish farm gate price structures, guide product differentiation, inform marketing strategies, and provide valuable insights for both farmers and policymakers. Its application in the study holds substantial potential for enhancing the commercial performance of apple products in Morocco by aligning production and marketing efforts with prevailing market dynamics.

Despite the fact that AAP produces a number of significant benefits (such as distributing the risks associated with production and marketing among the many stakeholders; the identified risks encompass challenges related to marketing dynamics as well as the potential risk of failing to attain the contracted volume under specified conditions, involving considerations of quality and price.), it is possible that a better understanding of the relationships between a number of attribute characteristics and the effects those characteristics have on selling price (farm gate price) may result in a more effective management of price and market risk. However, there is currently no study to evaluate agricultural aggregation. Marketing difficulties for agricultural products are common in the agricultural policy reports in Morocco. The research on hedonic pricing includes studies on the food industry as well: vinegars [6], fruit juices [7], olive oil [8], coffee [9], and non-perishable food [10]. Several researchers have utilized the hedonic analysis method to analyze the fruit and vegetable market ([11,12]; Relawati et al., 2007; Caroline et al., 2022). However, hedonic pricing research on agricultural products in Morocco does not exist.

Using hedonic pricing, the purpose of this investigation is to investigate the factors that influence apple prices in the province of Midelt, which is located in the Draa-Tafilalet region. The province was selected because it is responsible for roughly 90 percent of the overall apple output in the region on its own (53% of the national production). A limitation of our research is its exclusive focus on

conducting an economic analysis of apple prices in Morocco at the farm level, specifically among the sellers (farmers), without direct consideration of the perspectives and preferences of the buyers (consumers). Nevertheless, the consumer-level analysis is situated downstream and does not furnish insights into VC systems. This study's objectives are to (1) identify the attribute features that influence apple pricing, we examine the attributes influencing apple prices for farmers, comprising intrinsic factors related to the farms characteristics, and quality attributes such as fruit variety and fruit diameter. Additionally, we consider extrinsic variables associated with marketing factors, including VC systems, payment terms, seasonality of sale, cold storage, and geographical origin; (2) assess the significance of VC systems in the apple market by elucidating the correlation between apple prices set by farmers and contractual agreements within the context of the AAP, an innovative form of VC in Morocco. Additionally, examine the impact of other VC systems, including the spot market; and (3) evaluate the pricing preferences of farmers for individual attributes and define the relative importance of each attribute in the context of apple sales in Morocco. These objectives aim to provide policymakers and farmers with well-informed results, facilitating decision-making regarding production and marketing strategies. This study's relevance lies in the fact that it can shed light on the role that agricultural aggregation plays in the regulation of apple value chains in Morocco, which is one of the country's most important products.

2. Overview of apple production and marketing in Morocco

In Morocco, the cultivation of apple orchards has undergone substantial growth, increasing from 26,752 ha in 2008 to 51,871 ha in 2020 [1]. This expansion indicates a significant surge in apple orchard acreage over the specified period, reflecting the evolving landscape of apple cultivation in the country. The primary apple varieties cultivated in Morocco include Golden Delicious (50%), Starking Delicious (14%), Starkrimson, Golden Smoothie, Dorset Golden, Royal Gala, Ozargold, Anna, and Fuji. Rootstocks such as MM106, MM109, M2, and MM111 are commonly employed. Additionally, there is a growing adoption of other rootstocks like Pajam 1 and 2, as well as Lancep [13]. Fig. 1(1) displays the apple yield per hectare of land. This figure ranges from 8 to 18 t ha⁻¹. Apples are grown all over Morocco, although the majority come from the Fès-Meknès and Draa-Tafilalet regions (MAPM 2019). Sixty-seven percent of the country's cultivable land and 91 percent of its harvest come from these two areas. The dip depicted in Fig. 1(2) in 2016 is ascribed to a substantial 40% drop in the average annual yield. Unfavorable climatic conditions, most notably the effects of the great frost, as well as variations in tree productivity are the main causes of this reduction. The convergence of these factors in 2016 led to a noteworthy decrease in apple yield during that year. The primary apple-growing provinces in Morocco are El Hajeb, Sefrou, Ifrance, and Meknes in the Fès-Meknès area; Midelt in the Draa-Tafilalet area; and Khnefira in the Beni Mellal-Khenifra area. Nearly 90% of all output comes from the province of Midelt Smallholders who engage in low-mechanized, non-standardized agriculture own and run the majority of apple orchards in the High Atlas and Central Atlas Mountains.

There are 60,000 people who rely on income from the apple industry in the Draa-Tafilalet region, which is where apple production and packing take place. Employment is generated for an additional 2,250,000 days [1]. A region with chronically high unemployment rates really needs these positions. The regional infrastructure for storing apple fruits has expanded rapidly over the previous two decades, increasing from 4000 t in 2009 to 70,000 t in 2020. This growth was characterized by a significant development in the subsequent two decades. There are a total of 38 units for the cold storage of apples, plus processing and packing facilities (32 of which are located in the Midelt Province). Apples are the primary cash crop for smallholder farmers. Growth in apple orchards and cold storage facilities has boosted the regional economy and provided numerous new job opportunities. The emergence of new organizational structures, including cooperatives and start-ups across the entire value chain from production to logistics and marketing, significantly contributes to facilitating smallholder farmers' access to the market. These farmers are recognized as essential contributors to the realization of sustainable development goals [14]. Improving farmers' economic security requires increasing output and product quality in accordance with an integrated approach. Rather than putting more land into apple orchards, resources would be better spent bolstering the marketing of agricultural products through the construction of value-added processing and storage

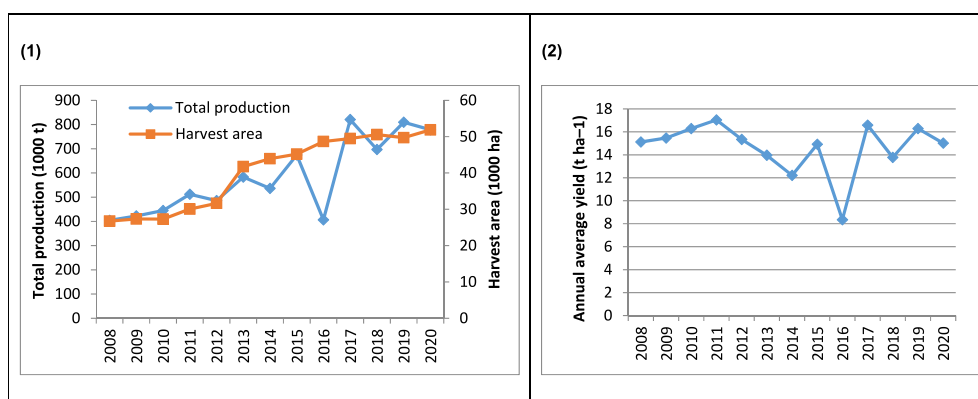


Fig. 1. Changes in Moroccan apple production over the past few decades in total production and growing area (1) and productivity (2). Data source: MAPM [1].

facilities.

3. Vertical coordination in the apple industry in Morocco

According to Mighell and Jones [15], VC refers to “all the ways of harmonizing the vertical steps of production and marketing.” Among the tools in coordination that can be applied separately or in a combined way, one can mention the market pricing system, vertical integration, the contracting system, and “co-operation.” Another definition is given by Davis [16], who stipulated that VC is “any kind of formal or abstract arrangement the purpose of which is to link more closely the successive steps of production and transformation of food and fiber.” Often, the concept of VC is confused with “vertical integration,” in the sense that agricultural economists employ indifferently these two concepts. Indeed, vertical integration should rather relate to the case corresponding to the extension of the role of the producer in the marketing of his products. VC became known for the first time in agriculture during the 1950s in the United States and Canada. It began in the animal sector (poultry, pork, dairy, etc.). Since then, it has experienced a spectacular advance caused by several factors: the progress of technology, risks related to prices and production, the evolution of consumers’ choices and preferences, the development of biotechnology, the technology of information, environmental constraints, etc.

Concerning theoretical approaches to VC, multiple social and economic theories come into play. The economic analysis of VC predominantly employs transaction costs [17]. The economy of transaction costs believes contractual difficulties are linked to transaction features. Indeed, transaction costs are economic exchange expenses, especially market transactions. Transaction costs include research and information (prospecting, comparing the quality/price ratio of services, market research), negotiation and decision-making (drafting and concluding contracts), and monitoring and execution [18]. The transaction cost economy is based on four basic elements. These include information asymmetry, limited rationality, opportunism, and product specificities. Since receivers have diverse strategic behaviors, contractual transactions occur in an imperfect informational environment, which is why information asymmetry is important. The second premise of limited rationality is that the economy of transaction costs acknowledges partial rationality in stakeholder behavior [19]. Even when people want to make a reasonable choice, they cannot analyze all the options precisely [20]. Bouichou et al. [13] examined the ex-ante and ex-post costs of AAP and their effects on relational transactions in Moroccan apple marketing. The research revealed 1090897 euros in AAP-related transaction costs. The data showed that negotiating and enforcement costs were the main barriers to apple farmers’ aggregate marketing participation. Non-aggregated members faced information search, harvesting, and transit expenses, which limited their spot market participation. Within the context of VC in the apple industry, the Transaction Cost Theory (TCT) and the Hedonic Price Method (HPM) are interconnected. TCT states that economic agents pick governance structures to reduce market exchange transaction costs, including negotiation, monitoring, and enforcement. Quality, output, and contracts affect apple pricing. Researchers may assess these features’ impact on apple market price using the HPM. TCT and the HPM relate to how VC models affect apple marketing and transaction costs.

According to Zhong et al. [21], the connection between systems of VC and farmers manifests in the degree of collaboration and reciprocal assistance within the agricultural value chain. Farmers stand to gain from vertical cooperation by enhancing their access to resources, information, and technology. Collaborative endeavors have the potential to facilitate improved market access and enhance the bargaining power of farmers during negotiations with other stakeholders in the supply chain. Moreover, the influence of effective VC on market prices is significant. A well-functioning VC system can contribute to price stability and a more equitable distribution of profits among stakeholders. This can translate to fairer compensation for farmers based on their produce [17]. The reduction of inefficiencies and the enhancement of VC within the apple value chains can positively influence market prices by ensuring a smoother flow of apples from the farm to the market (Muder et al., 2022).

VC in the context of this study refers to collaborative efforts among different players in the apple value chain. Its relationship with farmers is evident in the mutual benefits and support within the supply chain, leading to improved market access and bargaining power. Additionally, VC can positively influence market prices by promoting efficiency and fairness in the distribution of profits along the supply chain. Furthermore, VC can exert a positive influence on market prices by fostering efficiency and fairness in profit distribution across the supply chain. VC can take many different forms, ranging from straightforward cash transactions on a regular market, where prices serve as the mechanism of coordination, all the way up to complete vertical integration, in which the executives of businesses control the flow of goods from one level of the market to the next. In the middle of these two possibilities lie varieties of additional business structures, the most notable of which are strategic contracts, strategic alliances, and co-enterprises or joint ventures. In the Moroccan apple industry, VC is predominantly facilitated through two primary methods. The first involves free market transactions, which are characterized by direct exchanges between producers and distributors and frequently involve on-farm sales to wholesalers. The second method revolves around agricultural aggregation (AAP), wherein growers collaborate by forming organizations or cooperatives. This approach enhances resource consolidation and improves various aspects of apple production, distribution, and marketing, often-involving on-farm sales under contractual agreements. The utilization of hedonic evaluation is significant because it allows for a nuanced understanding of the various factors that contribute to the value and pricing of apples within the different coordination modes. In essence, the hedonic evaluation provides a sophisticated tool for navigating the complexities of pricing dynamics within the apple industry, thereby facilitating informed and strategic choices that positively affect producers’ economic outcomes.

Increasing VC in agricultural production and the effectiveness of vertical links between smallholder farmers is a key strategy for rural development and making use of new ways to produce, fund, and get to markets in developing countries [21]. The price volatility associated with the marketing of agricultural products is a major obstacle to smallholder farmers’ market participation in most developing economies [22]. Unavailability of vertical relationships, limited access to markets, and high transaction costs of accessing input and output markets are just a few examples of the complex production and marketing constraints that smallholder farmers often

face [23]. There is mounting evidence that agricultural contract farming in developing countries can improve the economic performance of smallholder farms by lowering price volatility and increasing the efficiency of supply chain links (Ma et al., 2018). In Morocco, the government intervenes by providing the necessary supports that will help to reduce price volatility, especially policies to provide adequate vertical links to enhance access to markets (e.g., agricultural aggregation).

Agricultural aggregation has emerged as the preeminent method for agribusiness companies to adopt in order to better coordinate their supply chains and ensure a steady supply of agricultural raw materials of high standard of quality. Agricultural aggregation is a form of business that is built on the optional gathering of farmers called Ag by an AG within an AAP. This form of VC is known as aggregation, as it is one of the most crucial fields of the GMP, and it is predicated on a relationship that benefits both the productive upstream and the commercial downstream. In accordance with Dahir no. 1-12-15, which promulgated law no. 04-12 (2012), we define an AAP in the apple sector as “any agricultural project built, for a fixed period, of aggregates and an aggregator for the development of one or more segments of an apple sector relating to production, packaging, storage and/or processing, and marketing of the apple products. In fact, the Ag can be defined as any apple farmer, natural or legal person governed by public or private law, including cooperatives, associations, or economic interest groups, brought together by the aggregator for the purpose of carrying out an AAP. While an AG can be any natural investor or legal person governed by public or private law, such as cooperatives, associations, or economic interest groupings, those who bring together other aggregators for the purpose of carrying out an AAP are considered to be economic interest groupings that act as economic interest groupings. The agreement reached between an aggregator and other aggregators in order to bring about the completion of an AAP is referred to as an agricultural aggregation contract (Fig. 2).

The movement toward agricultural aggregation is also visible on Moroccan territory, where the proliferation of new VC forms is seen as a strategy for assisting farmers in overcoming widespread market failures. In fact, recent estimates based on the primary accomplishments of the GMP suggest approximately the implementation of 63 aggregation projects totaling 177,000 ha [24] for the benefit of 55,000 farmers. Eighty percent of these farmers are small farmers owning less than 5 ha, and the number of these farmers is increasing (MAPM 2021). As part of the new “Generation Green (GG) 2020–2030” policy, this new regulatory framework will enable the rollout of AAP for the next generation, which plans, at its basic foundational level concerning the emphasis on the human element, to usher in a new generation of agricultural organizations, notably agricultural cooperatives and agricultural aggregation, which blend economic and social value. Many different types of innovative aggregation have been proposed as possible frameworks for the next generation of agricultural aggregation. These aggregations are intended to serve as regional and national hubs for the dissemination of cutting-edge agricultural technologies to farmers, in particular digital agriculture.

4. Materials and method

4.1. Methodology and estimating procedures

Hedonic pricing has been commonly employed in studies of Apple selling prices because of the characteristics of the Apple market. Apples, like many other products, may be evaluated across a number of dimensions (e.g., cultivar, packaging size, storage, fruit size).

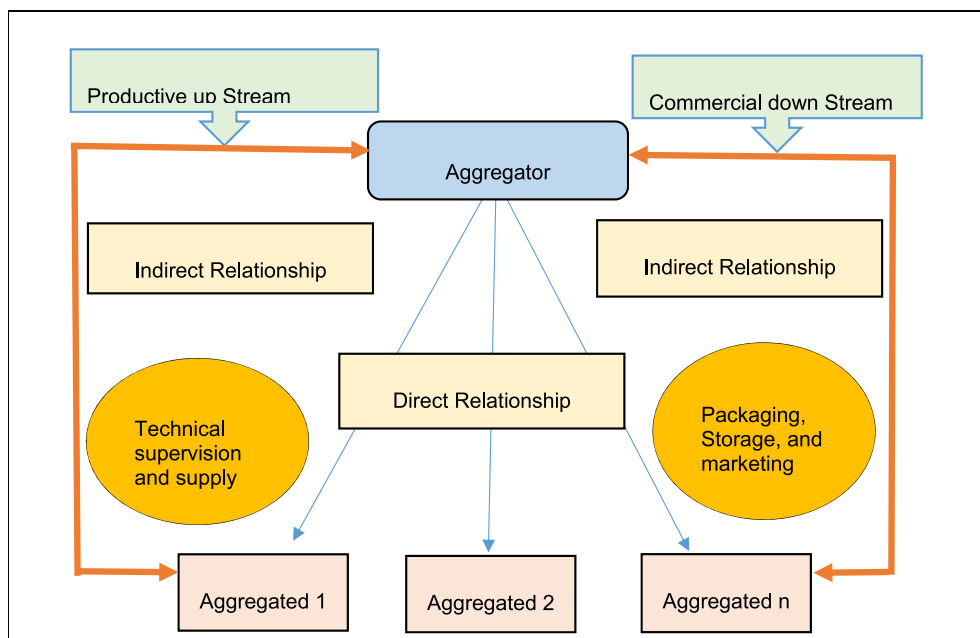


Fig. 2. Relationship between the aggregator and the aggregates in the apple sector.

Source: Authors own conceptualization.

The hedonic approach has the tendency to divide apple fruit into numerous categories. The methodology developed by Tronstad [25] was taken into account in this study (apple quality, location, and seasonality). The list of characteristics measured by Relawati et al. [26] is supplemented by the other characteristics discussed in this study, which are shown in Table 1. Furthermore, within the farm gate price, researchers have shifted their focus to farm-related variables to assess their impact on the pricing dynamics of agricultural products. Studies by Ntakyo et al. [27] and Shah, M. A [28]. have provided evidence that variables such as the educational qualifications of farmers, their age, occupational structure, size of land owned, and their expertise in agricultural practices and marketing influence significantly their bargaining power during negotiations.

4.2. Study area

The study was conducted in the Midelt province region of Drâa-Tafilalet in Morocco. The location of the study has a total area of 13,626 km² and may be found in the Moroccan Middle Atlas at an elevation of 1521 m. It accounts for 15.3% of the total land area in the Draa-Tafilalet region. The region is home to a diverse range of agricultural endeavors, including full-time and part-time cattle farming, fruit and field crop cultivation, and the rearing of other animals. The apple industry is particularly vital to employment opportunities in the province of Midelt, which is where apple production and packing take place; it is also source of income for sixty thousand people living in the area. It results in the creation of over 2.2 million workdays (MAPM 2021). The choice of the province of Midelt for conducting this study is based on several crucial factors. Firstly, the establishment of the province in 2010 underscores its relatively recent nature, providing a dynamic context for analyzing the impacts of VC on the business performance of apple producers in Morocco. The Midelt province boasts significant agricultural potential, particularly in the apple sector. Favorable climatic conditions, characterized by winter cold, coupled with the availability of land and irrigation water, have contributed to a substantial expansion of apple cultivation. Furthermore, government incentives, including investment subsidies in this sector and initiatives under the “GG 2020–2030” policy, have stimulated the development of the apple sector in the province. In terms of infrastructure, the province of Midelt is equipped with units for the cold storage of apples, representing 84% of the Draa-Tafilalet region. The diversity of VC systems, such as agricultural cooperatives, the Provincial Association of Apple Producers in Midelt (PAAPM), and the Union of Apple Cooperatives (UAC) in Imilchil, along with an aggregation project and spot markets, provides a conducive environment for studying the impacts of coordination on commercial performance. The high concentration of apple production in the province, accounting for nearly 53% of the national production, reinforces the relevance of Midelt as a study area. Despite this potential richness, apple-marketing channels remain poorly organized, underscoring the need for an in-depth analysis of VC mechanisms to optimize the commercial performance of farmers.

4.3. Data collection and attribute choice

The selection of profiling variables was influenced by Table 1 and the overall purpose of the research project. The data collection was divided into two parts. The first part involved the selection of the AAP located in the Midelt province (Fig. 3), from which we retrieved information on the characteristics of apple products sold to Ag. Two projects have been identified with 250 apple producers, 120 members involved in the AAP were surveyed. The second part of the study involves surveying 70 non-aggregated samples selected using the propensity score method, adding an additional layer of methodological rigor to the sample selection process. The investigation was carried out throughout the year 2022. This careful selection approach contributes to the overall robustness of the study and enhances its representativeness. The selected producers were directly inspected by investigators, who collected the prices, product characteristics, and farmer characteristics such as experience. (collected knowledge and proficiency of farmers in the realms of agricultural production and trade) and education were collected, as well as farm characteristics such as farm size (ha) and yield (t/ha).

Lastly, we collected information on the marketing factors: whether the product was sold under a recorded conditional sale, whether

Table 1
Apple attributes that are frequently employed in hedonic pricing models (Source: created by authors).

Attribute	Variables	Author(s)
Quality characteristics	Cultivar	Carew, R [29].
	Grade	Carew et al. (2004); Gallardo et al. (2015); Wang et al. [30].
	Fruit size	Wang et al. [30]; Kajikawa [31].
	Variety	Carew et al. [4]; Jaeger et al [32]; Troncoso et al [33]; Seppä et al [34]; Carew et al.(2012).
	Production technology	Dinis et al. [35].
	Traceability	Liu et al. [36]; Jaeger et al. [32].
	Colour	Carew et al. (2004); Hossain [37].
	Sensory	Seppä et al. (2015)
	Organoleptic	Dinis et al. [35].
	Marketing factors	Storage method
Package size		Troncoso et al. [33]
Seasonality of sale		Goossens et al. (2019); Troncoso et al. [33].
Geographical origin		Dinis and al. (2011); Relawati et al. [26]
Month of sale		Troncoso et al. [33]
Cold storage		Troncoso et al. [33]
Vertical coordination models		Turhan et al [40]; Beuchelt and al [41].

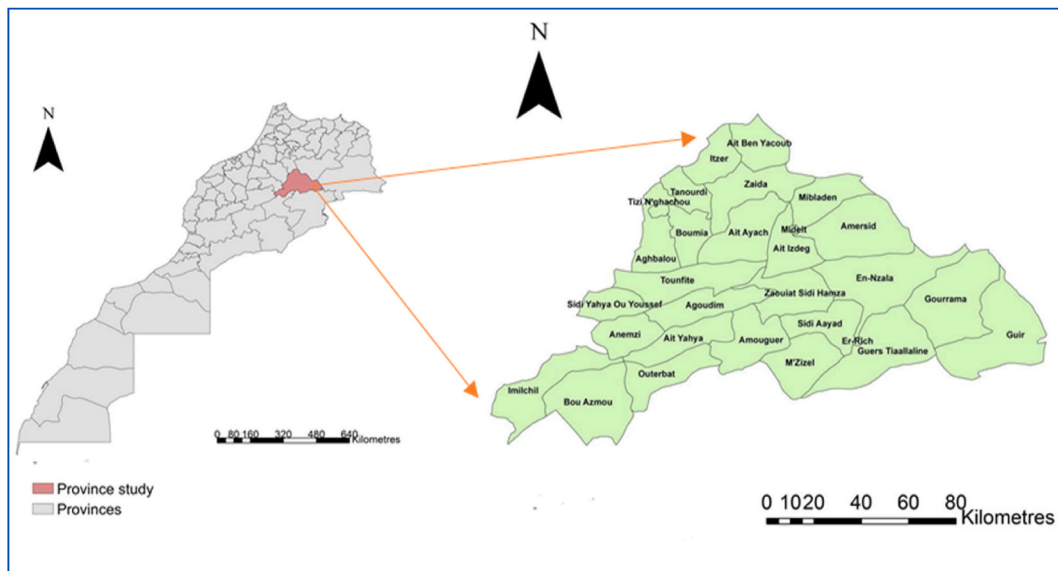


Fig. 3. Map of the study area: Midelt Province (Source: [13]).

the product was sold in a spot market, payment terms, and seasonality of sale. The questionnaire contains a variety of questions designed to collect information regarding the participant’s demographics as well as the quality characteristics of the products and marketing factors regarding the investigated topic. Additionally, the questionnaire was pilot-tested with a subset of participants to ensure its validity and reliability before being administered to the full sample. However, the hedonic model incorporates the effects of marketing strategies on prices. A VC system, payment terms, seasonality of sales, cold storage, and geographical origin are marketing factors. After apples are harvested, they are either packaged for sale on-site or stored (Table 2).

We used the Hedonic Price Model (HPM), which is based on microeconomic theory and was first put forth by Rosen in 1974, to determine the monetary value of an apple’s characteristics. Rosen [42] asserted that his model takes into account market equilibrium qualities, which is why the majority of research on the hedonic pricing of food products has employed this technique ([43]; Scholtenberg et al., 2012; [44,45]). In addition, there is literature on the hedonic pricing of many crop productions and marketing, including rice [46], cotton [47–49], wheat [50], subsistence crops [51], banana [52], olive [53], grapes [54], and peaches [55]. The hedonic method’s suitability for capturing the complex relationship between various product characteristics and their influence on prices justifies its selection for this study. In the context of the apple market in Morocco, where intrinsic factors related to the farm’s characteristics, socioeconomic variables (farmer attributes), quality attributes of apples, and extrinsic variables associated with marketing factors play a crucial role in determining their market value, the hedonic method is particularly well-suited. This econometric approach allows for the examination of implicit prices associated with different attributes, providing a detailed understanding of the factors influencing apple prices. The hedonic method is recognized for its precision in analyzing the complex interactions between multiple variables, making it the most suitable choice for exploring the intricate dynamics of the apple market and its VC

Table 2
Variables description.

Variable	Type	Description	(Expected Sign)
<i>Dependent variable</i>			
Price	Numeric	Price in MAD and Euros per kg	
<i>Farmers and farm characteristics</i>			
Farm size	Numeric	Number of hectares	+
Yield	Numeric	T/ha	+
Experience	Numeric	Number of years spent in apple marketing	+-
Education	Numeric	Years spent in formal education	+-
<i>Quality attributes</i>			
Apple varieties	Dichotomous	Golden Delicious = 1/0 if otherwise	+
Fruit diameter	Factor (2 levels)	Less than 65 mm or more than	+
<i>Marketing factors</i>			
AAP	Dichotomous	Yes = 1/No = 0	+
Payment terms	Numeric	full payment(Days)	+-
Seasonality of sale	Dichotomous	Yes = Early season varieties/No = 0	+
Cold storage	Dichotomous	Yes = 1/No = 0	+
Geographical origin	Dichotomous	Midelt = 1/0 if otherwise	+-

Note: AAP, Agricultural Aggregation Project.

systems in Morocco.

HPM is based on the idea that a person's willingness to pay for an agricultural product reflects the attributes of that product, including quality parameters such as the external appearance, firmness, flavor, and fruit size [56]. Other attributes may concern extrinsic characteristics [57]. In this study, three groups of elements are expected to affect the price of apples: 1) farmer characteristics (e.g., level of education of the producer and his experience) and characteristics associated with the farm itself (e.g., farm size and yield per hectare). 2) Quality characteristics (e.g., the fruit diameter and variety). 3) Marketing factors (e.g., the VC system, payment terms, seasonality of sale, cold storage, and geographical origin). In hedonic pricing analyses of food goods, models that use the natural logarithmic transformation of the dependent variable are most commonly seen. Many of these works ([58]; Chen et al., 2021) chose this specification in part due to its popularity in earlier investigations. Based on the empirical model used by Wang et al. [30], the present study employed the semi-log functional form, as depicted in equation (1), for the hedonic price model

$$\log P = \alpha + \beta_i x_i + \sum_{c=1}^d \beta_j x_j + \varepsilon \quad (1)$$

Where $\log P$ is price logarithm, x_i and x_j exogenous variables, β_i and β_j estimated parameters for econometric model, α is the constant value, and ε is the error terms.

Table 2 shows the variables used to explain the hedonic price of apples. According to the findings of Labiyi [59], the implicit marginal price (MIP) is calculated in a unique manner by each functional form (linear, log-linear, semi-log, and Box-Cox). Using the semi-log model, the expression from equation (2) can be used to calculate the implicit price of characteristic j on apple price i :

$$\frac{\partial P_i}{\partial z_{ij}} = \beta_j \cdot P \quad (2)$$

5. Results and discussion

The explanatory variables that were employed in the hedonic model are given as descriptive statistics in Tables 3 and 4. Table 3 provides descriptive statistics for the numeric variables, while Table 4 presents descriptive statistics for the dichotomous variables. The descriptive statistics in Table 3 include measures such as mean, standard deviation, and range for variables such as price, farm size, and education level. On the other hand, Table 4 displays frequencies and percentages for categorical variables such as VC system, geographical origin, and seasonality of sale. The collected product price data displayed a wide range of variation, from a minimum of 2.50 MAD/kg (0.23 €/kg) to a maximum of 5 MAD/kg (0.45 €/kg), with an average of 3.52 MAD/kg (0.32 €/kg). However, the median price of products sold is around 3.52 MAD/kg (0.32 €/kg). The compiled farm size data displayed a broad range of variation, from 0.25 ha to 10 ha, with an average of 3.26 ha. This suggests that there is significant diversity in the scale of cultivation areas among farmers in the area. Apple growers harvest an average of 32.48 tons per hectare annually (Table 3), with a broad range of variation, from 14 tons per hectare to 40 tons per hectare. The average revenue per hectare is 113.4 thousand MAD (10.24 thousand euros) based on mean volume, depending on the farm. This suggests that the technical support and VC systems of the farms play a significant role in determining their income potential. Additionally, it would be useful to analyze other factors, such as soil quality and access to water resources, to better understand the variations in income across different farms. Climate, soil quality, and farming methods are just a few of the variables that can affect this number. However, improvements in agricultural technology and practices have allowed some farmers to harvest even greater quantities.

Regarding socioeconomic factors, the results show that the mean age of the sample was 53 years old, with a maximum of 81 years. The education level variable had a mean of 6 years of education, a standard deviation of 3 years, and a range of 0–14 years. According to Table 3, the average experience of the surveyed farmers was 20 years, with a standard deviation of 7 years and a range of 6–45 years. This suggests that the vast majority of farmers surveyed have a wealth of knowledge regarding the raising of apple trees, including technical operations. However, the study also revealed that there is a need for more education and resources on marketing management to promote long-term economic and business sustainability in apple orchards. The descriptive statistics of product quality characteristics show that the most popular fruit size sold was medium, since 81% of farmers surveyed produce a medium-sized apple

Table 3
Descriptive statistics of the numeric variables included in the hedonic price models (190 observations).

Variable	Units	Mean	Median	S	Min	Max
Farm gate price	MAD/kg	3.52	3.75	0.47	2.50	5.00
	Euros/kg	0.32	0.34	0.47	0.23	0.45
Farm size	ha	3.26	3.00	2.19	0.25	10.00
Yield	t/ha	32.48	35.00	7.92	14.00	40.00
Payment terms	day	110	90	32.73	30	150
Farmer characteristics						
Age	year	53.21	52.00	6.31	46.00	81.00
Experience	year	20.52	18.00	7.38	6.00	45.00
Education	year	6.23	5.00	3.80	0.00	14.00

Note: S refers to the standard deviation, and Min and Max refer to the minimum and maximum response alternatives of the respondents. Authors' own estimations, field survey (2022). Euro (€) = 11.07 MAD

Table 4
Descriptive statistics of the binary variables included in the hedonic price models.

		f	(%)
AAP	0 = Non-Ag	70	37
	1 = Ag	120	63
Accessible_farm	0.00 = No	121	64
	1.00 = Yes	69	36
Previous_farm_client (Cold storage)	0.00 = No	94	49
	1.00 = Yes	96	51
Multi_variety_apple (Apple varieties)	0.00 = No	154	81
	1.00 = Yes	36	19
Fruit_diameter	0.00 = 60-75	154	81
	1.00 = 75-85	36	19
Protected_geographical_indications (Geographical origin)	0.00 = No	183	96
	1.00 = Yes	7	4
Tree_age (Seasonality of sale)	0.00 = less than 10 years	101	53
	1.00 = more than 10 years	89	47

Note: f, refer to the frequency. Authors' own estimations, field survey (2022); Ag, Aggregated. AAP, Agricultural Aggregation Projects.

(60–75). The second least common size produced was large, with 19% of farmers producing apples larger than 75 mm. However, these statistics provide valuable insights into the consistency and variability of the product's quality characteristics, which can inform decision-making for production and quality control processes. The results on the diameter of the fruits show that there is a significant difference between the diameters of the small and large fruits. The small fruits have an average diameter of 60–75 mm, while the large fruits have an average diameter of 75–85 mm.

The results show that the golden variety is dominant in the orchards surveyed, accounting for 70% of the total apple trees. The remaining 30% is composed of other varieties, such as Royal Gala and other cultivars. These results indicate that the orchard may benefit from sowing additional apple varieties in order to diversify its crop and potentially increase market demand. The descriptive statistics for the payment terms variable, measured in days, reveal key insights into the distribution and central tendencies of this crucial aspect. The mean payment term of 110 days signifies the average duration within which payments are typically made. The median value of 90 days indicates that half of the observed payment terms fall below this point, highlighting a certain level of skewness in the distribution. The standard deviation of 32.73 days underscores the variability or dispersion around the mean, showcasing the extent to which payment terms deviate from the average. The minimum payment term of 30 days reflects the shortest observed duration, while the maximum term of 150 days represents the longest payment period within the data set (Table 3).

Concerning the seasonality of sales, the results show that only 20% of producers harvested their apples between August and September, while the majority waited until October. This could be due to weather conditions or differences in apple cultivars and ripening times. The results indicate that there is a clear pattern of higher sales from late September to early October, with the highest spikes occurring during the months of September and October. This could be attributed to the sales of specific apple cultivars, which play a role in this seasonal trend. The results indicate that the early cultivars account for 80% of the total crop yield in the surveyed orchards. In contrast, the early cultivars contributed only 20% of the total fruit yield. This indicates that late cultivars are better adapted to the local climate and have greater yield potential than early varieties. This is a result of the extended growing season and

Table 5
Hedonic price analysis of socioeconomic, product attributes, and VC effects on apple prices (n = 190).

	log-linear			MIP
	β	SE	t-Statistic	
(Constant)	2.616	0.113	23.121	
Farmers and farm characteristics				
Farm_size	0.037***	0.009	3.934	0.130
Yield	0.006***	0.003	1.927	0.021
Experience	0.003**	0.002	1.280	0.011
Education	0.056*	0.073	0.775	0.199
Quality attributes				
Apple varieties	0.164***	0.065	2.537	0.578
Fruit diameter	0.192***	0.085	2.268	0.677
Marketing factors				
AAP	0.173***	0.071	2.427	0.609
Payment terms	-0.106***	0.052	-2.038	-0.374
Seasonality of sale	0.164***	0.082	2.007	0.576
Cold storage	0.245***	0.052	4.736	0.861
Geographical origin	0.140*	0.085	1.652	0.494
	R	R Square	Adjusted R Square	Std. Error of the Estimate
	0.940	0.883	0.874	0.1678

Note: *, **, *** indicate statistical significance at 10%, 5%, and 1%, respectively. B and SE are parameter coefficients and standard errors. Authors' own estimations, field survey (2022). AAP, Agricultural Aggregation Projects. MIP: Marginal Implicit Price; VC, Vertical Coordination.

cooler temperatures during the maturation period, which permit the crop to develop more effectively. In addition, late cultivars may have greater resistance to prevalent pests and pathogens in the region. Examining marketing factors, our results showed that for supply chain management, 63% of respondents used cold storage as a marketing channel, while 37% did not (Table 3). This suggests that a substantial proportion of producers recognize the utility of storage as a marketing tool. There are 38 storage facilities in addition to processing and packaging facilities (32 of which are located in the study area). Table 4 shows descriptive statistics for VC system data. Of the 190 farmers surveyed, 63% have sold their products under agricultural aggregation. The AAP suggests that the use of contracts is positively associated with higher levels of investment in quality and quantity of production, as well as increased access to credit and markets.

The apples are grown in the fertile soil of the Midelt region, which is known for its ideal climate and rich nutrients. These factors contribute to the distinct flavor and texture of the Midelt apple, making it a favorite among fruit enthusiasts worldwide. A sample of 190 apple producers covers the study areas, of which 30% are based in Midelt. The remaining 70% are distributed across other apple-growing areas in the Atlas Mountains of Morocco, such as Boumia, Zaida, Rich, and Imilchil. It is important to note that geographical origin does not necessarily determine the quality or safety of a product, as factors such as production methods and regulations also play a crucial role.

Table 5 shows the results of the econometric analysis. According to the results of semi-log regression (SLR), the majority of the selected attributes have a significant effect on apple prices. In addition, the findings indicate that the directions of the estimated coefficients are consistent with economic theory and comparable to the findings of earlier research (e.g., Ref. [60]; Bravin et al., 2009; [61]). This is in line with what was anticipated and the anticipated outcomes. In particular, with regard to the quality attributes, apple varieties and fruit diameter were shown to be attributes having a large and robust influence on apple pricing, in line with the findings of earlier studies (Cătălina et al., 2015; [39]). Table 5 provides an R-squared coefficient estimate for the hedonic model. The variables explain over 88% of the variation in apple prices, with the model summary suggesting that socioeconomic variables, quality characteristics, and marketing factors are the principal factors influencing apple prices. This indicates that the model is a good fit for predicting apple prices based on these variables.

The marginal effects of orchard size, indicating that larger orchards tend to receive higher prices for their apples, positively and statistically significantly affect net apple marketing prices. Regarding farm sizes, compared to smallholder farmers, farms with more than 3 ha earned a price premium of MAD 0.130/kg (11.74 euros per tonne). This suggests that economies of scale may be at play in the apple market, as larger producers are able to benefit from higher bargaining power with buyers. Additionally, larger sizes may be in higher demand and considered more valuable by some buyers, leading to a higher selling price. The data indicates that Moroccan apple growers can gain advantages from initiatives aimed at expanding their orchards. Encouraging farmer organizations, providing assistance for orchard consolidation, or implementing VC systems to enhance apple production are potential avenues. This counsel implies that the enlargement of orchards may result in higher net apple marketing prices, ultimately enhancing the economic success of Moroccan apple farmers. Larger orchards tend to have economies of scale, allowing for more efficient production and distribution, according to the findings of the majority of researchers (e.g., Ref. [60,61]). In addition, larger orchards may have greater bargaining power with purchasers and be able to negotiate higher prices for their produce [62]. A low benefit (MAD 0.021/kg/1.89 €/ton) was associated with yields per hectare (Table 5). As larger producers have the ability to produce and supply larger quantities of apples, they can negotiate better deals and secure prices that are more favorable from buyers. This creates a competitive advantage for them and allows them to capture a larger market share. Additionally, economies of scale enable larger producers to spread their fixed costs over a larger output, resulting in lower average costs per unit and ultimately higher profitability. The results also indicate that the price of apples is more sensitive to changes in farm size than it is to changes in yield per hectare, resulting in a delicate balance between supply and demand. Additionally, it highlights the importance of considering farm size when analyzing the economics of fruit production. The implications of these findings can be categorized into two main aspects. Firstly, the results suggest that larger orchards are associated with higher apple prices, indicating that large producers are inclined to opt for optimal VC methods, such as agricultural aggregation. Secondly, the data suggests that larger producers enjoy enhanced bargaining power and increased demand for their larger quantities, enabling them to negotiate advantageous deals and secure higher selling prices for their apples.

The results showed that the years of experience of apple growers increased apple prices by approximately 0.3%. Growers with more experience can expect to receive a higher price for their apples, as there is a positive correlation between the number of years in the business and the price of apples. This is because experienced growers are likely to have a better understanding of market demand and supply, as well as the quality standards required by buyers. In addition, apple growers with more experience are less vulnerable to the effects of market fluctuations than their less experienced counterparts. The results suggest that experience in the apple-growing business brings not only agricultural expertise but also a set of skills and insights that contribute to the economic success of growers in the marketplace. In light of this, one important suggestion is to implement a VC mode that incorporates thorough training programs in order to encourage apple producers to constantly learn and improve their skills. For the sake of both product quality and the apple industry's general competitiveness in Morocco, it is crucial to increase apple growers knowledge base and experience. A more robust and dynamic apple sector may be achieved through a strategic emphasis on a VC mode that includes training for farmers. This is in line with the necessity of improving the individual capacities and collective competence of apple producers. Given prior research on experience (Zhang et al., 2009; [27]), which demonstrated that skilled growers are likely to have solid relationships with buyers that can lead to higher prices for their produce, this conclusion seems reasonable. The hedonic analysis revealed that the educational level of producers has a significant effect on apple prices, independent of other socioeconomic variables and, in particular, apple cultivator experience.

The results revealed that the education level of apple producers contributed to a 5.6% rise in apple pricing. This suggests that farmers with higher levels of education may have a better understanding of market demand and pricing strategies. In accordance with

previous research (Wang et al., 2013), this analysis reveals positive and statistically significant marginal effects of the years of education variable, indicating that policymakers must consider the role of education in the agricultural sector and how it can influence market outcomes. However, the study did find that variables such as age and gender did not appear to influence apple prices. This outcome is in line with the findings of a prior study by Ma et al. (2016). The implications of these findings encompass three key aspects. Firstly, the positive correlation observed between the years of experience of apple growers and the rise in apple prices underscores the valuable role of experience in determining successful VC modes. Experienced producers, possessing insights into suitable VC methods and requisite quality standards, play a crucial role in shaping market dynamics. Secondly, the noteworthy impact of the education level of producers on apple prices, irrespective of other variables, underscores the importance of education in influencing the selection of an appropriate VC mode. Higher education levels contribute significantly to decision-making regarding the optimal mode of VC.

The results of this study show that there is a significant difference in the prices of apples with different quality characteristics. According to the hedonic price analysis, there are statistically significant marginal effects between the diameters of small and large fruits. Large apples with an average diameter of 75–85 mm are still more expensive, with a price premium of 19.2% compared to small fruits with a diameter of less than 75 mm (60–75 mm). According to previous research (Carew et al., 2004), cultivar and fruit size are the most significant variables determining apple pricing. Distributors forked up an extra \$2.25 to \$5.25 per tray for rare varieties. As compared to apples of a more average size, those that were larger were sold at a premium (\$1.73 per plate), and those that were smaller were sold at a discount (\$2.00 per plate). The economic analysis also demonstrates that apple varieties affect prices. The selling prices for the Golden variety were, on average, 16.4% higher than the selling prices for other cultivars of apples. This indicates that the golden variety is in high demand and is perceived as having higher value by consumers. Farmers may consider increasing their production of golden apples to take advantage of this price premium, which is consistent with Khan et al. [39]. Carew and Smith [63] found that the availability of a certain apple variety has a substantial effect on the price of that apple. According to the data, the widespread availability of older apple varieties like the Red Delicious, Jonagold, Sunrise, and Gingergold allows them to be sold at cheaper prices than the McIntosh in Washington. Royal Galas, Fujis, and Braeburns, on the other hand, sell for \$2.25–\$2.50 more per tray than McIntoshes since they are considered specialist cultivars. Because of their lower availability, Granny Smith and Ambrosia apples command a heftier price premium in British Columbia.

In the context of Morocco, the insights from Carew and Smith's research could be applied with considerations for the local apple market dynamics. While the specific varieties mentioned may not all be prevalent in Morocco, the general principle of supply impacting prices remains relevant. The study recommends that Moroccan apple growers prioritize cultivating and marketing larger apples while considering the economic importance of Golden apple varieties. These strategic decisions, when aligned with market dynamics, have the potential to improve individual producers' economic performance and enhance the overall competitiveness of the apple industry in the country. To achieve these objectives, collaboration between the National Agricultural Advisory Board (ONCA) and the National Institute for Agricultural Research (INRA) is crucial. This collaboration involves integrating research insights into practical farming practices, refining varietal selection, and improving production and marketing strategies, ultimately fostering a dynamic and competitive landscape in Morocco's apple industry. In the context of the Moroccan apple industry, VC modes, specifically agricultural aggregation, play a significant role, especially in cases where growers are connected to AAP. Agricultural aggregation streamlines the supply chain, and INRA ensures that the selected apple varieties meet market demands. ONCA provides guidance to growers in adopting the aggregation model and facilitates connections with potential buyers. This collaborative effort serves as a catalyst for reconnecting growers with the broader market, resulting in an integrated and responsive supply chain that benefits both producers and consumers.

The marketing factors in the analysis were measured by dummy variables (values 0 or 1), which show that the selling price through agricultural aggregation is significantly higher than in other variables such as VC systems, payment terms, and seasonality of sales. Furthermore, the analysis also considered external factors such as geographical origin and cold storage to provide a comprehensive understanding of the market landscape. The estimated coefficients can therefore be defined or interpreted as premiums (MAD per kg and €/kg) or discounts, if negative, relative to the default variables. The average difference in selling price between sales conducted under contracts and sales conducted under non-contractual agreements was found to be 17.3% higher, which suggests that contract arrangements provide a significant advantage to sellers. This could be due to the stability and predictability of contract agreements, which may attract buyers willing to pay a premium for that security. This result shows that agricultural aggregation can be a more profitable option for farmers looking to sell their products. The size of these price premiums is comparable to that which Miyata [64] reported for the apple markets in China for the outcomes of contract apple growers. In the context of comparison, apple producers in China primarily engage in forms of VC characterized by transactional engagements with small retailers, wholesalers, and cooperatives. Farmers choose their VC based on the selling price and benefits. Within the framework of the spot market, two distinct transactional models have been embraced [3]. The first involves small-scale dealers directly procuring products from the farmers. In this arrangement, farmers engage in direct sales with local dealers, facilitating a more immediate and localized exchange. The second transactional approach in the spot market entails selling to wholesalers who operate on a larger scale. These wholesalers, with a broader market reach and greater resources, often enlist the services of local villagers as brokers. This intermediary role is crucial in facilitating transactions between wholesalers and farmers, contributing to a more structured and expansive distribution network. In this country, the inclusion of cooperatives in VC mechanisms signifies a relatively recent progression [65].

A significant differentiator in the observed modes of VC between China and Morocco lies in a crucial advantage: the flexibility allowed in the Chinese system. In China, not all cooperative members are obligated to deliver their products exclusively to the cooperative. Moreover, non-member farmers also have the option to sell their products to the cooperative. This suppleness stands in contrast to the situation in Morocco, where participation in an arrangement with an AAP entails a mandatory commitment to sell the entire production to the aggregator, adhering to the terms of the contract even if the offered price is not favorable. The Chinese VC

model offers a significant advantage over the Moroccan system, as it allows for more elasticity in product delivery and non-cooperative transactions. This allows farmers to explore various market avenues, negotiate prices, and make strategic decisions based on market dynamics. This tractability allows for more adaptability, allowing apple producers to optimize their commercial outcomes. This contrasts with the rigid structure observed in Morocco, which restricts options for producers and potentially compromises their commercial performance. The Chinese model underscores the importance of flexibility in VC mechanisms for agricultural producers' commercial success and autonomy. However, further research is needed to determine the long-term sustainability and scalability of this approach. Several studies have looked at farmers' two options: either VC with modern agro-food supply chains like cold storage warehouses through contractual arrangements or selling their produce at more volatile spot markets. They have found that farmers who participate in advanced agro-food supply chains tend to receive higher prices and better market access (e.g., Ref. [66–68]). However, these arrangements may also require farmers to meet certain quality and quantity standards, which can be challenging for small-scale farmers with limited resources [69]. Additionally, some studies suggest that participating in advanced agro-food supply chains may lead to increased dependency on a few large buyers and reduced bargaining power for farmers [70].

The results indicated that the selection of cold storage operations, early harvests, and extended payment periods increased apple prices by approximately 24.5%, 16.4%, and 10.6%, respectively, compared to instantaneous transactions, late harvests, and immediate payment terms. These findings suggest that implementing these strategies could potentially benefit apple farmers by increasing their profits and improving their overall financial stability. The results of this study also show that farmers who preferred timely payment were more likely to sell their apples at a low price, according to the negative and significant marginal effects of the payment terms variable for a relatively short time (less than 30 days). On the other hand, the positive and significant effects of the payment terms variable for extended payment periods (more than 30 days) suggest that farmers who can accept delayed payment are more likely to sell their produce at a high price. This finding highlights the importance of understanding farmers' preferences for payment terms in order to negotiate a mutually beneficial price (Ma et al., 2016). As indicated by Dries et al. [71], it may be beneficial for buyers to offer flexible payment options to cater to different farmer preferences and ultimately increase their profits. This indicates that the apple growers may receive additional benefits associated with late payments, such as additional bonus payments. Furthermore, it may also suggest that the apple growers have strong bargaining power in the market, which allows them to negotiate favorable payment terms with their buyers. However, it is important to note that late payments can also have negative impacts on the cash flow and financial stability of the growers.

The marginal effects of seasonality on sales variables are positive and statistically significant for early harvests, indicating that the earliest apple varieties harvested from late August to early September have enjoyed advantageous market prices. However, the effect of seasonality on sales variables for late harvests is negative and statistically significant, suggesting that the latest apple varieties harvested from late September to early October have faced lower market prices. These findings highlight the importance of timing in apple production and marketing strategies. This finding is in line with the findings of an earlier study conducted by Goossens et al. [72], as well as another study conducted by Carew et al. (2000) and Deda et al. [73]. Carew and Smith [63] state that higher apple prices are common in September, which may be attributable to the release of early-season cultivars. November and December prices are also higher than they were in October. This shows persistent demand or specific market circumstances during these eras. According to the research, the introduction of early-season apple varieties to the market is likely responsible for the increase in pricing seen in September.

In addition, the significant marginal effects of the cold storage variable indicate that respondents who used cold storage as a marketing channel were less likely to sell their apples for a low price. This was found to be the case despite the fact that these respondents were more likely to sell their apples at a higher price, suggesting that cold storage may be an effective strategy for apple farmers to increase their profits. Djekic et al. [74] discovered similar outcomes in the case of cold storage for the apple fruit chain, with cold storage having a positive impact on apple prices. However, further research is needed to explore the potential drawbacks and limitations of using cold storage as a marketing channel, such as the additional costs and logistical challenges involved in implementing this strategy. Contrariwise, Kim et al. [75] noted that the length of time in cold storage played a significant role in determining the quality and price of the apples. Specifically, apples stored for longer periods tended to have lower prices due to decreased quality.

The results indicate that the price per kilogram of apples increases by approximately 14% if they originate from Midelt producers and are grown in Midelt orchards. This suggests that there is a premium placed on apples from Midelt and their unique characteristics. Further research could investigate the factors driving this premium and how it affects consumer behavior. Additionally, the study could explore whether the perceived quality of Midelt apples justifies the higher price, and if consumers are willing to pay more for these apples based on their reputation. Furthermore, understanding the impact of this premium on the overall apple market, such as the competition between Midelt apples and apples from other regions, would provide valuable insights for apple growers and policymakers. Overall, delving deeper into the reasons behind the premium on Midelt apples would contribute to a better understanding of consumer preferences and market dynamics in the apple industry. This result is similar to previous studies that have found that the origin of a product can significantly impact its price [76]. Fotopoulos et al. [77] also found that there was a significant difference between the prices of apples from different regions. However, it is important to note that other factors such as the accessibility of the farm and tree age may also play a role in determining the price of apples from the same locality. Furthermore, market demand and competition can also affect the pricing of apples in a particular area. Therefore, it is crucial for farmers to consider these factors when setting the price of their apples to remain competitive in the market.

Within the framework of this research, the proposed VC model should consider five essential elements. Firstly, it recommends the implementation of flexible contractual agreements, accommodating the diverse needs of apple growers, particularly emphasizing extended payment periods for experienced growers who exhibit a positive correlation with higher prices. Secondly, collaboration with institutions such as INRA and ONCA is suggested to establish a varietal selection advisory program, enhancing market competitiveness

based on research insights. The third element involves integrating market intelligence mechanisms to aid growers in strategic seasonal planning by providing timely information on market demand trends. Encouraging the adoption of flexible payment terms through incentive programs constitutes the fourth element, offering benefits like preferential access to credit or market promotions for growers embracing extended payment periods to improve cash flow management. Lastly, the proposal suggests the establishment of collaborative platforms and training programs to facilitate knowledge exchange among growers, industry experts, and institutions, fostering collective expertise. This amalgamation of elements aims to leverage differences in orchard size, grower experience, varietal preferences, and market dynamics, fostering a more interconnected and resilient apple industry in Morocco.

6. Conclusion

This article examines and evaluates the factors that affect apple pricing and the impacts of VC on business performance amongst apple producers in Morocco. In economics, hedonic price functions are a prevalent method for estimating the value of a product or service based on its characteristics. According to the study, socioeconomic factors such as the level of education of the producer and his experience have a significant effect on apple prices. In addition, apple quality characteristics such as variety and fruit diameter have a significant effect on their prices. Market factors, such as seasonality and the VC system, also influence apple prices. These results can help apple producers and marketers make pricing decisions and enhance their marketing strategies. The study concludes that marketing characteristics are one of the most influential factors on apple prices, with payment terms, storage, marketing season, and geographical origin also accounting for a significant portion of the price variance. In the apple market, interactions such as cultivar grade and storage marketing season demonstrate the significance of interdependencies among fruit characteristics and commercial demand. In addition, terms of payment and the date for payment play a role in determining apple prices, as payment facilities can cause prices to rise regardless of other factors. Researchers can obtain insight into consumer preferences and market trends by analyzing the relationship between these attributes and their corresponding prices. This analysis can assist businesses in making informed pricing strategies and product development decisions. In addition, understanding these relationships can help identify potential areas for cost savings and upselling opportunities. This information can be beneficial for farms seeking to optimize their pricing strategies and policymakers seeking to more effectively regulate markets. Farms can maximize profits and remain competitive by analyzing market trends and consumer behavior and adjusting prices accordingly. In addition, policymakers can utilize this data to identify potential market inefficiencies and implement regulations that promote fair competition and safeguard smallholder farmers.

This study establishes a strong basis for future exploration in agricultural economics, particularly in Moroccan apple marketing. Key prospects include conducting longitudinal studies to track the impact of VC over time, analyzing policies to foster a favorable business environment for apple farmers, and comparing strategies with other apple-producing regions for global competitiveness. By aligning policies with market dynamics and stakeholder needs, policymakers can support sustainable growth. Comparative studies offer insights into best practices, aiding Moroccan farmers in identifying opportunities for improvement and innovation in their marketing approaches, ultimately contributing to the sector's long-term success and resilience. The study provides valuable insights, but gaps remain. Long-term implications of VC on apple farming sustainability need investigation. Understanding how coordination affects competitiveness, market access, and economic viability over time is crucial. Further research on consumer behavior and market dynamics is warranted to grasp the underlying price drivers.

The findings indicate that wholesale fruit purchasers are prepared to pay a premium for the new generation of agricultural organizations, such as agricultural aggregation. Therefore, producers should be provided with incentives to expedite the replacement of spot markets with newer VC systems (agricultural aggregation projects). This would not only create opportunities for smallholder farmers, but it could also increase the regulation of apple value chains in Morocco. By improving the regulation of apple value chains, consumers can have greater confidence in the quality and safety of the apples they purchase. Additionally, this could lead to increased exports of Moroccan apples to international markets. This would necessitate modifying the AAP implementation procedure and placing a greater emphasis on transaction cost reduction in AAP. Furthermore, it would require a comprehensive analysis of the current implementation process to identify areas where transaction costs can be reduced. This could involve exploring new technologies or partnerships with other organizations to streamline the aggregation process and reduce costs for farmers.

Based on our findings and prior research [78,79], it is crucial for policymakers to consider VC models, marketing factors, and transaction costs faced by apple producers in order to improve system performance and business performance among apple producers in Morocco [13]. Furthermore, our study highlights the importance of developing marketing policies that support the adoption of research results and technology transfer to enhance marketing factors and productivity in the apple production sector. These policies should also aim to improve sales prices for small-scale apple producers to facilitate their participation in higher-value markets.

Data availability statement

All data used in the generation of the results presented in this manuscript will be made available upon reasonable request from the corresponding author.

CRediT authorship contribution statement

El Houssain Bouichou: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Aziz Fadlaoui:** Validation, Supervision, Software, Resources, Project administration, Methodology. **Abdelghani Bouayad:** Visualization, Conceptualization. **Khalil Allali:** Visualization,

Validation, Supervision, Resources, Methodology, Data curation, Conceptualization.

Declaration of competing interest

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

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