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DEPARTMENT OF MANAGEMENT AND PRODUCTION ENGINEERING

Master's Degree in Engineering and Management

THE MOTORCYCLE INDUSTRY. AN ASSESSMENT OF PRICE IN SECOND HAND ITALIAN MARKET

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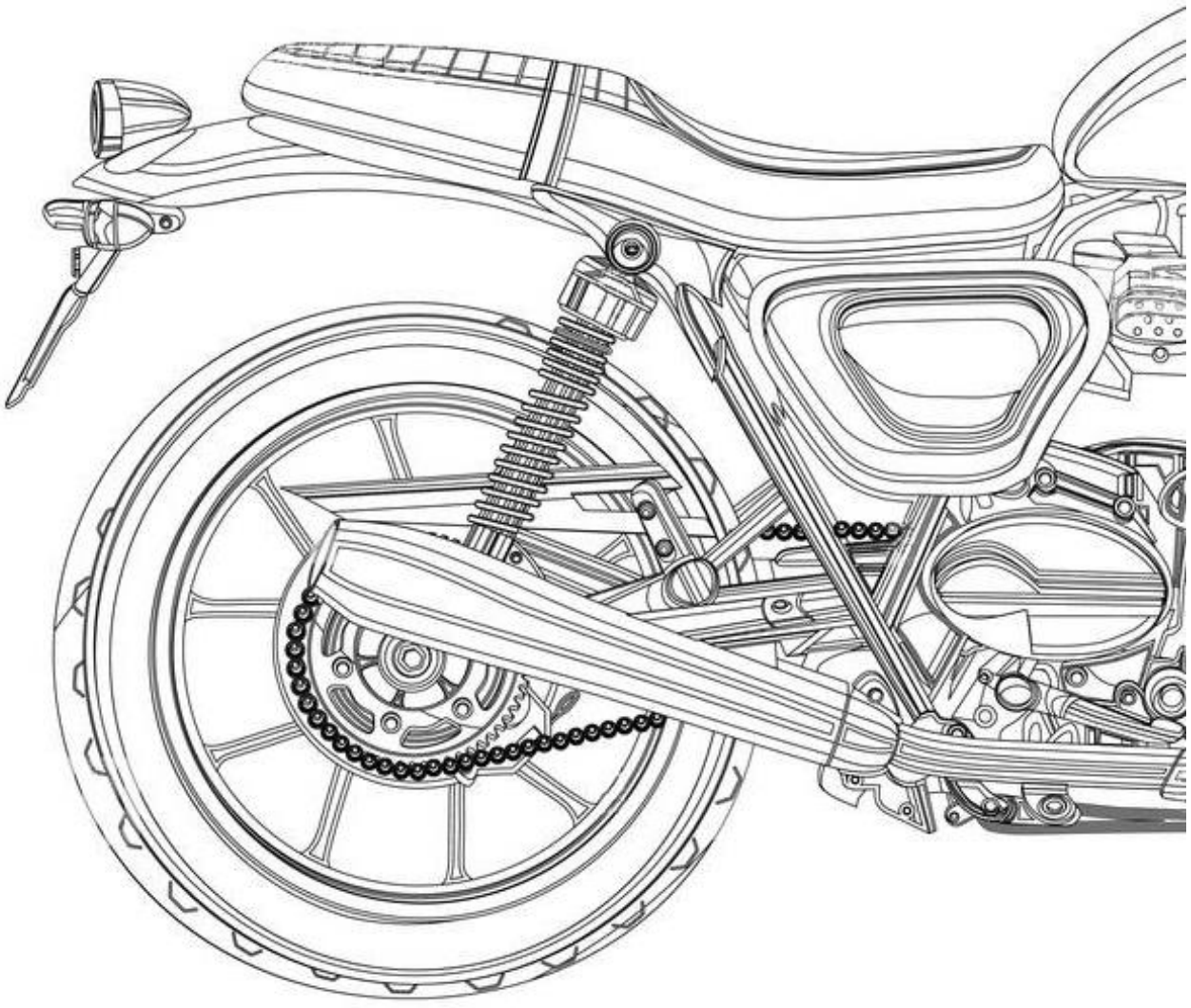
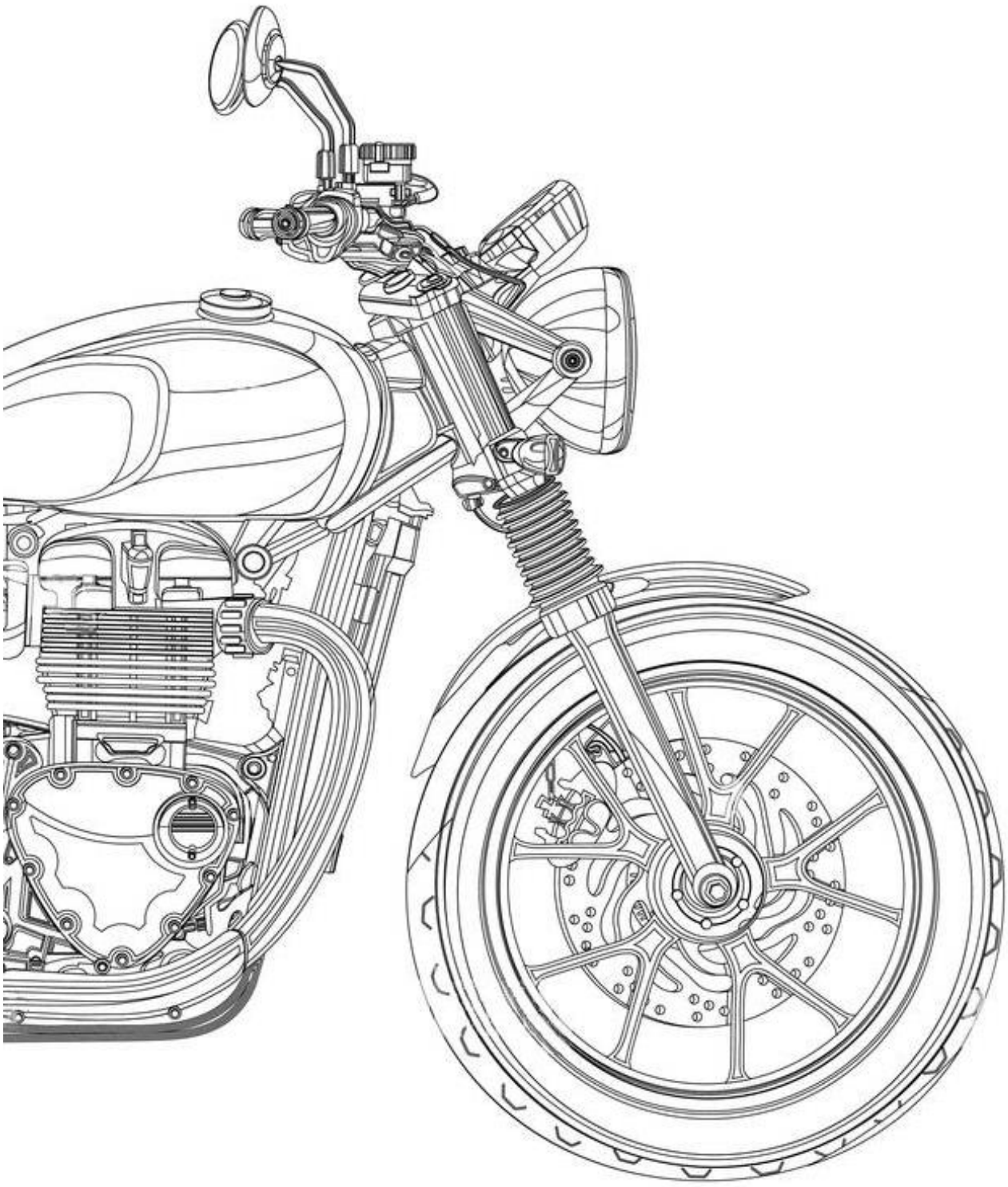
INTRODUCTION

In the contemporary mobility landscape, two-wheeled vehicles play a fundamental role for millions of people worldwide. From emerging economies, where they represent an essential means of daily transportation, to industrialized countries, where they are increasingly associated with lifestyle and leisure, motorcycles, scooters, and mopeds occupy a central position in modern transportation systems.
Within this context, the primary objective of this thesis is to analyze the motorcycle market with a specific focus on the used segment. The work aims not only to describe the main products and statistics that characterize the sector but also to empirically identify the key factors that determine the price of a second-hand vehicle, assessing whether predictive tools can effectively estimate it and to what degree of reliability. To achieve this, the analysis is grounded in a structured understanding of the market: descriptive and statistical evidence is not presented merely as background information, but rather serves to frame the dataset, motivate the choice of variables, and support the interpretation of the observed price patterns.
Building on this foundation, the empirical component of the thesis develops data-driven models capable of predicting and explaining price variations across hundreds of online listings. The models evaluate the impact of variables such as segment, mileage, seller type, registration year, and other features commonly considered by buyers and sellers. From a methodological standpoint, this work aligns with a broader body of literature that applies hedonic pricing models and machine learning techniques to vehicle markets. Several studies focus on used cars, employing econometric models to quantify how specific attributes shape second-hand prices, while more recent contributions increasingly rely on supervised learning algorithms, such as Random Forests, to enhance predictive accuracy using large datasets collected from online platforms. Drawing on this literature, the thesis extends approaches used in the automotive field to the motorcycle domain, adapting them to the peculiarities of the two-wheeler market and to the structure of the Italian used segment.
The outcomes are significant not only on an academic point of view, but intend to offer real meaningful insights for multiple stakeholders. For consumers, the predictive models provide a valuable reference for evaluating whether a listed price is fair (particularly on digital platforms), thus enabling more informed purchasing decisions. For manufacturers and retailers, the findings highlight which models tend to retain their value more effectively, supporting sales strategies, product positioning, and marketing activities. Moreover, the study offers potential benefits for online marketplaces, suggesting the integration of similar predictive tools to automatically identify and flag advantageous listings, improving transparency and helping users navigate large volumes of announcements more efficiently.

CH. 1



MOTORCYCLE and TWO WHEELED VEHICLES



Chapter 1

MOTORCYCLE and TWO-WHEELED VEHICLES

To better understand the analysis involved in the thesis, it is essential to provide a detailed and comprehensive overview regarding the world of motorcycles and, more in general, two-wheeled vehicles. This preliminary study will allow us to obtain a much clearer vision related to the product characteristics, its development, and the differences with other two wheelers, both from a structural point of view and in the way they fulfill needs and tastes of customers around the world.
The first chapter has this purpose: exploring the past and the present of motorcycles, from their history, to construction and key components. In addition to this, before shifting to the market analysis, the final part of this section will include a short brief regarding trends and innovations that are impacting on the future of the industry.

1.1 HISTORY AND EVOLUTION OF THE MOTORCYCLE

The Second Industrial Revolution of the 19th century led to a massive concentration of population from the rural areas to the cities, in search of new job opportunities. Industries and services were evolving driven by the introduction of electricity, petrol and supported by mass production. The substantial and increasing need for movement within those areas and the income growth for individuals, led to the birth and evolution of public transport such as trams, but not only. In parallel to these solutions, a new type of mobility was emerging, the one of personal transportation. Two-wheeled vehicles are part of this category, expressing the need for a new agile, flexible, and autonomous way of moving into the city.
Although someone could think that the birth of the motorcycle industry has a simple and linear course, from the advent of bicycles to modern bikes, the reality is more complex and involved a simultaneous evolution of various technologies and systems, which have also brought to the definition of different products[a].

[a] *To know more about them go to 1.2 Modern Two Wheelers Classification*

1.1.1 Bicycle's history

Despite the complex evolution of motorcycles, the starting point from which all begun is certainly the advent of the bicycle. Differing from other two wheelers for the absence of an engine, it generate forward movement transferring energy from a person's legs to one wheel (generally the rear, but in origin the front one).
The discussion about which invention represent the fist ancestor of the bicycle presents a curiosity. Some sort of myth sustain that in 1791 the French count Mede de Sirvac create a prototype that was similar to a wooden bar ending in two forks holding two carriage wheels, but with no means of steering. It was baptized 'cheval de bois' and later 'celerifere' (from the Latin celer, fast, and fero, meaning to carry), but its real existence and the one of Sirvac himself, is strongly in doubt. The fist testimony of it, in fact, is founded nearly a century after its presumed appearance, in the late 19^{th} century, from Louis Baudry de Saunier, a french populizer who probably just wanted, as others historians, to claim France and not Germany as the motherland of this invention.
It was in Germany in fact, that Karl Friedrich von Drais, a forester and inventor, build in 1815 the first steerable bicycle-like device, similar to the one shown in Fig.1.1. He fixed the front wheel to a vertical shaft, allowing the rider to turn, and added a stomach rest to help in the use of the device, which, like the cheval de bois, was based on pushing forward with the feet against the ground. Called for this reason the 'laufmaschine' (running machine), and subsequently the 'draisine', it was patented on the 5^{th} of January 1818(1).
Starting from this date, different vehicles were modeled on its design, becoming more generally known as velocipede (from velox pedis, fast foot). Although the drasine could be considered the first reported precursor of the bicycle, the velocipedes still lacked of any means of independent propulsion. The next step in the evolution of the bicycle was taken by a pair of Frenchmen who solved this problem.

Figure 1.1: *An early evolution of the drasine, the hobby horse*

In 1855 the team of Pierre and Ernest Michaux tried to fit a arms powered lever to the wheel, but the design failed due to balance problems and structural weakness. To solve this they tried a new path, attaching two connecting cranks to the front wheel fastening them with large nails (later replaced by a piece of bent tube) forming a foot rest, and creating the first pedal. In 1861 they produced the vehicle shown in Fig.1.2, the 'michaudine', on which the rider could employ feet on pedals of the front wheel to move forward. Their design was so successful that they established the first real bicycle industry, the 'Michaux et Cie'.

(1) Herlihy David V. , *Bicycle: The history*, Yale University Press, 2004

The pedaling was a revolution, but the iron-tired wooden wheels did not make driving comfortable, as demonstrated by the vehicle nickname "bone-shaker". In the late 19th century, the velocipede started to obtain more attention, and various prototype appeared, differing in shape and dimension. Journals and dedicated events document the widespread of the invention, while the run for innovation was at its peak. The objective was to increase the speed and the comfort of these devices.

Figure 1.2: *The michaudine*

In the 1870 James Starley from Coventry, started to produce the 'penny farthing' shown in Fig. 1.3. Despite its strange appearance, the bigger front wheel allow riders to reach higher speed than its predecessors, with a better shock absorption. The more elevated position of the seat however, comported a significant increase in dangerousness. It was difficult to get on and off, complex to maneuver, and could case some major injuries in case of falling.

Figure 1.3: *The penny farthing*

The most significant improvement arrives in the 1885, when Starley's nephew presented the 'Rover safety bicycle' shown in Fig. 1.4. John Kemp Starley's model had two equal size wheels, a diamond shape metal frame and a chain drive connected to the rear wheel, ensuring greater stability and safety. It was a real revolution, it eliminated the risks associated with the height of the penny farthing and made the vehicle more accessible to a wider segment of the population, including women. Its design represents the basis of the modern bicycle and allowed a mass diffusion of the vehicle, transforming it into a practical tool for daily mobility.

Figure 1.4: *The safety bicycle*

The last problem so solve were the complaints about the 'bone shaking' experience of riding. While most bicycle manufacturers relied on rubberized strips of cloth nailed to the wheels, in the 1888 John Dunlop produced the first air-filled tires. Later on others contributed to improving his technology, including Giovanni Battista Pirelli (1892) and André Michelin (1895).

1.1.2 Motorcycle's history

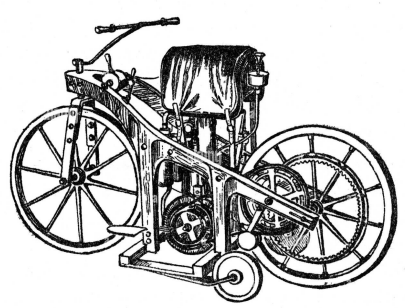


Figure 1.5: *Daimler's motorcycle prototype*

Figure 1.6: *Millet's motorcycle*

Figure 1.7: *Hildebrand and Wolfmüller motorcycle*

By the end of the 19th century the bicycle was already an established means of transport. At this point all the necessary conditions for the development of the motorcycle were present, with one fundamental exception, the engine.
Already in the 1867-1868[3] Sylvester Howard Roper in the US, and Louis Guillaume in France, developed and patented models characterized by a steam engine mounted on the bicycle built by Pierre and Ernest Michaux, but, despite the similarity with a motorcycle, historians define the German engineer Gottlieb Daimler, as the father of two wheeled powered vehicles.
In 1885 in fact, he took the gasoline, four-stroke, one cylinder engine, created by his boss Nicholas August Otto in 1876, and built the "Daimler Einspur" shown in Fig.1.5, which is considered to be the first motorcycle of the history. Named 'bone crusher', for its discomfort (a direct reference to early bicycles' nickname 'bone shakers'), it consisted in a wooden frame and wheels, with the engine positioned vertically in the center of the machine. Ironically, Daimler never rode his creation, his interest was in testing the engine, not creating a vehicle, this because he wasn't a motorcycle enthusiast, seeing this prototype as a mere precursor to the more stable automobile.
The next step was taken by the French engineer Felix Millet in 1892. He built the prototype shown in Fig.1.6, an extension of the safety bicycles with pneumatic tires. Millet's motorcycle featured a highly original design: it was equipped with a 5-cylinder rotary engine, directly coupled with the rear wheel, eliminating the need for external chains or gears. Despite its cleverness, it still presented pedals to start the engine and its complexity represented an issue in pursuing mass production, causing these vehicles to be used by very few riders.

[3] Khatri A., *Motorbike History*, Publifye, 2025

[4] Panchal D. U., *Two and Three Wheeler Technology*, PHI Learning, 2015

The first successful motorcycle series-production arrived in 1894, introduced by Heinrich and Wilhelm Hildebrand, two German steam-engine engineers. They started to produce and sell the "Hildebrand and Wolfmüller motorcycle" shown in Fig.1.7, which unlike earlier experimental motorized bicycles, was designed from the ground up to be powered by an internal combustion engine. Made of metal tubing, similar in shape to a reinforced bicycle frame, it mounted a two-cylinder, four-stroke, water-cooled engine, which powered the vehicle up to 45 km/h[(4)]. The pedals were not present anymore, signing an important distinction between what would have become motorcycles, and instead mopeds, each with a separate evolution and market. Around 1,000 units of this vehicle were built, mainly in Germany and France, showing how motorcycles were starting to be accepted by people.
Despite this they still faces major problems such as unreliable ignition, carburation and weight of the engines, which were producing less power with higher fuel consumption. *(For other information see the degression below).*
The solution arrived in 1895, when Albert de Dion and Georges Bouton, designed in France a tricycle with a 125cc engine that, licensed in various European countries and America, became the standard for motorcycle engines. It was accepted by almost all manufactures, because of its power output, fuel consumption and weight. This evolution permitted to sustain the increasing demand for motorcycles, improving mass production, and helping to the widespread of different machines.

> "***Major early motorcycles problems:*** *The mechanism of internal combustion engines is complicated and frequently changing in relation to different models. In early motorcycle design, three elements were causing major issues: ignition,carburation and lubrication. To achieve the rotational force necessary to move the motorcycle forward, the engine's piston(s) need to be propelled upward and downward inside the cylinder through a controlled explosion. To make the engine crank, an exploding substance (most commonly a mixture of air and petrol), and an ignition source are needed. In early engines both the mixing of fuel–air and igniting were tricky and often dangerous, and lubrication inefficient.*
> *Ignition designs went through three iterations: flame, hot tube and magneto ignition. In flame ignition, a portion of the cylinder was opened and literally exposed to an open flame, prompting the explosion. This method was dangerous and difficult to control. In hot tube ignition, rather than exposing the fuel–air mixture directly to a flame, a flame heated a tube mounted on the cylinder head, which then ignited the fuel–air mixture. Daimler's motorcycle presented this type of ignition, which, like the previous flame method, created problems with timing and shortened the life of the engine. Developed by Robert Bosh in 1887, Millet introduced the magneto system on his motorcycle, allowed a controlled spark that ignites*

the mixture. Dion-Bouton engine evolve this with a battery-and-coil ignition, which, like in the magneto system, used a spark to ignite the mixture, but it employs an external power source (the battery) rather than an internal flywheel magnet. Both these parallel technologies that lasted at least until the early 1960s.
Second major issue was the quality of the carburation , the mixing of air and fuel. Ideally, the ratio should be 14.7:1, a ratio known as the Stoichiometric air–fuel ratio, but of course, this was unknown to early engine designers. The original means to mix air and fuel was done drawing air across an open reservoir of fuel, but the motion of the engine disturbed the fuel, making the mixture unreliable. The spray carburetor, which atomized the fuel as it was drawn into the cylinder, was invented by Wilhelm Maybach, a colleague of Gottlieb Daimler. However, Maybach's design did not allow the air–fuel mixture to be easily varied, a necessity for engines that ran at more than one speed. Carl Benz solved this problem introducing the butterfly valve in 1893, and allowing for variations in the mixture.
Last major problem was represented by the lubrication process. Early motorcycles, including the de Dion-Bouton, featured a "total loss" lubrication system. Oil was fed into the engine through a valve actuated by a hand pump, exiting at the bottom throughout a breather, and not reused. Next evolutional steps were the "splash lubrication", which used engine motion to distribute oil and later,the "pressurized systems", with oil pumps and filters, offering greater efficiency and protection. In modern engines, reliable lubrication is obtained by wet or dry sump systems, which refers to whether the oil reservoir is part of the engine crankcase or sits outside it."

By the turn of the century, the concept of the motorcycle as a vehicle distinguished from both the bicycle and the automobile was in place, as was the concept of producing machines for sale. As production volumes grew, innovations multiplied and the first motorcycle companies were founded, many of which still exist today.
In the early 1900s, two iconic American motorcycle manufacturers emerged almost simultaneously. In 1900, Carl Oscar Hedstrom and George M. Hendee started a motorcycle manufacturing company known as the "Hendee Manufacturing". Coming up with a tiny single cylinder engine for their first motorcycle, the company imposed itself on the market with the name of "Indian".
Meanwhile in 1902 William Harley and Arthur Davidson originated the "Harley–Davidson Motor Company". Initially, starting with the elementary De Dion layouts, before earning renown for their robust, handcrafted machines and superior quality.

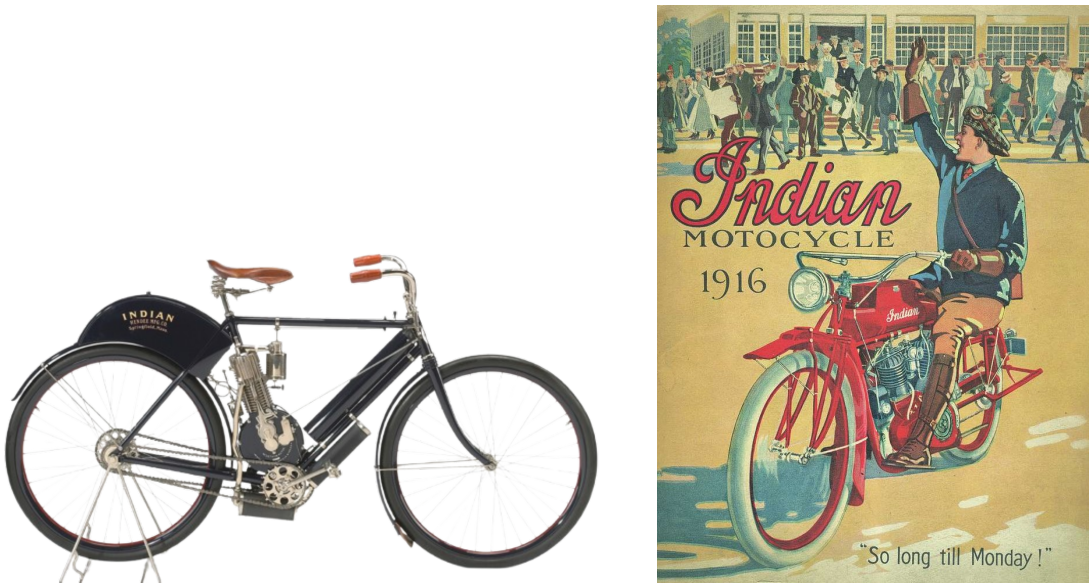


Figure 1.8: *Hendee Manufacturing first motorcycle with a poster from 1916*

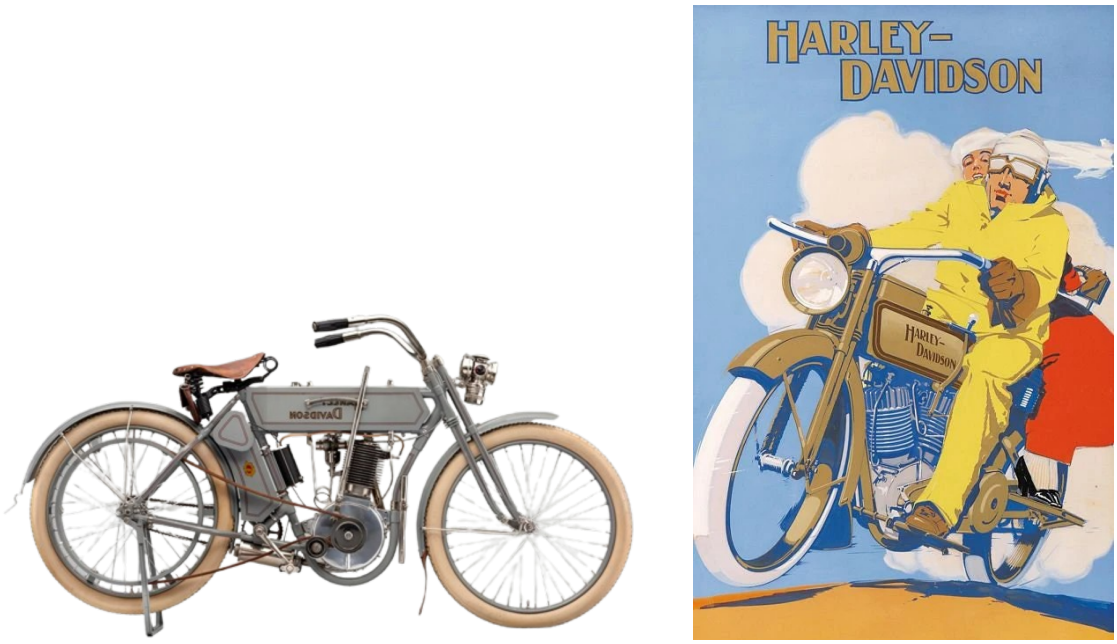


Figure 1.9: *Harley Davidson first motorcycle with a poster from the 20's*

Figure 1.10: *Ducati "Cucciolo" from 1950*

Figure 1.11: *Yamaha "YA-1" from 1955*

Figure 1.12: *Honda "CB750" from 1969*

World War I marked a pivotal moment for Harley-Davidson and the motorcycle industry in general. When it started in 1914, the motorcycles were already accepted, but considered as alternative reliable vehicles. During the war, their effective nature was utilized to accomplish different tasks, from exploration, to medical support, postal service and gunship; increasing the familiarity and the appreciation of people towards two wheelers.
After the conflict, the motorcycle began to consolidate itself as a practical and economical means of transport, finding a central role in commuting, leisure, and sport. The large manufacturers, such as Harley-Davidson, Indian, Norton, Triumph and Guzzi, leveraged military-grade durability to launch more powerful and reliable models, while in parallel, Europe witnessed the birth of a new category of two-wheeled vehicles: scooters. Lighter, more agile and easier to ride than traditional motorcycles, these vehicles found a large urban public thanks to their ease of handling.
Second World War restored the war-utility of motorcycles, but after the end of the conflict customers benefit of wartime advancements, especially in standardization. In the late 1940s and 1950s, new manufacturers emerged, Italian Ducati (in 1946)[6] and Japanese Honda, Yamaha, and Suzuki, further diversifying the range of two-wheel transport and shaping once more what can be considered from that point the modern motorcycle industry.
The detailed description of the incremental advancement in motorcycle technologies and layout from the 60's to the present, could lead to unnecessary degression. Understood the major steps that have brought to the foundation of modern two-wheeled vehicle, is better to shift the attention to the modern classification utilized in the market.

[6] Richetti C., *Il comparto motociclistico nel secondo dopoguerra*, Thesis, UniTo, 2019

1.2 MODERN TWO WHEELERS CLASSIFICATION

Excluding bicycles, which, although being an historical starting point, are not considered in the next analysis; there are multiple ways to classify two wheelers, each referring to different aspects or characteristics.

1.2.1 Cubic capacity classification

- 50cc
- 100cc
- 150cc...

Cubic capacity, also known as engine displacement, refers to the volume of space inside an engine's cylinders where the fuel-air mixture is combusted to produce power. It is one of the key indicators of an engine's size and, by extension, its potential power output. Cubic capacity is typically measured in cubic centimeters (cc) and is calculated using the following formula:

$$^{(8)}\ \text{Cubic Capacity(cc)} = \left(\frac{\pi}{4} \times D^2 \times S\right) \times N$$

where:

D is the bore (the diameter of the cylinder),
S is the stroke (the distance the piston travels within the cylinder),
N is the number of cylinders.

This definition represents a primary metric used to classify two-wheelers for regulatory, licensing, insurance, and segmentation purposes, while in market terms, cc also serves as a proxy for expected performance, fuel consumption, and pricing tier.

1.2.2 Fuel classification

- Petrol
- Diesel
- Electric

Two-wheelers can be categorized based on the type of fuel they use. Petrol-powered are the most common and utilize engines running on gasoline. Diesel, while less common, offer higher fuel efficiency and are often used for long-distance or commercial purposes. Electric two-wheelers are gaining popularity, using electric motors and batteries to provide an environmentally friendly and low-maintenance alternative.

(8) Heywood J. B., *Internal Combustion Engine Fundamentals*, McGraw-Hill Education, 2018

1.2.3 "Type of use" classification

As already introduced in the previous historical paragraph, the development of the motorcycles took multiple steps, defining different prototypes and machines, some of which generated two-wheeled vehicles still in use nowadays. These vehicles, despite being similar to motorcycles present distinct mechanical and usage characteristics. Motorcycles typically feature engines with a displacement greater than 125cc and are equipped with manual transmissions and larger wheels. These characteristics make them suitable for high-speed travel, long-distance riding, and varied terrain (in respect also to their segment). Scooters instead, are only designed for urban mobility, characterized by smaller engine capacities—usually between 50cc and 250cc, with automatic transmissions, and a step-through frame that often includes built-in storage compartments. One famous example is the "Vespa", legendary scooter released by Piaggio in the 1946, wich easily became a cultural icon across Europe and in particular in Italy. Mopeds share with scooters the limited engine sizes (50cc or less) and the simple usability, but with a big difference. Originally conceived as motorized bicycles, they still present pedals, used to start the engine or as alternative, utilize them as bicycles. All these characteristics define a clear distinction between motorcycle, scooter and mopeds, and understanding it is fundamental for analyzing user preferences and regulatory frameworks within the industry.

To better describe the market, it is also useful to discuss the segmentation commonly used to group motorcycles with determined characteristics, as it allows for a clearer understanding of product positioning, and competitive dynamics.

Figure 1.13: *Motorcycle by Triumph*

Figure 1.14: *Vespa scooter by Piaggio*

Figure 1.15: *Ciao moped by Piaggio*

1.2.4 Segment classification (only motorcycle)

In the motorcycle market, a segment refers to a group of motorcycles that share similar characteristics, intended use, and target consumers. Segmentation helps manufacturers and analysts to better categorize products and understand market dynamics more effectively. The most common motorcycle segments include Sport, Touring, Cruiser, Adventure, Naked, and Off-road.

1. **Sport** - Built for high speed and strong performance. They have aerodynamic shapes, light frames, and powerful engines that allow fast riding. The riding position is forward-leaning to help reduce wind resistance. These bikes are often used on race tracks or for fast rides on the road. Examples include the Yamaha YZF-R1 and the Ducati Panigale.

2. **Touring** - Made for long journeys. They focus on comfort, with large seats, windshields, and big fuel tanks for traveling long distances. Many touring bikes also have extra features like luggage storage, heated grips, and cruise control. Well-known examples are the BMW R 1250 RT and the Honda Gold Wing.

3. **Cruisers** - Designed for relaxed riding, especially at lower speeds. They have low seats, forward footrests, and classic styling. Their engines give strong power at low speeds, making them easy and smooth to ride. Brands like Harley-Davidson and Indian Motorcycle are famous for making cruisers.

4. **Adventure** (also called "ADV bikes") - Can be used on both paved roads and dirt roads. They are strong and durable, with a tall seat and long suspension travel to absorb bumps. Adventure bikes are great for long trips across different terrains, with large fuel tanks and protective equipment. Examples include the BMW GS series and KTM Adventure bikes.

5. **Naked** - Simple and practical. They do not have a lot of bodywork or fairings. Their upright seating position makes them comfortable for daily riding. Naked bikes usually offer a good mix of performance and comfort. Examples are the Yamaha MT-07 and the Triumph Street Twin.

6. **Enduro/Offroad** - Made for riding on dirt, mud, and rough terrain. They are lightweight and have knobby tires for better grip. Their suspension systems are long to handle jumps and bumps. Some off-road bikes are only for racing, while others can also be used on roads. Popular models include the Honda CRF series and KTM EXC bikes.

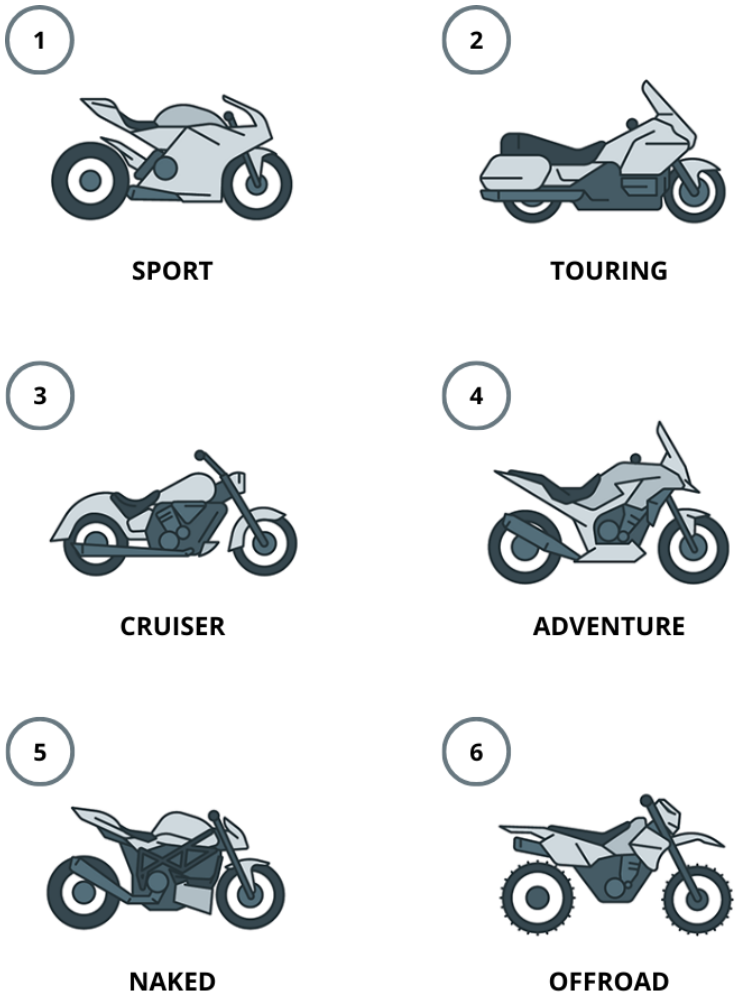
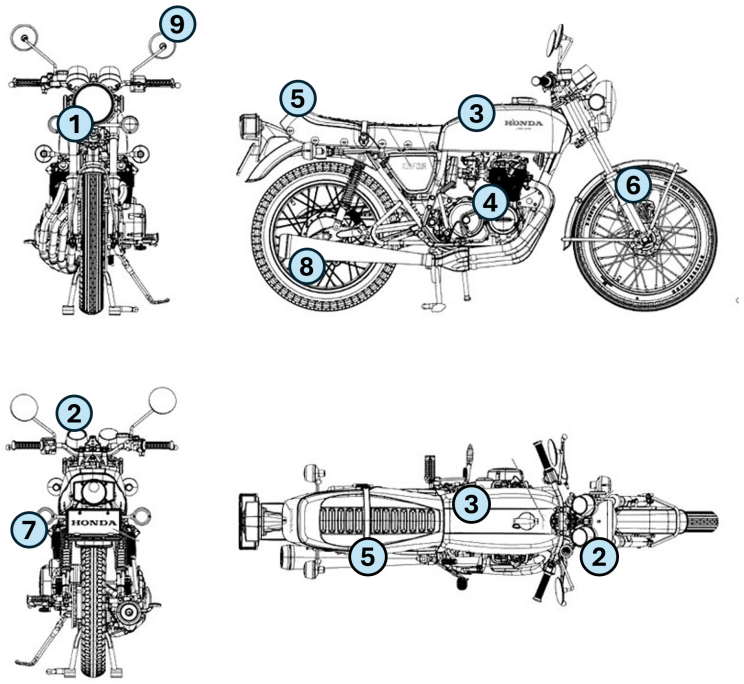


Figure 1.16: *Motorcycle's market segmentation*

1.3 MOTORCYCLE COMPONENTS and MANUFACTURING

A motorcycle is a complex machine made of many interconnected components, each playing a specific role in performance, safety, and comfort. This section describes the most important parts of a motorcycle and the manufacturing processes behind the two-wheel industry.



1. *Headlamp*
2. *Instrument panel*
3. *Fuel tank*
4. *Engine and drive line*
5. *Seat*
6. *Wheels, tires and suspension*
7. *Turn indicator*
8. *Exhaust system*
9. *Rearview mirrors*

Figure 1.17: *Layout of a motorcycle*

Figure 1.17 above represents a simplified view of a motorcycle's layout. It is useful to have a first overview on the general structure and position of the main parts. Although this layout looks simple, the actual complexity of these machines is much higher, relying on many different technologies.
For the purposes of this thesis, this paragraph will group motorcycle components into a few basic systems that are essential to its function. These systems include the frame, wheels and brakes, suspensions, engine, drive line, fuel system, ignition system, electrical system. In the following sections, each of them will be described, focusing on how they are built and how they work inside the motorcycle.

1.3.1 Frame

The frame represents the skeleton of the motorcycle, connecting all other parts and keeping them in position. Made up from steel (strong and cheap) or aluminum (lighter but more expensive), several configurations exist, each suited to different motorcycle types and purposes. Examples of them are the tubular, trellis and monocoque frames. The tubular is made from welded metal tubes, offering simplicity, strength, and cost-effectiveness. It's commonly used in various motorcycle types, from cruisers to off-road bikes. The trellis frame uses a grid of small, triangulated tubes for better rigidity and stress distribution, providing an excellent balance between flexibility and stiffness. The monocoque frame is a single, unified structure that integrates various components like the fuel tank, providing aerodynamic and structural efficiency. It's often found in premium motorcycles, especially racing and high-performance models. Frame also includes the mounting brackets to attach other components such as seats, suspensions, foot pegs etc.

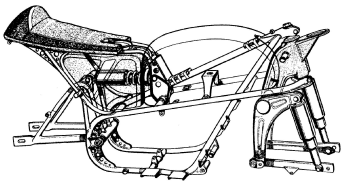


Figure 1.18: *Tubular frame with seat and fuel tank positioning*

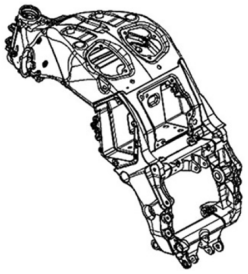


Figure 1.19: *Aluminum alloy monocoque frame*

1.3.2 Wheels and Brakes

The wheel and braking system plays a critical role in ensuring safety, performance, and rider comfort. While some off-road and retro-style motorcycles still mount spoke wheels, modern motorcycle wheels are typically made from cast aluminum alloys, valued for their strength and lightweight characteristics. Tires are composed of rubber compounds tailored to different applications, such as street, racing, or off-road use. The internal structure of a tire consists of multiple layers, including the carcass, which maintains the shape and load-bearing capability; the tread, which contacts the road; and reinforcing belts that resist deformation under stress.
Motorcycle braking systems use hydraulic disc brakes, which offer effective and reliable stopping power. These systems include brake discs, usually made of steel[(b)], which are clamped by calipers that press the brake pads against the disc surface to create friction. It's important to underline that modern motorcycles are equipped with ABS (Anti-lock Braking System), which prevents wheel lock-up during sudden braking or on slippery surfaces, enhancing safety and stability.

[(b)] *In high performance motorcycle discs are made of carbon fiber reinforced carbon matrix (C/C).*

1.3.3 Suspensions

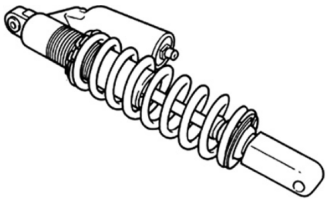


Figure 1.20: *Mono shock suspension*

Front and rear suspensions keeps the ride stable, absorbing bumps. On motorcycles, the most common front suspension system is the telescopic forks that use a combination of sliding tubes, internal springs, and hydraulic damping to provide a smooth ride. The rear suspension consists of swing arm that attach the frame to the rear wheels. Coil spring shock absorber combination are attached near the axle on the swing arm and fixed to a solid frame point. Nowadays, higher capacity motorcycles make use of either double-sided or single sided swing arm with mono shock suspension as the one shown in Figure 1.20.

1.3.4 Engine

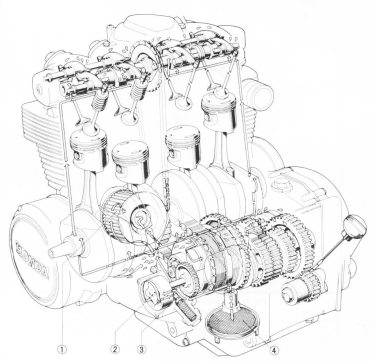


Figure 1.21: *Four cylinder inline engine*

The engine can be considered the heart of the motorcycle, as it converts fuel into motion through the process of internal combustion. This process involves the ignition of a mixture of air and fuel inside enclosed spaces called cylinders, where controlled explosions generate the force needed to move the pistons. The pistons, in turn, transfer this motion to the crankshaft, converting the up-and-down movement into rotational energy that powers the motorcycle[(c)]. The number of cylinders varies depending on the performance and capacity required, typically ranging from one to six, and they can be arranged in different configurations such as single-cylinder, inline, or V-twin. In an inline engine, the cylinders are arranged in a straight line, either vertically or horizontally, which helps keep the engine compact and smooth in operation. In contrast, a V-twin engine arranges its two cylinders in a V-shape, usually at an angle between 45 and 90 degrees, allowing for a narrower engine design and a distinctive power delivery and sound. The creation of the engine pass through the casting and machining of the engine block, typically from aluminum alloys, followed by the assembly of components like the crankshaft, pistons, and camshaft, which are made of steel to ensure durability.

[(c)] *Cooling and lubrication systems manage heat and reduce friction between moving parts.*

1.3.5 Transmission

In motorcycles, engine power is transferred to the rear wheel through a system known as transmission or drive line. Typically, this begins with a gear or chain reduction between the engine's crankshaft and the clutch, which lowers rotational speed while increasing torque. Most motorcycles use a wet multi-plate clutch, operated by a hand lever and cable. Power then flows through the gearbox to the final drive system—most commonly a chain drive with a small sprocket on the gearbox output shaft and a larger sprocket on the rear wheel.

1.3.6 Fuel System

The fuel system of a motorcycle is responsible for delivering to the engine the correct mixture of fuel and air, which is essential to burn gasoline effectively. Achieving the right ratio is critical for engine performance and emission control. At the start of this system there is the fuel tank, which stores the gasoline and is usually positioned above the engine to allow gravity or a fuel pump to assist in delivery. Traditionally, the air-fuel mixture was managed by a carburetor, a mechanical device that combines air and fuel using vacuum pressure generated by the engine. While carburetors are simple and cost-effective, they offer limited precision and are sensitive to altitude and temperature changes. In modern motorcycles, fuel injection systems have largely replaced carburetors, using electronic control units and sensors to adjust the fuel delivery with high accuracy based on factors such as engine speed and temperature.

1.3.7 Ignition

Once the air-fuel mixture reaches the engine's combustion chamber, it must be ignited to produce power. This is the role of the ignition system. Currently, there are three main types of ignition systems in use. The magneto ignition system, commonly found in small motorcycles and competition bikes, generates its own electricity without relying on a battery. The battery and coil ignition system, on the other hand, uses electrical power from the battery to energize a coil, which then produces the high voltage required to create a spark. The third type is the electronic ignition system, which uses electronic controls to precisely manage spark timing and improve overall efficiency. Today, most motorcycles and two-wheelers rely on either battery ignition, electronic ignition, or a combination of both systems.

1.3.8 Electrical System

Besides the electrical parts needed to operate the ignition system, the modern two-wheeler has many electrical components to increase a rider's safety, ease and comfort. These include sensors, head and tail lights, brake lights, turn lights, buzzers and horns, radios, engine malfunction, gear indicators, etc. All the indicators are generally mounted on the single console above the headlight.

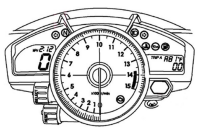


Figure 1.22: *Motorcycle's speedometer*

1.3.9 Manufacturing process

Motorcycle manufacturing is a detailed and multi-step process aimed at producing safe and reliable vehicles. It begins with design and engineering, where advanced 3D modeling and simulations help develop detailed motorcycle plans. After the design phase, manufacturers select materials based on important factors like strength, weight, cost, and environmental impact. These choices affect the durability and overall performance of the motorcycle.

Production then focuses on frame and engine manufacturing. Using advanced computer-aided design (CAD) software, the design of these components is created through techniques like welding, forging, and CNC machining. While this is happening, other essential components, including suspension and braking systems, wheels, exhausts, and electrical units, are manufactured either in-house or by specialized suppliers. If needed, once completed, components enter the painting and finishing stage. Part as the frame, body panels, and fuel tank is cleaned, primed, painted using electrostatic spraying, and finished with a clear coat for to protect against scratches and UV.

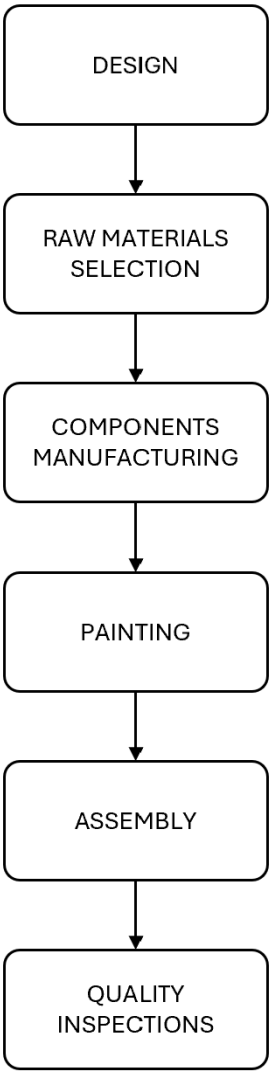


Figure 1.23: *Production stages*

After painting, the components move into the assembly phase. The layout of this stage varies by manufacturer. Large companies like Honda, Yamaha, and Harley-Davidson typically use an assembly line layout, where motorcycles move through sequential workstations, allowing for fast production, cost efficiency, and easy automation. In contrast, brands like Ducati, MV Agusta, and Triumph adopt a cellular layout, which offers more flexibility, better quality control, and the ability to accommodate customizations, although it tends to result in lower output and higher production costs. Some manufacturers, like BMW, combine both approaches with a hybrid system, which balances flexibility and efficiency.

Once assembly is completed, each motorcycle undergoes rigorous quality testing. Performance tests assess key factors such as acceleration, braking, handling, and fuel efficiency, ensuring the motorcycle meets safety standards and performs reliably under real-world conditions.

1.4 INNOVATION and FUTURE TRENDS

The motorcycle industry has always been a dynamic sector, influenced by technological advancements, consumer preferences, and broader economic factors. As environmental regulations tighten and consumer demand for performance and fuel efficiency increases, manufacturers and aftermarket suppliers are innovating rapidly, reshaping what the concept of motorcycle will be in the future.

1.4.1 Electrification and Sustainability

As environmental concerns and regulatory pressures continue to mount, manufacturers are increasingly investing in sustainable technologies. The most significant one is the electrification of two-wheelers, which following the example of automotive market, refers to the transition from internal combustion engine (ICE) motorcycles to those powered by electric motors and batteries (BEV). Benefits include the reduction of gas emissions, noise pollution, and reliance on non-renewable energy sources, making them especially well-suited for urban environments where air quality and noise are major concerns.
Despite this during past years the rate of electrification has been under 5 percent[12] across all major markets because of several obstacles. These include higher acquisition costs, lower performance in comparison with ICE variants, limited product options from incumbents, and the lack of charging ecosystems. However, most of these issues are being addressed, thank to significant battery improvements, leading to an increasing optimism for this technology, especially in Asia. The current energy density of lithium iron phosphate (LFP) and nickel manganese cobalt (NMC) batteries is already between 180 and 250 Wh/kg, respectively, which is capable of giving 80 to 120 kms per charge. Additionally to this battery costs, which have traditionally comprised about 35 percent of the two-wheeler's bill of materials (BOM) value, are falling significantly as manufacturers attain economies of scale and production efficiencies.

Figure 1.24: *Sustainability innovation trends*

Companies like Zero Motorcycles and Energica are leading the charge with impressive electric models that boast long ranges, high performance, quick charging capabilities, and also established brands such as Harley-Davidson and Honda are entering the electric space, reflecting a growing acceptance of this technology.
While full electrification could represents the long-term direction of the industry, hybrid motorcycles and biofuels are emerging as viable transitional solutions, especially in segments where electric technology still faces limitations. Hybrid powertrains, which combine an internal combustion engine with an electric motor, offer a balance between performance, efficiency, and reduced emissions. This configuration enables motorcycles to operate in electric mode at low speeds and rely on the combustion engine for higher power demands, extending range while lowering fuel consumption. In parallel, bio/renewable fuels derived from biological sources such as plants or agricultural waste present another path toward decarbonization. Bioethanol and biodiesel can often be used with minimal modifications to existing ICE motorcycles, providing a drop-in solution that reduces carbon emissions without requiring major infrastructure changes. In markets like Brazil and India, where biofuel availability is increasing, several manufacturers are exploring or already offering flex-fuel models capable of running on high bioethanol blends. These complementary technologies, hybridization and biofuels allow the industry to progress toward sustainability even in contexts where full electrification may not yet be feasible or economically viable. Beside this, sustainability does not translate only into fuel replacement, it also include a broader shift toward a circular economy. This involves practices like refurbishing, recycling, and reselling motorcycles and components to minimize waste and extend products lifecycle. To support this transition, manufacturers are increasingly adopting eco-friendly materials and designing bikes for durability and ease of disassembly at the end of life. Additionally, modular motorcycle design is gaining attention, allowing key components such as batteries, motors, and body panels to be replaced or upgraded individually. This not only reduces material waste and simplifies maintenance but also enhances customization and extends the overall usability of the vehicle. Together, these strategies contribute to lowering the motorcycle's total environmental footprint while aligning with evolving consumer expectations for sustainability, efficiency, and long-term value.

1.4.2 Safety and Smart Assistance

Because of the risk associated to riding a motorcycle, safety remains a top priority in the industry, driven by both regulatory requirements and consumer demand for more secure experiences. Recent years have seen significant advancements in safety technologies, especially on Advanced Rider Assistance Systems (ARAS), which are an emerging technology in the motorcycle industry, aimed at enhancing rider safety, comfort, and overall riding experience.

[12] Gupta R. et al., *The real global EV buzz comes on two wheels*, McKinsey and Company, 2023

Inspired by similar systems in the automotive sector, ARAS includes features such as adaptive cruise control, blind-spot detection, collision warning systems, lane-keeping assistance, and automatic braking. These technologies rely on sensors, cameras, and radar systems to monitor the surrounding environment and provide real-time feedback or intervention to prevent accidents. While still in the early stages of adoption compared to cars, ARAS are gaining momentum, particularly in high-end touring and adventure motorcycles.
In addition to this, motorcycle manufacturers are investing in rider protection gear with enhanced safety features, like Modern helmets with integrated communication systems, smart airbag vests, and high-visibility clothing.

1.4.3 Connectivity and Artificial Intelligence

Connected technology and artificial intelligence (AI) are and will transform motorcycles into smart machines. Thank to the integration of Internet of Things (IoT) riders will be able to update their motorcycle's tuning software without visiting a service center, and technicians will diagnose issues remotely, saving time and improving convenience. Furthermore, wireless connectivity will enable continuous performance monitoring and data collection, providing valuable insights into the motorcycle's operation and facilitating proactive maintenance and optimization.
Future systems are also expected to incorporate machine learning algorithms that will enable them to continuously learn and adapt motorcycle's performance to the rider's behavior, riding conditions, and needs. As a result, motorcycles will become more intuitive and personalized, offering a riding experience tailored to the rider's individual preferences and requirements.

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CH. 2


DUCATI


Norton
MOTORCYCLES


KTM


Hero


MOTO GUZZI


TRIUMPH


ZERO
MOTORCYCLES


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AGUSTA

THE MOTORCYCLE MARKET

Chapter 2

THE MOTORCYCLE MARKET

In recent years the global motorcycle market has undergone significant transformations, influenced by a complex set of economic, technological, social, and environmental factors. This chapter aims to provide a comprehensive overview of the current state of motorcycle industry by examining its composition of supply and demand, both from an international and national point of view. The goal is to understand not only how the market functions today, but also its evolution in response to broader combination of trends and challenges.
The first part of the chapter will explore the structure of the global motorcycle market, outlining the major players involved, including key manufacturers and leading nations in terms of production and sales. The analysis of supply will take into account the segmentation of the market and the degree of concentration among producers, while on the demand side, factors such as urbanization, consumer preferences and policy incentives will be discussed to better understand what drives consumers' choices across different geographical areas. Special attention will be given to the Italian market, which plays an important role in the global motorcycle landscape due to its rich industrial heritage, world-renowned brands (such as Ducati and Piaggio), and significant domestic demand. Using Statista, Eurostat and ANCMA data this section will analyze current sales and consumer behavior, including thoughts about Covid-19 pandemic, new electrification trend and environmental regulations.
To sum up, this chapter serves as a key foundation for the thesis, outlining the economic and structural context in which the motorcycle industry currently operates. It lays the base for a deeper understanding of the second-hand market and, consequently, for a more comprehensive interpretation of the econometric model presented in the final chapter.

2.1 GLOBAL OVERVIEW

The motorcycle market refers to the global industry involved in the design, manufacturing, distribution, and sale of two-wheeled motor vehicles, including motorcycles, scooters and mopeds. It encompasses all the categories already introduced in the

engine size or fuel type (gasoline, diesel or electric). To deliver a complete and exhaustive study of it and its dynamics, multiple data have been collected, belonging to multiple sources, each time indicated in the text or in graphics' captions. Personal re-elaboration has been conducted to present a more effective sight of the topic.

2.1.1 Global sales and revenue

Graphics 2.1 contain information regarding international sales related to the motorcycle market. The data behind these representations were collected from "Statista Market Insight 2024 (Motorcycle Market)" which covers over 150 countries and territories. Are excluded from the analysis only mopeds under 50cc. This source was selected due to its accessibility, clarity, and the free availability of aggregated data categorized by continent. While data are considered reliable for an aggregated high-level comparative analysis it is acknowledged that some figures may vary slightly due to differences in definitions (e.g., sales vs. registrations) and regional reporting practices. Focusing on temporal covering, data provide not only historical information starting from 2014 but also future forecasting. These predictions are based on a combination of statistical models and industry analysis. For mature markets, such as motorcycles one, traditional forecasting methods like exponential smoothing,ARIMA, and Holt-Winters seasonal smoothing are applied to large historical datasets[(a)] considering also macroeconomic indicators, such as internet penetration, consumer spending, infrastructure, and urbanization rates, as well as trend scouting to identify future growth drivers.
Explained the scope and data characteristics its time to deep down into numbers. From an aggregate point of view, the global motorcycle industry sales have shown an increasing trend over the past decade, which will continue in the upcoming years (+1,4% CAGR 2014-2029)[(b)]. Despite a significant dip in 2020 likely due to the COVID-19 pandemic, which made sales drop to 47.68 million units, the market had grown from 50.84 million units in 2014 to a peak of 53.40 million in 2019. After the 2020 decline, the industry quickly recovered, reaching 56.84 million units by 2024. Future projections indicate steady growth, with sales expected to reach 58.43 million in 2025 and continue rising to 62.28 million units by 2029.
Dissecting numbers into two category, as in Graph 2.1B, it is clear how motorcycle consistently makes up a larger share of total two-wheeler sales compared to scooters and mopeds. In 2014, motorcycles accounted for approximately 59% of global sales (29.91 million out of 50.84 million units), while scooters and mopeds represented around 41% (20.94 million units). This proportion changed during the years, whin an increase in motorcycles' share. While scooter and mopeds sales remained stable, motorcycles shown a +25% highlighting a sustained preference, possibly due to higher performance and broader utility.

[(a)] *To know more about the forecasting model go www.statista.com*
[(b)] *CAGR: Compound Annual Growth Rate / average growth rate per year*

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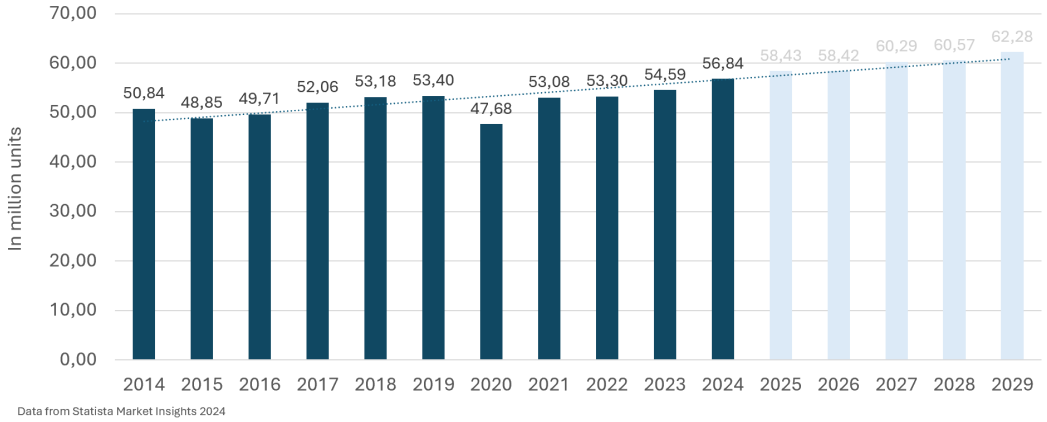

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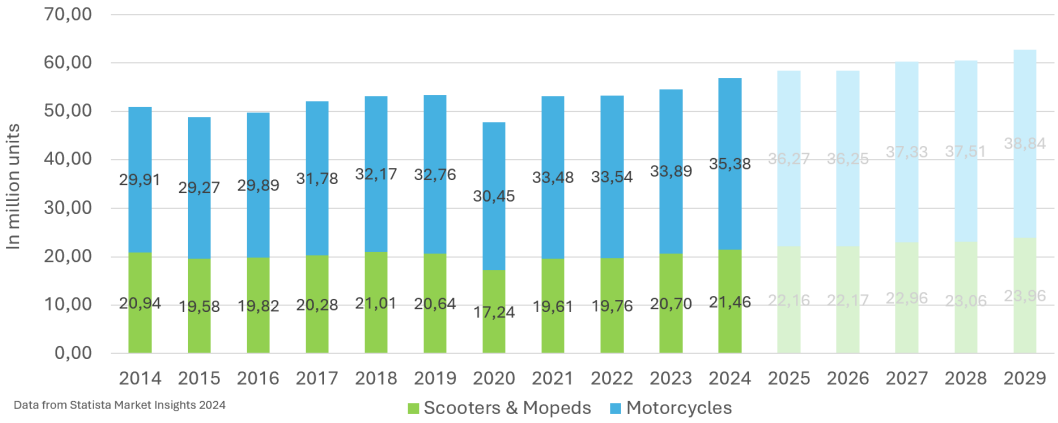

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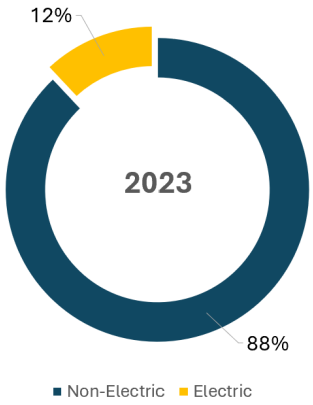

Graphics 2.1: *International sales by year, type of vehicle and fuel*

It is important to underline that outer from this initial overview both sales and preferences could vary shifting the scope to national markets, including the one on electric trend, which has signed a 12% of overall total sales in 2023 (Graph 2.1C).
Moving on into the analysis of the economic trajectory of the global motorcycle industry, the data collected from Statista could be used to describe historical and future revenues of this sector. Revenues represented in Graphics 2.2A-B consist of total yearly market earnings, which have been calculated as the product of average prices per unit (Graph 2.2C) and the number of units sold. As shown by the figures, annual revenues rose from $104.5 billion in 2014 to $147.9 billion in 2024, with a singular drop in 2020 ($115.63 billion), rapidly followed by recovery. This suggests an apparent stable growth which can be described by a +3,5% CAGR.
However, these preliminary results should be assisted by major considerations. Statista's data, and in particular prices, are provided in nominal terms reflecting the currency value at the time of measurement and including for this reason the effect of inflation. To obtain a more accurate view of real economic growth, all nominal prices were adjusted using the U.S. Consumer Price Index (CPI), setting 2024 as base year. This deflation process allowed to express prices and revenues in constant 2024 dollars, removing the inflationary effects and providing a more realistic picture of the market's evolution After applying this adjustment, some key information emerged. While nominal revenue suggested a market growth of +3,5% from 2014 to 2029, real data indicates a more modest increase moving from $138.8 billion to just $147.9 billion in 2024. This shows that a substantial part of the revenue growth in nominal terms was actually due to inflation rather than increased market size or real consumer spending.
Disaggregating the data by vehicle type offers deeper insights into the market's dynamics. Scooters and mopeds experienced a nominal increase in average unit price, rising from $1.24 in 2014 to $1.67 in 2024. However, once adjusted for inflation, their real prices remained remarkably stable, fluctuating only slightly between $1.64 and $1.67 over the entire period. This could suggests that manufacturers may have prioritized affordability and accessibility in this segment, possibly due to its role as an entry-level or utilitarian transport option in many emerging economies. Moreover, the consistency in unit sales implies that demand has been relatively inelastic to price changes, possibly reflecting a customer base driven by necessity rather than discretionary spending. As a result, revenues in this segment showed little real growth over time.
The motorcycle segment, on the other hand, tells a more complex story. Nominal average prices increased from $3.64 in 2014 to $4.15 in 2024, yet inflation-adjusted prices actually declined significantly, from $4.19 to $3.17, a real drop of almost 25%. This suggests that while consumers paid more in nominal terms, the actual economic value of these transactions decreased over time. Several factors could explain this trend: increased competition, especially from emerging Asian manufacturers, may have driven prices down; technological advancements and improved production efficiency could have reduced costs; and shifting consumer preferences may have favored lower-priced or mid-range models over premium ones.

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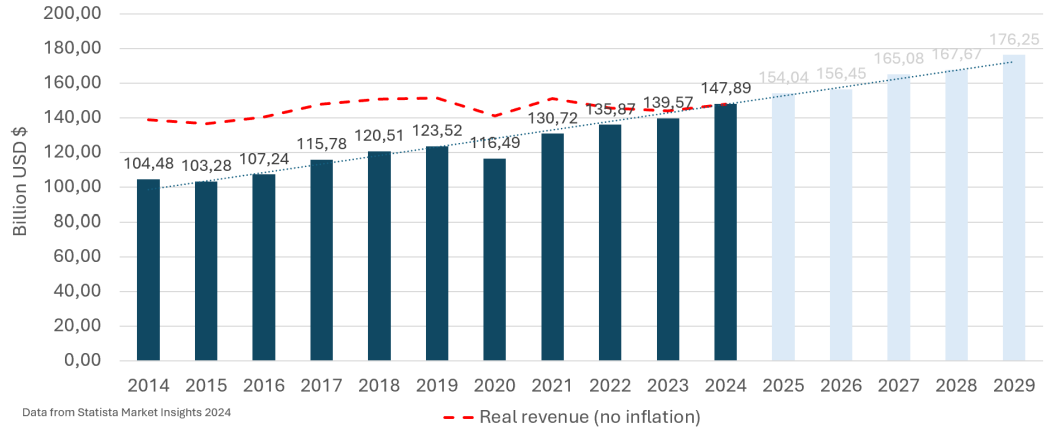

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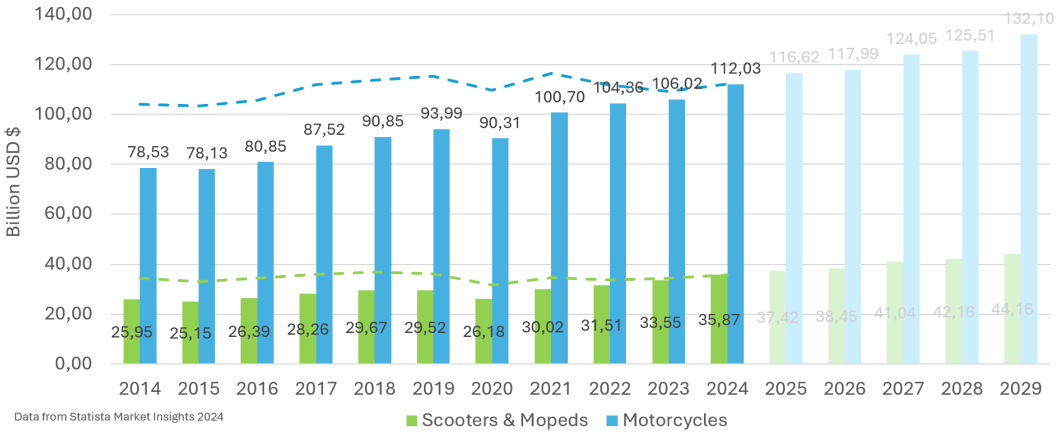

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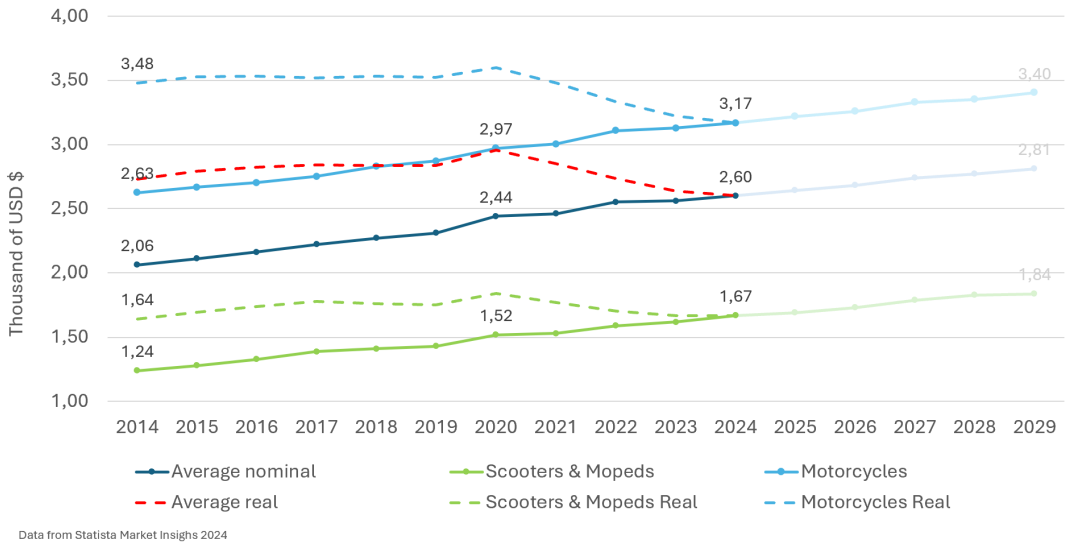

Graphics 2.2: *International revenue and average prices*

Interestingly, this real price decline coincided with a rise in unit sales, indicating growing market penetration. However, this volume driven growth did not translate into a proportional increase in real revenues, underlining the challenge of sustaining profitability in a price-sensitive and competitive market.

2.1.2 Producers

The global motorcycle industry is shaped by a wide network of producers located in different parts of the world, with Asia being the most dominant region in terms of both production and revenue share. Japan is the clear leader, home to some of the most important motorcycle companies in the world: Honda, Yamaha, Suzuki, and Kawasaki, known for their advanced engineering and reliability. Among them, Honda stands out as the top player worldwide, generating according to Statista 29.3% of global motorcycle revenues. Yamaha follows with a significant share of 11.1%, confirming Japan's central role in the global motorcycle economy.
India is another major production center. Manufacturers such as Hero MotoCorp, TVS Motor Company, and Royal Enfield focus mostly on low-cost and fuel-efficient motorcycles. TVS accounts for 3.9% of global motorcycle revenues, while Hero follows closely at 3.8%. Royal Enfield, known for its classic and mid-size bikes, holds 2.9%, showing that India is not only a volume producer but also capable of building a strong brand identity.
The United States is home to iconic brands like Harley-Davidson, Indian and newer electric-focused companies such as Zero Motorcycles. Harley-Davidson, despite being one of the most recognized motorcycle brands in the world, currently represents a smaller portion of the global market, with 2.5% of total revenues. Its premium positioning and focus on heavyweight touring bikes target a specific segment of customers, especially in North America and Europe.
Europe also hosts several important motorcycle manufacturers. In Germany and Austria, we find companies like BMW Motorrad and KTM. BMW is known for high-performance and touring motorcycles, while KTM specializes in sport and off-road models. Italy, with its long tradition in design and motorsport, is home to Ducati and Moto Guzzi. These brands are known for their stylish and powerful motorcycles and maintain strong reputations, especially in Europe. The United Kingdom adds to the European scene with historical brands like Triumph and Norton, which continue to produce motorcycles with classic design and modern performance.
Last major producer country is China, which is becoming an increasingly important player in the motorcycle sector, mainly through companies like CF Moto and Zontes offering affordable models with competitive pricing and growing quality.
It is important to note that 37.8% of global motorcycle revenues are generated by a large number of smaller companies grouped under the category "Other". This high percentage shows that, beyond the major global players, many small or regional producers contribute to innovation and variety, fragmenting the market and leaving space for growth and competition.

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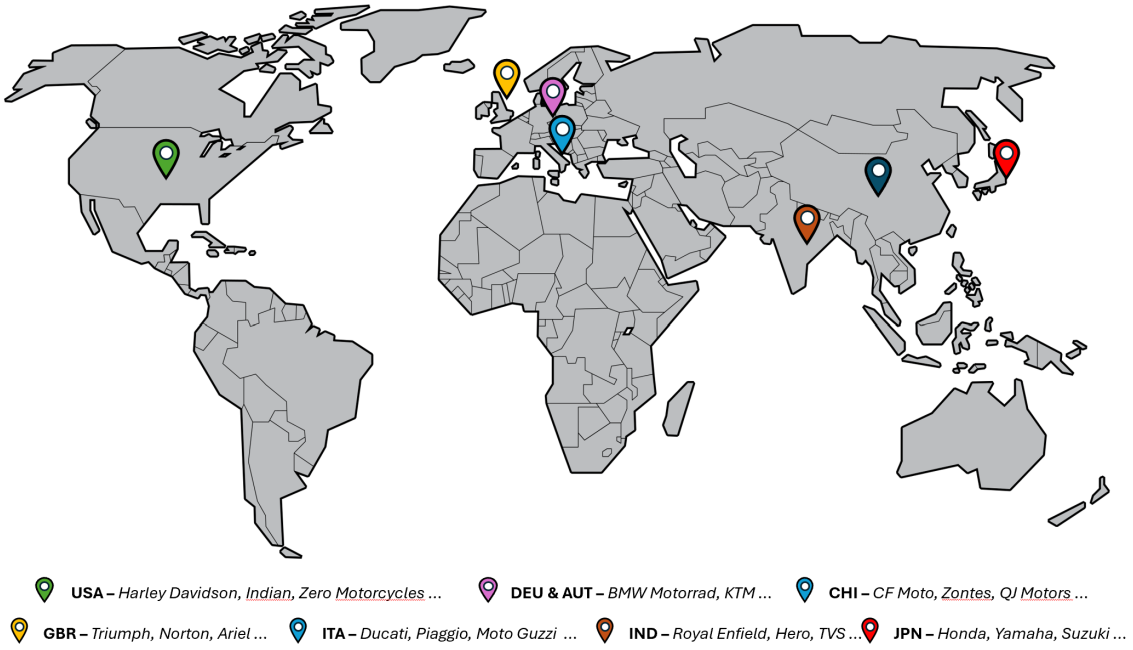

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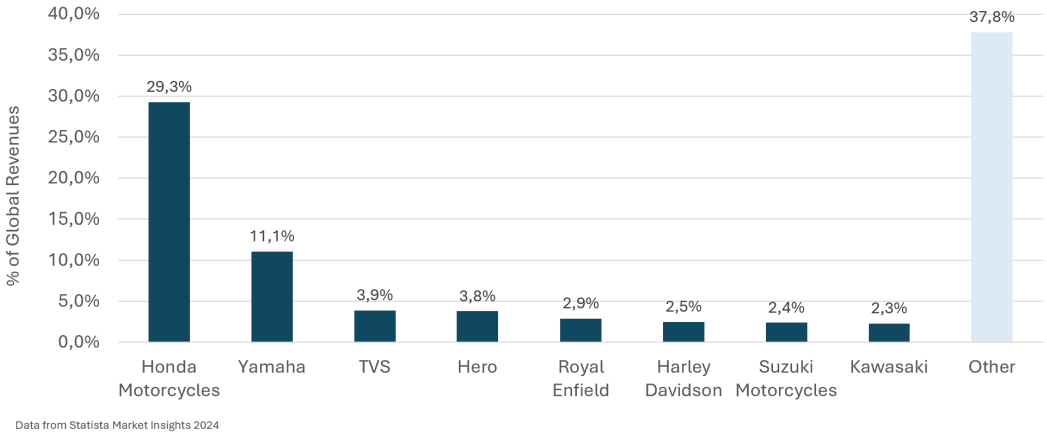
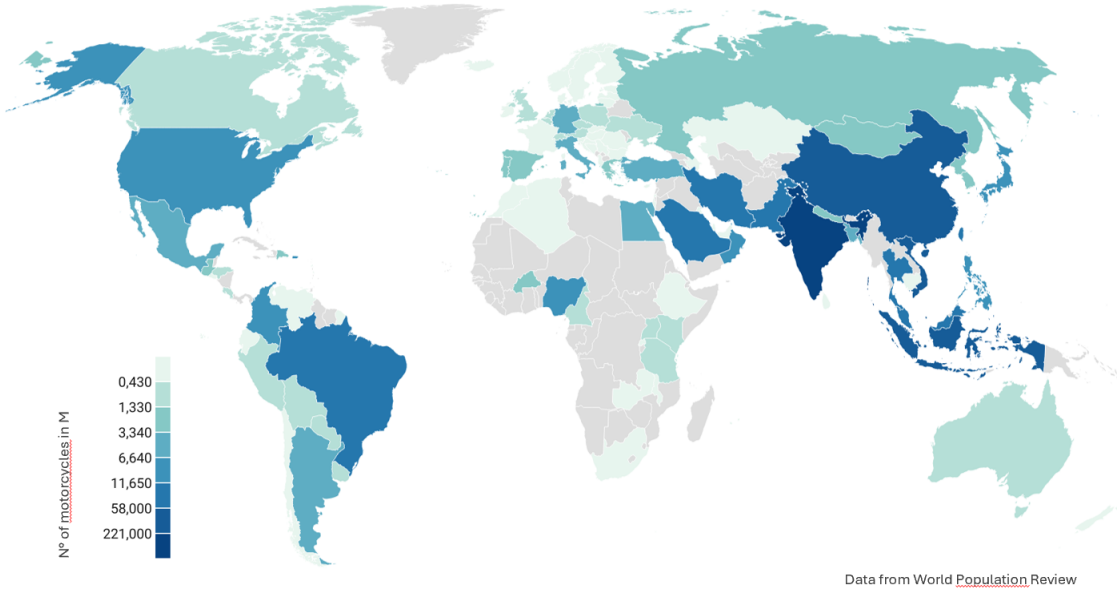


Graphics 2.3: *Biggest global manufacturers and revenue share*

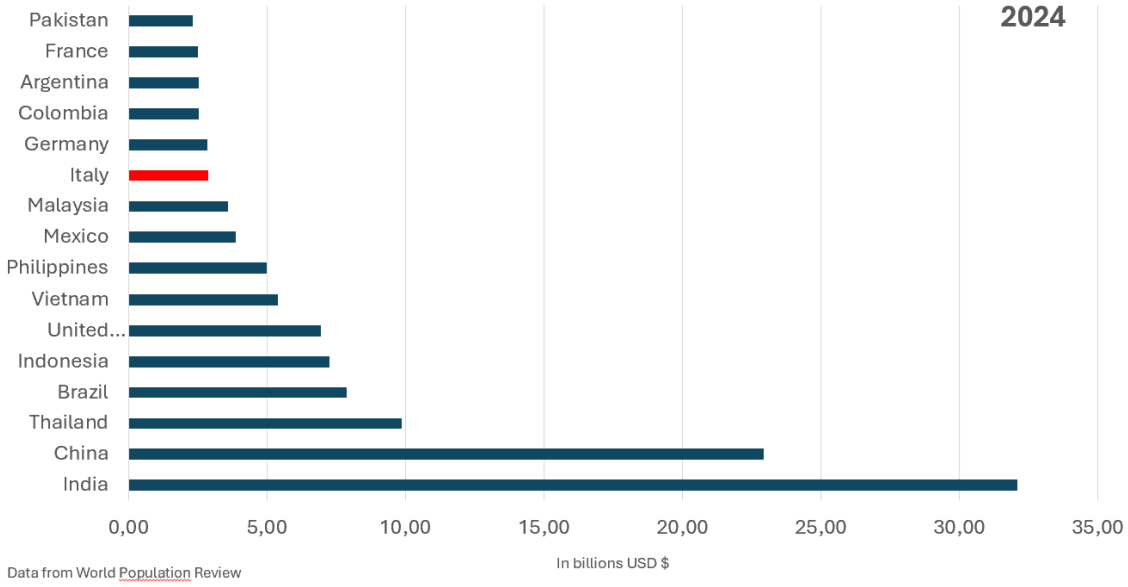
2.2 NATIONAL MARKETS

While global statistics help us in the understanding of the overall importance and evolution of the motorcycle industry, a closer look to national markets reveals significant differences between countries in terms of vehicle volume, consumer behavior, and economic value. These differences are shaped by a variety of factors including population density, urban infrastructure, income levels, local regulations, and cultural attitudes toward mobility, all playing a key role in shaping how the motorcycle market functions, and the trajectory it will follow during the next years.
Analyzing the data on motorcycle ownership by World Population Review (Graph 2.4) we see a first striking contrasts between countries. While globally we can estimate a total 600 million motorcycles, the concentration of them it's very clear, addressing Asia as the region with the highest number of riders. Between all Asian countries India stands out as the largest motorcycle market by volume, with over 221 million motorcycles in circulation. Indonesia shows 112 million, followed by China at 85 million. These numbers reflect not only population size but also a widespread reliance on two-wheelers for commuting in congested urban centers or areas with less developed public transportation. Other Southeast Asian countries like Vietnam (58 million), Thailand (21.5 million), and Malaysia (14.8 million) also show very high rates of motorcycle use, confirming the region's dependence on this type of mobility.
In contrast to this, countries in Europe and North America have significantly fewer motorcycles in absolute terms. For instance, the United States has around 8.6 million motorcycles, and Italy—despite its strong motorcycle culture and heritage, has about 5.2 million. Germany, another major European economy, records just under



Graphic 2.4: *Number of motorcycles for each country*

3.8 million motorcycles. These lower figures suggest a different positioning of motorcycles in these societies: rather than being a necessity, motorcycles often serve as a secondary mode of transport, used for leisure or lifestyle purposes. This will be better supported later, analyzing segments, prices and major producers for each territories, highlighting how the means of having a motorcycle changes across regions. Shifting the focus from the number of motorcycles to revenue, the picture becomes more nuanced. India again leads with arounf $30 billion USD in revenue in 2024, confirming its dominance not only in volume but also in market value. China follows with $22 billion, while Thailand reaches $9.8 billion, showing that mass market sales can produce significant revenues.
Interestingly, countries with lower motorcycle numbers still generate substantial revenue. The United States, with far fewer motorcycles than India or China, ranks sixth globally in revenue with around $7 billion, reflecting a strong preference for more expensive models. Similarly, Germany and Italy, with smaller volumes, generate respectively $2.8 billion and $2.84 billion. This pattern suggests that in wealthier economies, the average price per unit is higher, often due to consumer interest in premium models, higher safety standards, or stronger brand preferences.
These observations lead us to conclude that the motorcycle market cannot be understood solely through a global lens. While some markets are driven by affordability and practicality, others are shaped by lifestyle, income levels, and technological preferences. These differences highlight the importance of context-specific strategies for manufacturers and policymakers. In the next sections, we will explore regional markets more in details to identify the main drivers of growth and future development.



Graphic 2.5: *Motorcycle sales revenues by Country*

2.2.1 Asia

In the following paragraphs the global market will be divided into five main regions: Asia, Americas, Africa, Australia & Oceania and Europe. Each regions will be analyzed separately to highlight specific characteristics and carry out a comparison to identify key differences and similarities.
The first territory that will be analyzed is Asia, which, as shown previously, represents the largest motorcycle market in the world. As illustrated in Graph 2.6A the region is led by India and China, which together account for over 30 million units sold in 2023. India alone reached 15.5 million units, generating approximately 27.5 billion USD in revenue, the highest among the listed countries. China follows closely with 14.7 million and over 20 billion USD in revenue. Other key players include Indonesia (5.7 million units), Vietnam (2.7 million), and Thailand (1.75 million), all contributing significantly to the regional market.
Shifting attention to aggregates numbers in Graph 2.6B, total motorcycle revenue in the continent reached 93.3 billion USD in 2023, with around 45.9 million units sold. The market shows stable growth, with a Compound Annual Growth Rate (CAGR) of +3.4% in revenue and +1.0% in unit sales between 2014 and 2029 (including inflationary effect). In addition to this, the shift toward electric mobility is significant, with 13.7% of motorcycles sold in 2023 being electric, indicating that electrification in the Asian market is expanding.
To better understand consumers preferences Graph 2.6B breaks down sales into types of motorcycles sold. On-road motorcycles represent the largest share of the market (60.0%), followed by scooters and mopeds (39,6%), particularly popular in urban areas, while Off-road motorcycles account for only a minimal portion of unit sales (0,4%). This could be explained also

A

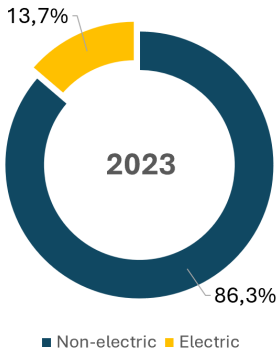
#	Country	Unit Sales in thousand	Revenue in million US$
1	India	15455.7	27552.7
2	China	14679.0	20014.9
3	Indonesia	5704.7	10934.9
4	Vietnam	2685.1	7176.5
5	Thailand	1757.0	7572.8
6	Philippines	1499.3	5591
7	Pakistan	1310.7	1793.2
8	Taiwan	786.9	2755.5
9	Bangladesh	631.9	1844.7
10	Malaysia	574.2	2716.2

Data from Statista Market Insights

B

(1) Compound Annual Growth Rate - Data from Statista Market Insights

C



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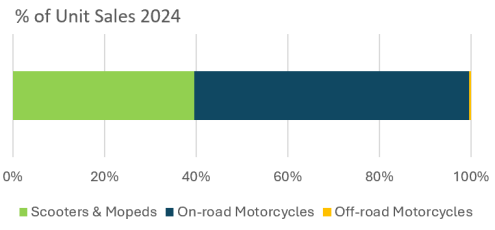

Graphics 2.6: *Asian sales and revenue*

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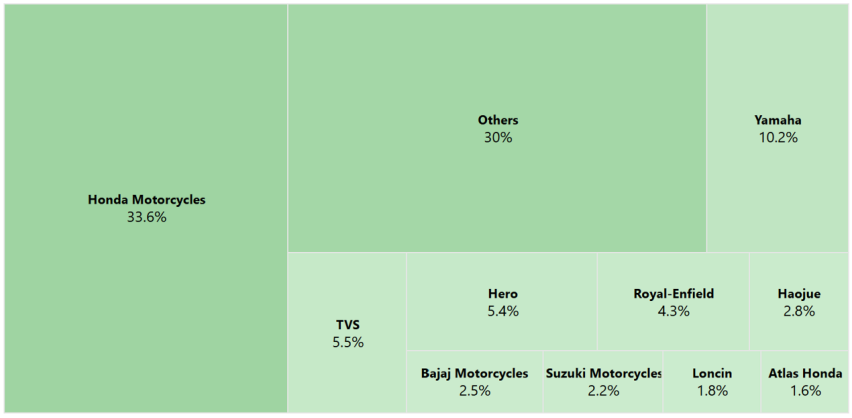

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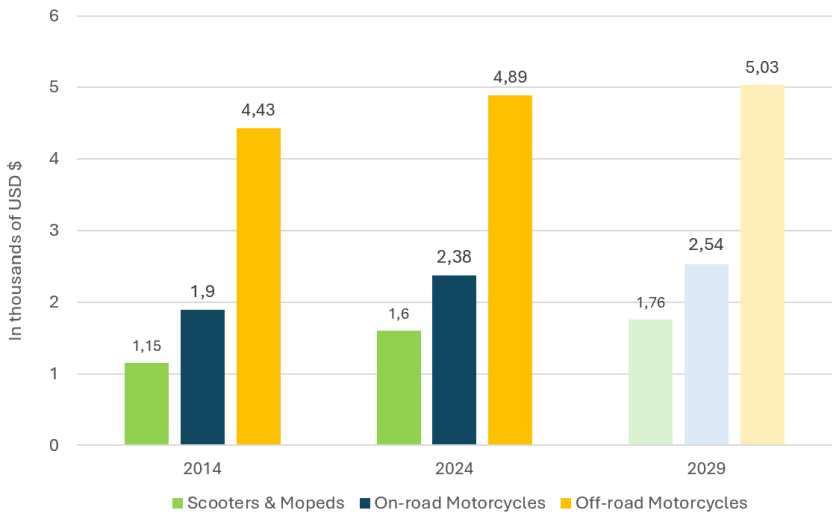

Graphics 2.7: *Producers' revenues and average prices*

by the differences in prices among vehicle types, as shown in Graphic 2.7 F. In 2024, the average price of scooters was around 1,600$, on-road motorcycles averaged 2,380$, while off-road motorcycles were considerably more expensive (4,890$). The data highlights how the cost represent a key selling factor for the region, with Asian riders preferring vehicles for commuting and urban mobility.
In terms of market leaders, Honda Motorcycles leads the market with a 33.6% share, followed by Yamaha at 10.2%, and several other manufacturers such as TVS (5.5%), Hero (5.4%), and Royal Enfield (4.3%). In summary, Asia's motorcycle market is characterized by high volume, strong revenue generation, and strong movement toward electrification. The dominance of on-road vehicles and scooters reflects the importance of motorcycles in daily transportation, probably as result of high population density and traffic congestion. Japanese and Indian companies dominate the revenues of the region, with still significant segmentation of minor local producers.

2.2.2 Americas

Although there are significant economical and structural differences between North and South America, for simplicity these regions have been grouped together under in this section. As shown in Graph 2.8A, Brazil represents the largest market both in terms of unit sales and total revenue, with approximately 1.44 million motorcycles sold in 2023 and 7.1 billion USD in revenues. Mexico with about 1.25 million units positioned as second, followed by Colombia and the United States, which, while showing lower unit sales with 547,400 motorcycles sold, generated a substantial revenue of 6.5 billion USD, reflecting the higher average price of motorcycles in its market.
Overall, the region generated approximately 24.2 billion USD in 2023, with a total of 4.8 million sales (Graph 2.8B). The predicted CAGR between 2014 and 2029 is 3.4% and 3.1% for unit sold and revenue. Despite the ongoing growth, the transition to electric vehicles remains very limited (Graph 2.8C) with only 3% of motorcycles sold in 2023 being electric, highlighting a market still largely dependent on IC engines.
In terms of vehicle categories, the market is dominated by on-road motorcycles, which account for roughly 60 to 70 percent of unit sales, as shown in Grap 2.8D. Scooters and mopeds are also widely used, particularly in urban areas of Latin America, where affordability and ease of use are major advantages. Off-road motorcycles, while a smaller segment overall, maintain a notable presence in certain markets like the United States and Mexico, often used for recreational or rural purposes.
The brand landscape across the Americas is led by Honda, holding a 25.1% revenue share, followed by Yamaha at 15.1% and Harley-Davidson at 10.2%. Other key players include Italika (6.6%), mainly

A

#	Country	Unit Sales in thousand	Revenue in million US$
1	Brazil	1441.9	7099.3
2	Mexico	1254.5	3110.3
3	Colombia	726.7	2805.8
4	United States	547.4	6531.5
5	Argentina	425.0	1309.1
6	Peru	229.5	553.8
7	Canada	68.9	870.2
8	Chile	37.7	192.4
9	Ecuador	22.4	126.8
10	Guatemala	20.3	84.3

Data from Statista Market Insights

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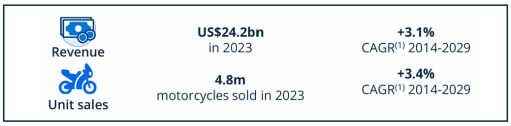

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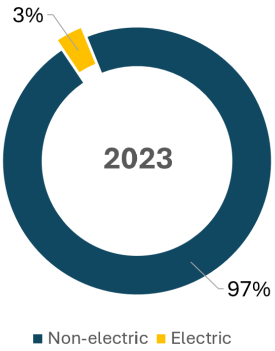

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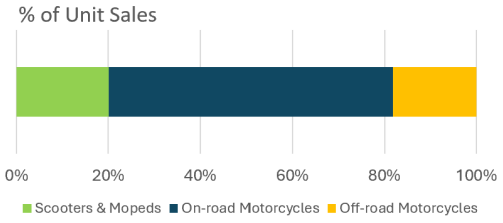

Graphics 2.8: *Americans sales and revenue*

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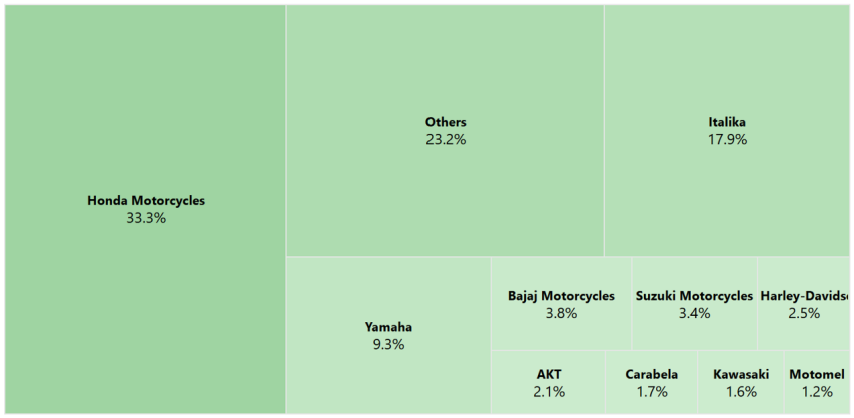

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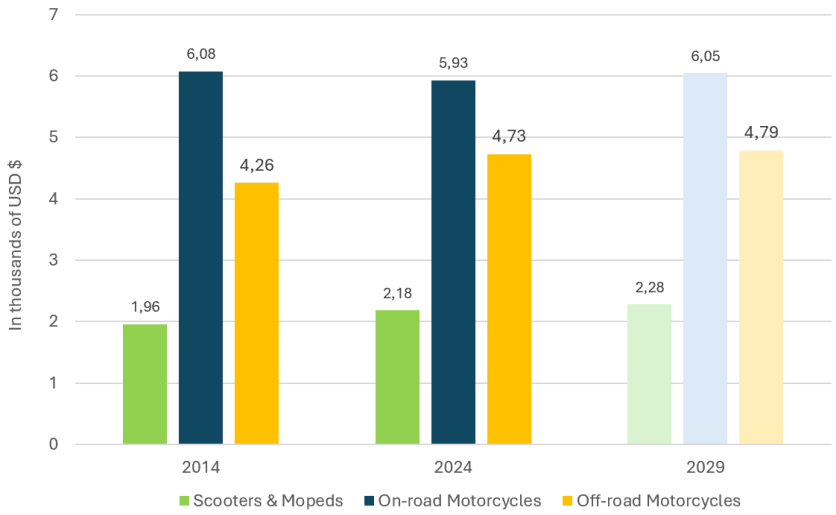

Graphics 2.9: *Producers' revenues and average prices*

active in Mexico, as well as Kawasaki and Suzuki, each with 3.7%. Shifting the focus to US the data differs considerably, with Honda still leading at a lower 20%, closely followed by Harley-Davidson at 19.9%, reflecting the strong local brand loyalty and interest in premium and performance segments. Price data further illustrates this distinction between sub-regions. According to Graph 2.8F, the average motorcycle price in the Americas in 2024 was around 2,180$ for scooters and mopeds, 5,930$ for on-road motorcycles, and 4,730$ for off-road motorcycles. In contrast, the United States shows significantly higher average prices, with scooters, on-road and off-road motorcycles respectively positioned at 6,050$, 13,930$ and 6,410$.
Overall, while the region shares common trends like Honda's dominance and the persistence of combustion engine, strong internal differences are present: the U.S. market focuses on high-value, premium motorcycles , while Latin American countries drive the region's high volume through affordable, utility-oriented models.

2.2.3 Africa

The motorcycle market in Africa is an expanding sector, essential to addressing the continent's transportation challenges. The market is highly uneven across nations, as shown by Graph 2.10A. Nigeria dominates the region recording 644.3 thousand motorcycle sales and 1.28 billion in revenue, followed by Ethiopia and Egypt, with 342.2 thousand and 256.8 thousand units sold respectively. Other countries such as Tanzania, Kenya, Uganda, and Sudan also present significant, though comparatively smaller, markets. These variations point out deep differences in purchasing power, infrastructure, and mobility needs across the continent, in which overall, 2.2 million motorcycles were sold during 2023, with total revenues reaching 4.6 billions (Graph 2.10B).

Electric motorcycles remain a really small part of sales. In 2023 only 3.8% of motorcycles sold in 2023 were electric, highlighting the dominance of combustion engines and major challenges such as inadequate charging infrastructure, higher acquisition costs, and limited public policy support for electric mobility.

Regarding vehicle type preferences, Graph 2.10D shows that on-road motorcycles account for the largest share of unit sales (51.6%), followed by scooters and mopeds (35.3%), with off-road motorcycles comprising a smaller but concrete segment (13,1%). This distribution reflects the utilitarian function of motorcycles in Africa, where they are primarily used for commuting, delivery services, and even public transport. Scooters and mopeds are particularly relevant in urban settings, given their affordability and fuel efficiency, while off-road bikes are generally less accessible due to their higher costs and limited application in daily transport.

The market is led by Honda with 17.4% of revenue, followed by KTM with 11.2%,

A

#	Country	Unit Sales in thousand	Revenue in million US$
1	Nigeria	644.3	1282.9
2	Ethiopia	342.2	1107.5
3	Egypt	256.8	791.8
4	Tanzania	122.7	416.1
5	Kenya	113.4	395
6	Uganda	73.5	229.3
7	Sudan	54.9	205.6
8	Ghana	53.8	192
9	Mozambique	52.9	179.1
10	Algeria	38.8	121.4

Data from Statista Market Insights

B

Revenue	**US$4.6bn** in 2023	**+3.3%** CAGR(1) 2014-2029
Unit sales	**2.2m** motorcycles sold in 2023	**+2.7%** CAGR(1) 2014-2029

Data from Statista Market Insights

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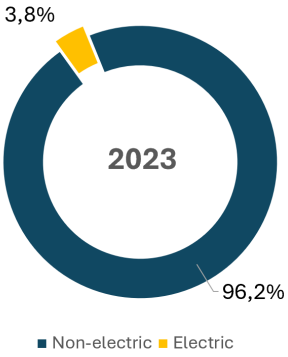

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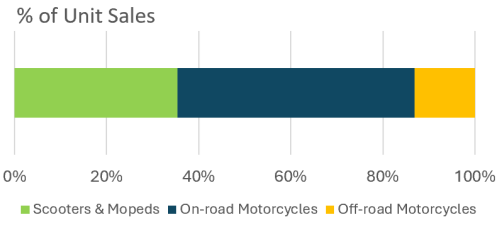

Graphics 2.10: *African sales and revenue*

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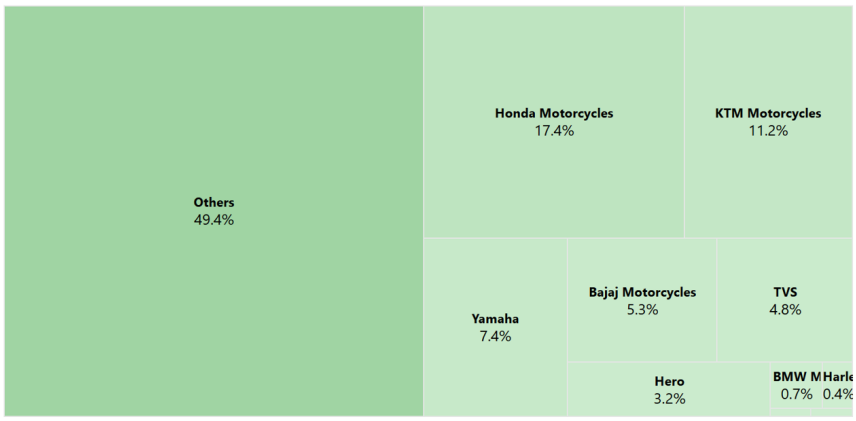

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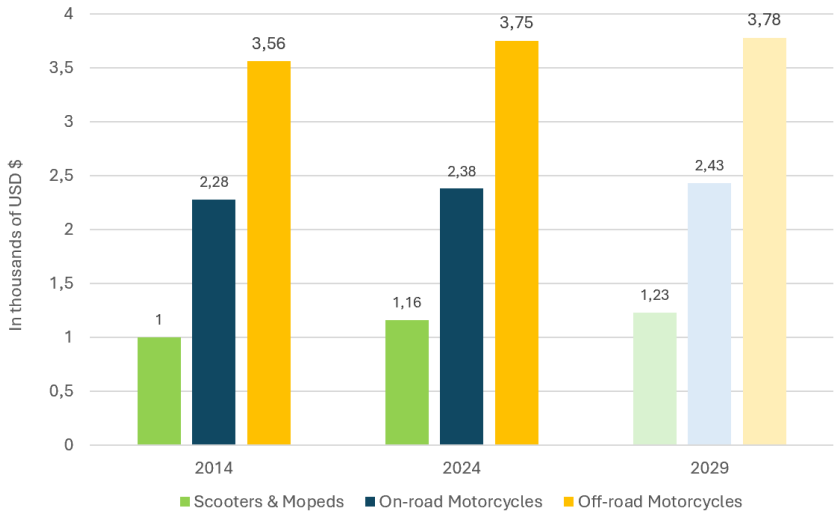

Graphics 2.11: *Producers' revenues and average prices*

and Yamaha at 7.4% (Graph 2.11E). However, a significant majority of the market (49.4%) is made up of smaller manufacturers, delineating a fragmented market. This fragmentation offers both challenges and opportunities: while it complicates brand consolidation and supply chain efficiency, it also allows for adaptability to specific local needs and price points. Prices remain low compared to other regions: in 2024, the average price was around 1,160$ for scooters, 2,380$ for on-road motorcycles, and 3,750$ for off-road models.

Overall, Africa's motorcycle market is characterized by strong internal combustion engine dominance, modest prices, and fragmented producer landscape, with only few major players commanding a significant share. Yet, the low electric adoption rate and price sensitivity suggest that the path to modernization and sustainability will require targeted policy interventions, improved infrastructure, and continued innovation from manufacturers to meet the continent's evolving mobility needs.

2.2.4 Australia and Oceania

The motorcycle market in Australia and Oceania presents a unique and regionally concentrated dynamic, with Australia clearly leading in both unit sales and revenue with 94.3 thousand motorcycles sold in 2023, generating nearly 993.3 million USD in revenue. In contrast, other countries such as Papua New Guinea, New Zealand, and Fiji represent much smaller markets, with 7.9, 7.4 and 0.3 thousand units sold.

Overall, the motorcycle market in Australia and Oceania reached a total value of 1.1 billion USD in 2023, with 0.1 million units sold. Growth indicators show modest progress : the CAGR for revenue between 2014 and 2029 is estimated at +1.9%, while unit sales are expected to grow at +1.5% over the same period. These figures suggest a mature market, with slow expansion likely due to economic stability, limited new consumer base, and a gradual pace of technological transformation.

One clear example of this slow evolution is in the adoption of electric motorcycles. In 2023, only 3.8% of motorcycles sold in the region were electric, while the vast majority (96.2%) were still non-electric. This minimal penetration of electric vehicles indicates several underlying barriers, such as limited charging infrastructure, consumer hesitation, and possibly a lack of government incentives compared to other regions. The cultural preference for internal combustion engine motorcycles, especially for off-road or recreational use, also plays a significant role in maintaining the status quo.

Looking at consumers preferences on-road motorcycles represent the largest share of the market at 52.5%, followed by off-road motorcycles at 39.3%, and scooters and mopeds at just 8.2%. This distribution reflects the lifestyle patterns common in the region. The strong presence of on-road motorcycles suggests a market

A

#	Country	Unit Sales in thousand	Revenue in million US$
1	Australia	94.3	993.3
2	Papua New Guinea	7.9	20.7
3	New Zealand	7.4	95.1
4	Fiji	0.3	1.1

Data from Statista Market Insights

B

Revenue	US$1.1bn in 2023	+1.9% CAGR(1) 2014-2029
Unit sales	0.1m motorcycles sold in 2023	+1.5% CAGR(1) 2014-2029

Data from Statista Market Insights

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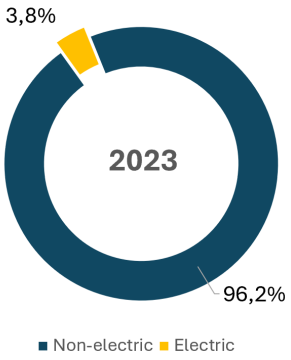

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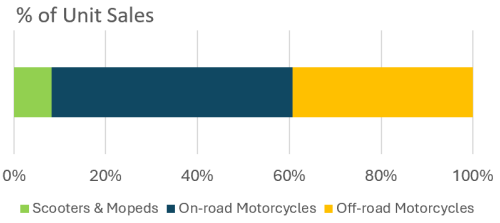

Graphics 2.12: *Australia and Oceania's sales and revenue*

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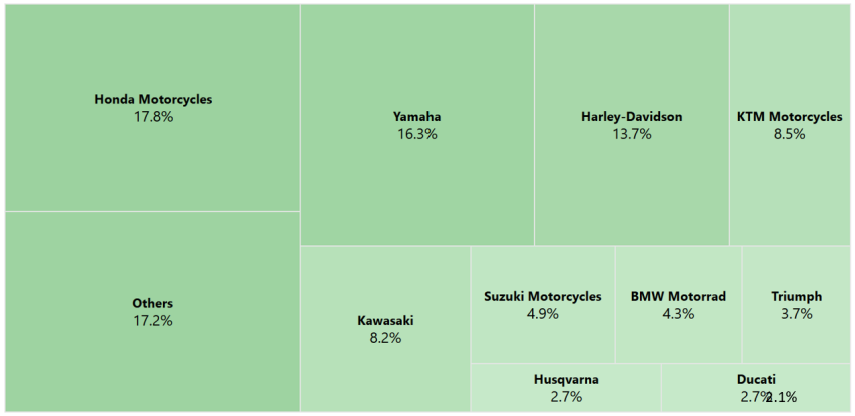

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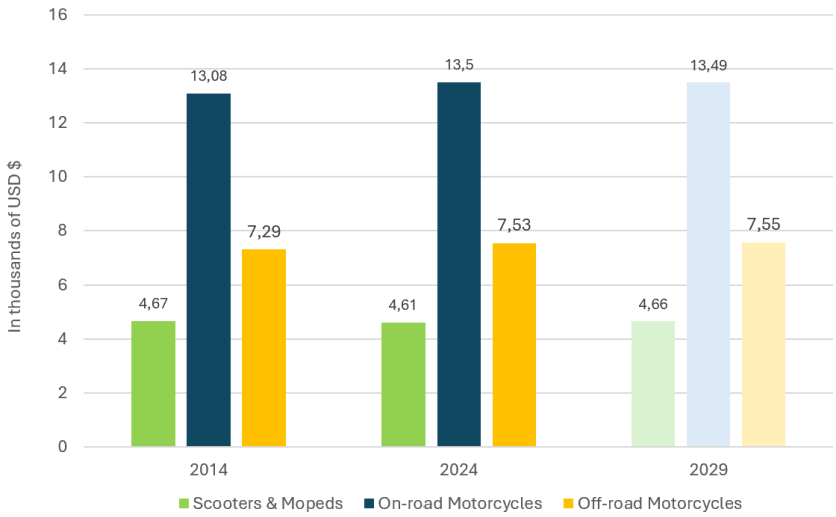

Graphics 2.13: *Producers' revenues and average prices*

oriented toward performance, touring, and commuting over longer distances. Off-road motorcycles also play a significant role, likely due to the popularity of recreational riding and the practicality of these vehicles in rural areas. In contrast, the limited share of scooters indicates that urban friendly two wheelers are less in demand, which corresponds to the region's lower urban density and reduced need for compact city transport compared to more densely populated areas like Asia.
From a competitive standpoint, the market is shared among several global brands, with no single player holding an overwhelming majority. Honda leads with 17.8% market share, followed closely by Yamaha at 16.3%, and Harley with 13.7%.
In summary, the motorcycle market in Australia and Oceania is marked by a modest but mature market with a strong preference for ICE, on and off-road motorcycles. The transition to electric motorcycles remains limited, while pricing data suggests consumer willingness to invest in performance and quality.

2.2.5 Europe

The European motorcycle market is one of the most significant and diversified, both in terms of sales and revenue. In 2023, total revenue in reached 16.3 billion USD, with approximately 1.57 million units sold. These figures signal a robust and steadily growing market, as illustrated by a CAGR of +4.8% for revenue and +4.1% for unit sales, calculated on 2014 - 2029 period. This solid performance is underpinned by both high consumer demand and a strong manufacturing presence across the continent.
A closer look at individual country shows that Italy leads the market with 290.3 thousand motorcycles sold, generating 2.86 billion in revenue. It is followed by Germany, which also report high sales and revenue figures. France, Spain, and the United Kingdom follow closely behind, reinforcing the notion that Western and Southern European countries are central hubs for motorcycle activity. These countries benefit from strong local production, established consumer bases, and favorable cultural attitudes toward two-wheeled transportation.
Despite the growing interest in sustainable mobility, the transition to electric motorcycles remains limited in Europe. Non-electric motorcycles dominate the market, representing 96.2% of total vehicles sold in 2023. As in other countries, barriers such as cost, infrastructure, and performance limitations likely contribute to the slow adoption of electrification.
In terms of vehicle types, on-road motorcycles(59.3%) constitute the majority of unit sales in Europe, reflecting the continent's extensive road networks, well developed urban and interurban transport infrastructure, and lifestyle preferences. Scooters and mopeds also have a meaningful presence (24.1%), especially in Southern European cities like Rome, Barcelona, and Athens, where compact

A

#	Country	Unit Sales in thousand	Revenue in million US$
1	Italy	290.3	2863.1
2	Turkey	223.4	781.9
3	Germany	205.6	2687.5
4	France	197.9	2503.4
5	Spain	184.3	2292.1
6	United Kingdom	108.3	1288.6
7	Greece	58.3	441.2
8	Switzerland	46.1	583.7
9	Portugal	38.0	364
10	Austria	33.3	432

Data from Statista Market Insights

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Data from Statista Market Insights

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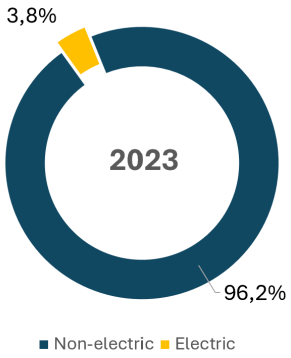

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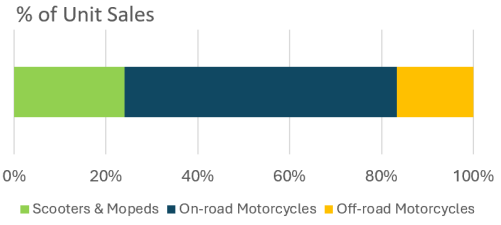

Graphics 2.14: *European sales and revenue*

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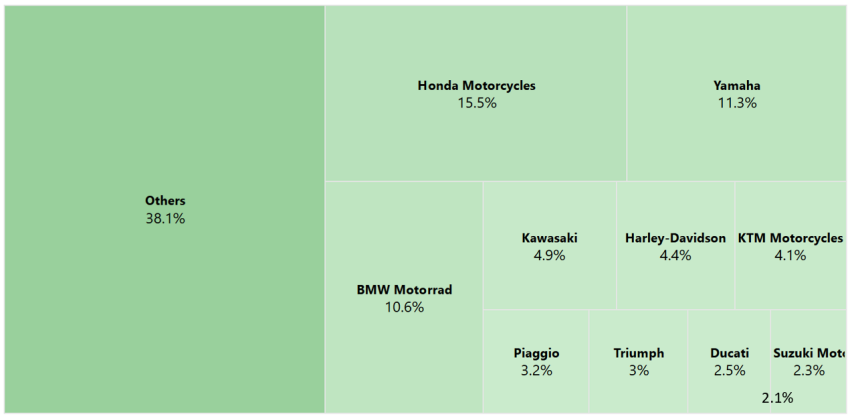

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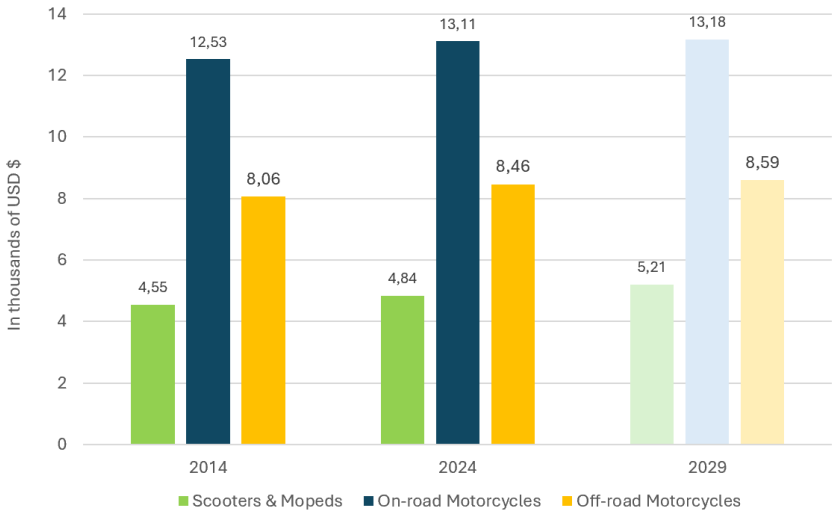
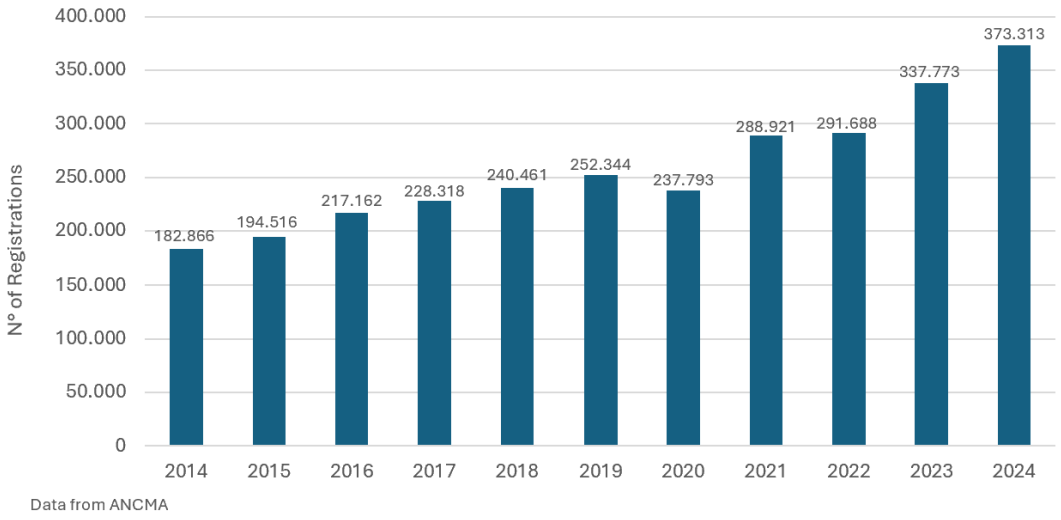


Graphics 2.15: *Producers' revenues and average prices*

and fuel-efficient vehicles are ideal for dense urban environments. Off-road makes up a smaller but still significant portion (16.6%), appealing to sport and leisure riders. From a manufacturer perspective, the European market is highly competitive. Honda and Yamaha lead, holding 15.5% and 11.3% of the market share respectively, but different brands have significant shares too. BMW Motorrad holds a strong position with 10.6%, reflecting the success of European made motorcycles in both domestic and international markets. Other notable producers include Harley-Davidson, KTM, Ducati and Piaggio, which is particularly influential in the scooter segment. Overall, Europe's motorcycle market is characterized by high volume, broad product diversity, strong brand competition, and low transition toward electric mobility. Its long established culture of motorcycling and robust manufacturing base make it a central player in the global motorcycle industry, with European consumers preferring high level motorcycles for leisure, and scooters when dealing with utility.

2.2.6 The Italian market

After having analyzed all geographical macro-areas it is time to focus on the central subject of this thesis, the Italian market. Data contained in this study were sourced from ANCMA (Associazione Nazionale Ciclo Motociclo Accessori), the official body representing the two-wheeler industry in Italy, which provides monthly and annual reports on registrations of motorcycles, scooters, and mopeds (including under 50cc), offering detailed insights by vehicle type, engine displacement, and powertrain. These data are considered highly reliable, as they are based on official vehicle registration records and are widely used by manufacturers, analysts, and policymakers. Unlike global aggregated data, the ANCMA database enables a more accurate and granular examination of national trends, including the performance of specific segments (e.g., electric vehicles).
Starting with volumes analysis as already seen previously, Italy stands out as the major European player in motorcycle market. Graph 2.16 shows national registrations during the last decade. The term registrations refers to the official recording of a vehicle with governmental authorities, which allows it to circulate legally on public roads. They differ from sales, which instead refer to the commercial transaction between a manufacturer or dealer and the final customer. While the two metrics are related, they do not always align due to factors such as delays between the sale and the registration, dealer stock accumulation, pre-registrations, or exports. As a result, registration figures are generally considered a more accurate reflection of actual market demand within a country. Looking into data a positive picture emerges.



Graphic 2.16: *Two wheels vehicle registration in Italy by year*

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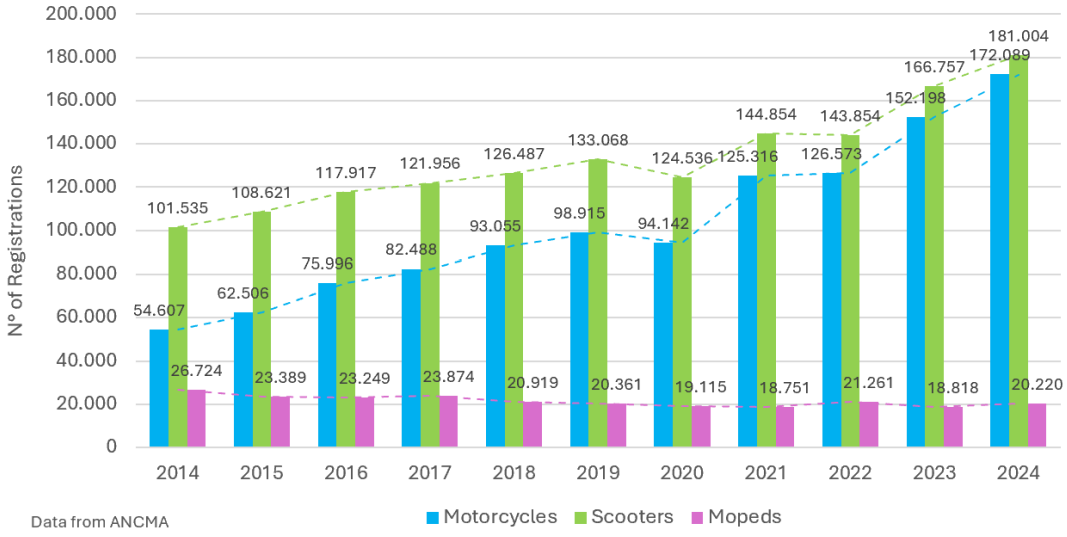

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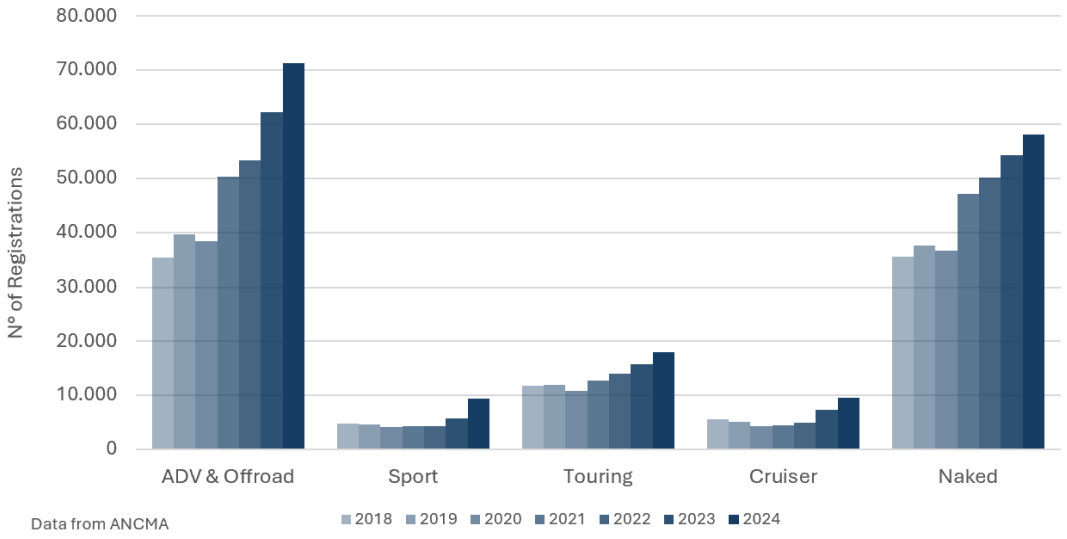
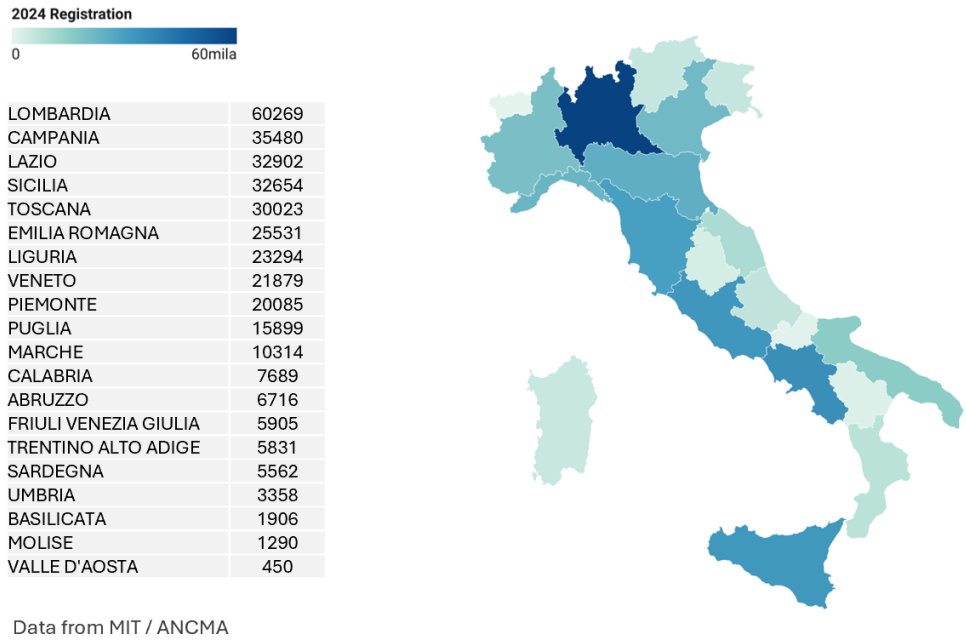


Graphics 2.17: *Two wheels vehicle registration in Italy by type and segment*

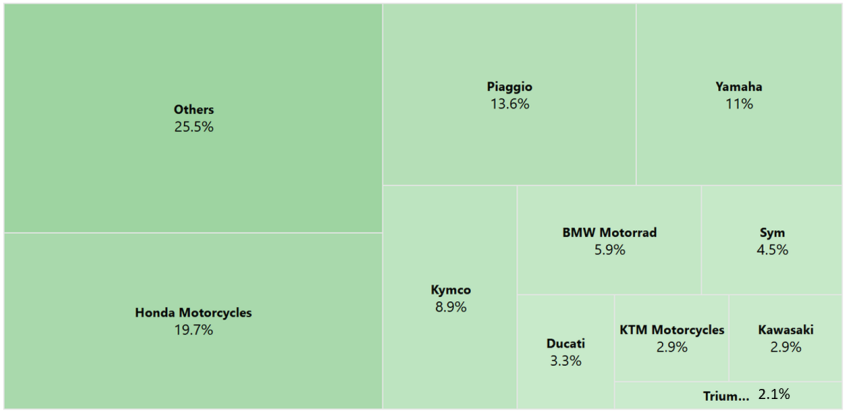
The data show a consistent upward trend in two-wheeled vehicle registrations in Italy over the past decade, with the number of newly registered vehicles growing from approximately 183,000 units in 2014 to over 373,000 in 2024. This reflects not only a rebound from the pandemic dip, but also a structural growth in demand. Graph 2.17A highlights the breakdown by vehicle type, showing that scooters remain the most registered category, followed by motorcycles and then mopeds. Interestingly, motorcycles have experienced the most significant growth in recent years, particularly from 2021 onward. Graph 2.17B provides further detail on the motorcycle market by segment, revealing that the ADV & Offroad and Naked categories have driven much of this growth. These two segments, which combine functionality and style, reflect a consumer preference for versatile and visually distinctive models, especially suited to both urban environments and leisure use. Other segments have shown more moderate but still noteworthy trends. The Touring segment, while smaller in absolute numbers, has seen steady growth, suggesting a loyal customer base interested in long distance travel and comfort. The Sport segment has maintained relatively low volumes, though it has shown slight increases in recent years, likely driven by a niche of performance oriented enthusiasts. Meanwhile, the Cruiser segment remains the least registered, indicating a limited but stable market, often linked to lifestyle branding and older demographics.



Graphic 2.18: *Two wheels vehicle registration in Italy by region*

Graph.2.18 shows geographical internal differences, with significant regional disparities. In 2024 Lombardia led the market with over 60,000 new registrations, followed by Campania, Lazio, and Sicilia, each exceeding 30,000 units. These figures highlight a strong concentration of demand in populous and economically active regions, in contrast with Valle d'Aosta, Molise, and Basilicata, which recorded the lowest numbers, reflecting their smaller populations and potentially lower mobility needs. Shifting the attention to market and money, the overall national revenues amounted to approximately €2,879.87 million in 2024 (Statista). These revenues were shared according to Graph 2.19A. "Others", which includes also local brand like Benelli and Aprilia, collectively represent 25.5% of the market, indicating a competitive landscape. Among major players, Honda as always leads with 19.7% , followed by Piaggio Group (13.6%), which holds brands like Vespa and Moto Guzzi. Notably, premium brands like BMW Motorrad and Ducati maintain smaller but significant shares, suggesting as the previous analysis on registrations a consumer base with varying preferences for brand identity, performance, and price points, aligned with

A



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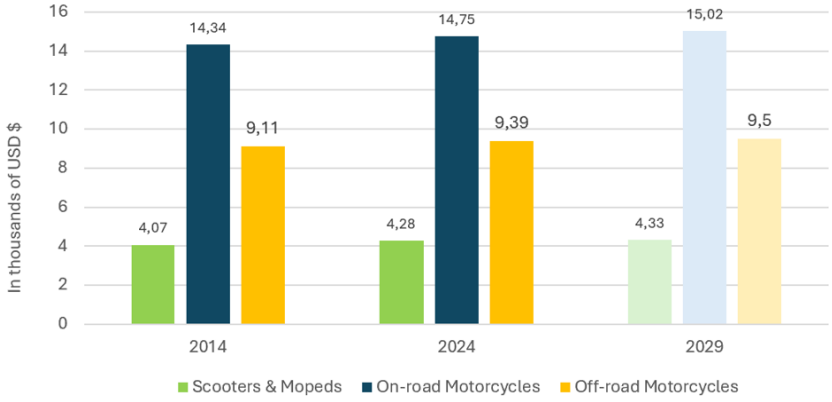
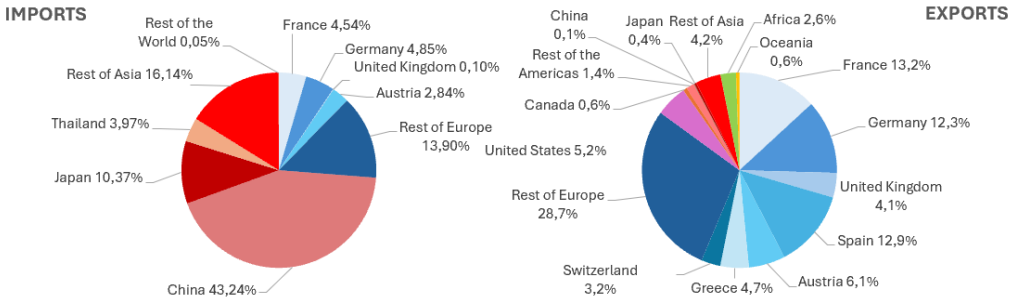
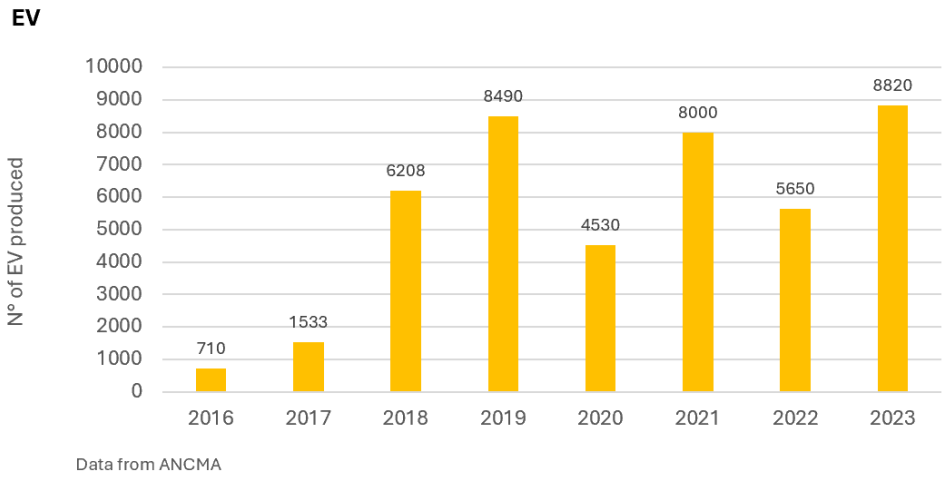


Graphics 2.19: *Producers' revenues and average prices*



Graphic 2.20: *Italian imports and exports*



Graphic 2.21: *Italian EV production*

European regional characteristics. This can be seen also by price analysis. In 2024, average prices reached approximately $4,280 for Scooters, $14,750 for on-road Motorcycles, and $9,390 for off-road, highlighting the segmentation of the market based on product type and consumer purchasing power. These figures reflect a diverse demand structure: scooters and mopeds cater to urban commuters and price-sensitive consumers, while on-road and off-road motorcycles appeal to enthusiasts seeking higher performance and specialized use. Italian trends align with European consumption patterns, where quality, brand heritage, and riding experience often justify premium prices, contrasting with the affordability preferences in Asian markets and the larger, high-displacement preference typical of the American market.

This dynamic is further reflected in Italy's international trade structure. As shown in Graph.2.20, imports are heavily skewed toward Asian countries, with China alone accounting for over 43% of the total, followed by Japan and Thailand. These imports typically consist of low/mid range models, related to affordability and mass production. On the export side, however, Italy's motorcycles are mainly destined for European neighbors such as France, Germany, Spain, and Austria, with a combined share that illustrates the regional demand for the Italian made, high quality vehicles. This supports the notion that Italy plays a dual role in the global motorcycle market: a major importer of budget oriented products and a strong exporter of premium, brand driven models.

While brand identity remains fundamental to the market, trends like the adoption of electric motorcycles is still limited. As shown in Graph 2.21, production in Italy started from only 710 units in 2016 and, despite consistent growth, reached just 8,820 units by 2023. Although this upward trend demonstrates some domestic interest and increased capability in sustainable mobility, the overall volumes remain marginal when compared to the broader two wheeler market. This suggests that, despite alignment with European environmental objectives, electrification in the Italian motorcycle sector is still in an early stage and far from becoming mainstream.

In this context, regulatory developments such as Euro 5 and the more recent Euro 5 bis play a pivotal role. These stringent emissions standards, which apply to all newly registered motorcycles in the EU, aim to reduce pollutants such as NOx, CO, and hydrocarbons, indirectly pushing manufacturers toward cleaner technologies, including electrification. However, rather than causing an immediate transition to electric, these regulations have so far encouraged optimization of internal combustion engines and hybrid solutions. As a result, while EV production is gradually increasing, much of the industry's effort is still focused on meeting regulatory compliance with conventional technologies, slightly delaying full electrification.

Notably, the enforcement of Euro 5 bis by 2025 has led many dealers and manufacturers to pre-register non-compliant vehicles in 2024 in order to avoid stricter homologation constraints. This phenomenon of pre-registration has caused a temporary inflation of 2024 figures and is resulting in a drop in new registrations in 2025, as the market absorbs the excess inventory. This regulatory anticipation distorts annual comparisons and highlights the industry's sensitivity to legislative changes, influencing not only production strategies but also short-term market dynamics.

2.3 MARKET ANALYSIS RECAP and CONCLUSIONS

In recent years, the motorcycle market has shown steady global growth, shaped by factors such as rising urbanization, shifting mobility needs, and evolving consumer preferences. From 2014 to 2024, unit sales increased from about 51 million to nearly 57 million, with projections pointing toward over 62 million units by 2029 (Statista). Revenues has followed a similar trend, increasing from approximately $104.5 billion in 2014 to nearly $148 billion in 2024 with a significant part of this increase due to inflation. When adjusted to constant 2024 dollars, the growth appears more modest, and in some segments, such as motorcycles, real prices have even decreased. This suggests that manufacturers have focused more on increasing volume than on expanding profit margins, often through competitive pricing and cost reduction strategies, especially in mass production countries.
The market experienced a notable dip in 2020 due to the COVID-19 pandemic, which caused widespread economic disruption, supply chain delays, and reduced consumer spending. However, the recovery was swift, driven by renewed interest in individual mobility, avoidance of crowded public transport, and increased use of motorcycles for delivery and urban logistics. These factors, along with government incentives in some regions and improvements in production capacity, helped restore and accelerate market growth in the years that followed.
Asia remains the heart of the global motorcycle market in both volume and value. Japan and India lead the supply side with major companies like Honda, Yamaha, Hero, and TVS, while Southeast Asian countries show extremely high ownership rates. In contrast North American markets are shaped by lifestyle oriented demand and even though unit sales are lower, revenue remains high due to the popularity of premium brands and large displacement motorcycles. Latin America and Africa shows a preference for affordable, utility focused models, while Australia and Oceania present a small but mature market, with consumer preferences leaning toward on-road and off-road models rather than urban scooters. Europe is one of the most structured and diversified motorcycle markets. High competition, strong domestic brands, and significant regional differences define its landscape. On-road motorcycles lead in sales, but scooters and mopeds maintain relevance in urban settings. Italy stands out as Europe's largest motorcycle market, both in terms of registrations and revenue. In 2024, over 373,000 new two-wheeled vehicles were registered, marking a significant increase compared to previous years (also due to pre-registrations). While scooters remain dominant, motorcycles, especially in Naked and ADV/Offroad categories, have experienced substantial growth. These trends reflect a demand for vehicles that combine style and versatility, suitable for both commuting and leisure. Geographically, the market is strongest in Lombardy, Lazio, Campania, and Sicily, mirroring broader demographic and economic patterns.
The adoption of two wheeler EV has grown at different paces across various continental regions, driven by distinct economic, regulatory, and infrastructural factors. In Asia, especially in countries like China and India, electric vehicles have gained significant traction due to government subsidies, rising fuel prices, and high urban population density. China leads globally in production and sales, while India is rapidly expanding its infrastructure. In other regions electrification remain moder-

ate and at early stages with stagnation caused by a combination of limited charging infrastructure, higher initial purchase costs, and consumer skepticism regarding range and performance. In Europe and North America, despite strong environmental policies, electric two wheelers still represent a small share of total production. Efforts to promote electrification are often hindered by the high cost of electric models compared to their combustion engine counterparts and the relatively low perceived value among traditional riders. Africa and parts of Latin America face even greater challenges, where limited grid reliability, low purchasing power, and lack of policy support slow down the transition. Overall, while electrification in the market is progressing, it remains uneven and dependent on region specific conditions.

To conclude, this analysis reveals a global motorcycle industry in transformation. Growth is consistent, but uneven, and often driven by necessity in developing countries or by lifestyle and brand appeal in wealthier ones. The path toward electrification is advancing slowly and differently across regions. Italy, with its rich industrial tradition and evolving consumer trends, reflects many of these dynamics on a national scale making it an ideal case for studying how various factors affect not only new vehicle sales but also the overall motorcycle market. In particular, analyzing the second-hand market is crucial because it reveals important information about the real world performance, durability, and user preferences of different models over time. This approach helps identify key characteristics of motorcycles that influence their long term value and popularity, providing deeper insights into market behavior and future mobility trends.

CH. 3

ITALIAN SECOND-HAND MARKET

Chapter 3

ITALIAN SECOND-HAND MARKET

The used motorcycle market plays a key role in the overall two-wheeled industry. In recent years, it has become an essential part of mobility, allowing a large number of riders to access vehicles at more affordable prices. It is not only a space for private exchanges but also a dynamic segment that reflects broader economic trends, consumer preferences, and technological changes. For this reasons, before dealing with data modeling in the last chapter, this part describes the reality and characteristics this Italian sector, bringing a better comprehension to the study, especially regarding selling/buying modalities, volumes and preferences among costumers.

3.1 MARKET DIMENSION

While the thesis previously focused on the market for "new" motorcycles, understanding volumes, trends and differences between continents and countries, it will now shift the attention to the "used" ones, using data collected from different sources to create a more clear picture of this world. To do so information has been gathered from different articles, sites and public organizations archives, defining a strong structural base on which possible thoughts have been developed.

3.1.1 Volumes, trends and possible external correlations

Starting from volumes, while sales represent a key indicator to understand the market of "new", what can describe the dimension of the Italian second-hand sector are ownership transfers. An ownership transfer refers to the process through which the legal ownership of a vehicle is officially moved from one person (the seller) to another (the buyer). In the context of the motorcycle market, this means that a used motorcycle changes hands and is registered under a new owner in the national vehicle registry. In Italy, ownership transfers are recorded by the Public Vehicle Re-

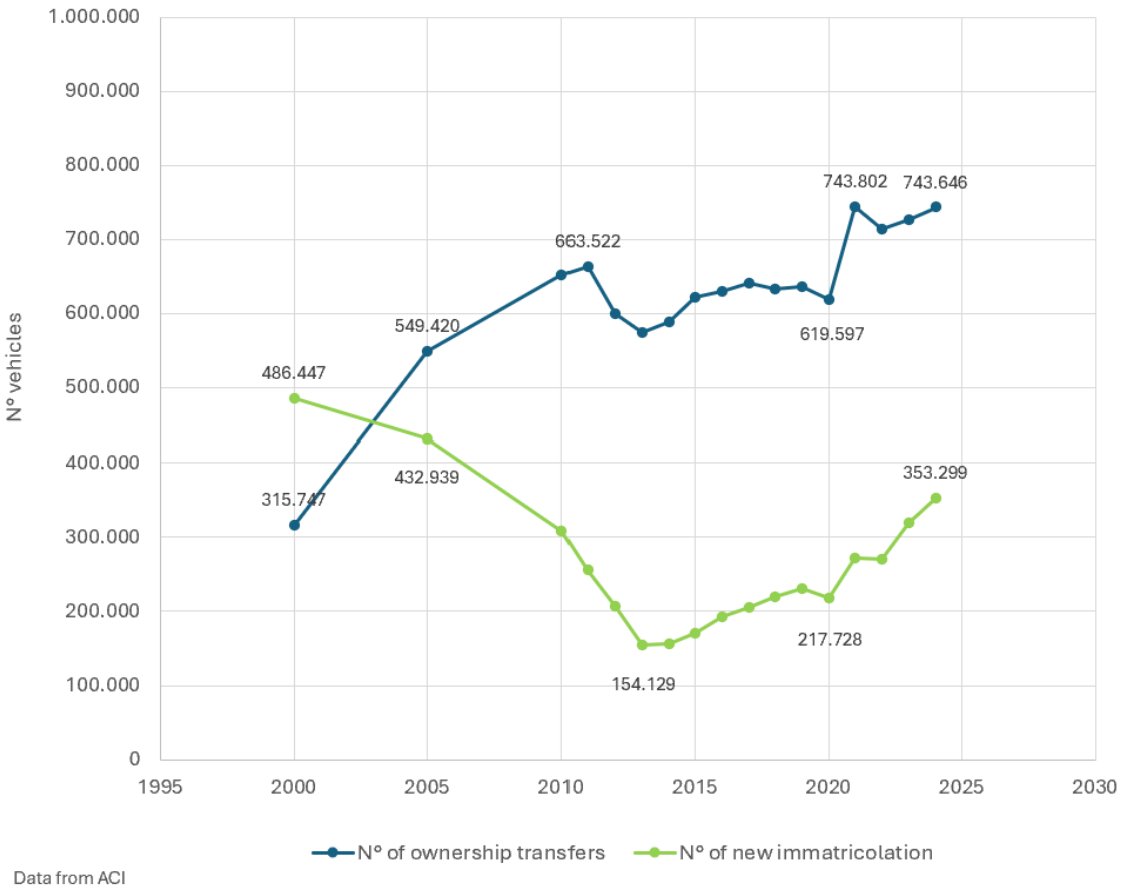
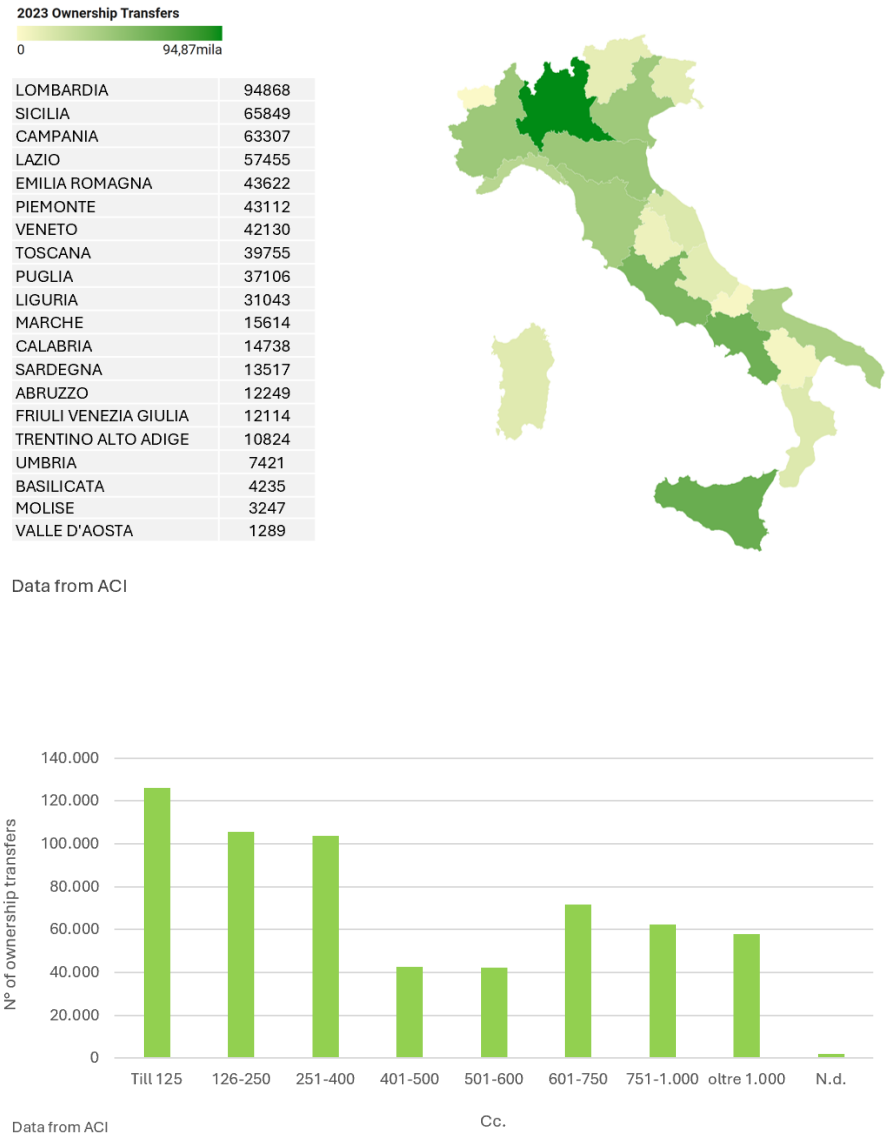


Figure 3.1: *New Immatricolation vs Ownership Transfers in Italy*

gister (Pubblico Registro Automobilistico – PRA) and represent one of the main indicators used to measure the activity of the second-hand market. Each transfer corresponds to a completed sale or change of ownership, and therefore it provides a direct estimate of the volume of the used vehicle sector.
Ownership transfers data have been collected from ACI (Automobile Club d'Italia) and later used to generate Graph.3.1 and 3.2, useful to understand how big the second-hand motorcycle market is and how it has changed over time. The green line shows new registrations, while the blue line represents transfers. To be precise, these data also include "minivolture", which are temporary transfers made by dealerships before a vehicle is sold to the final customer. This means that the total number of transfers shown in the graph is slightly higher than the actual number of final sales between private owners, since each motorcycle passing through a dealer may generate more than one registration movement. Although this, the difference between the two trends is clear. Around the year 2000, the two lines were relatively close, with about 315,000 ownership transfers and 486,000 new registrations. In the following years, however, the situation reversed: ownership transfers started to increase steadily,



Graphics 3.2: *N° of Ownership transfers divided by region and cubic capacity*

while new registrations began to decline. Between 2005 and 2010, ownership transfers peaked at around 660,000 units, while new registrations dropped sharply, reaching a minimum of about 150,000 units in 2013. After this point, the number of new registrations slowly recovered, while ownership transfers remained consistently high, with a clear rise again after 2020.
This trend shows that, over the last two decades, the used motorcycle market has become much larger and more stable than the new one. Even during years of economic slowdown or uncertainty, the second-hand market maintained high volumes, suggesting that consumers increasingly turn to used motorcycles as a more affordable and flexible option, confirming that the sector not only as a residual market, but a fundamental part of the entire motorcycle ecosystem.

More details can be gathered observing how transfers are distributed across Italian regions and different engine sizes. Graph 3.2 illustrates this division, highlighting both geographical distribution and technical dimensions of the market.
From a regional perspective, the used motorcycle markets display a similar geographical pattern to the new one. Lombardia clearly stands out as the leading region, with almost 95,000 transfers registered in 2023, followed by Sicilia, Campania, and Lazio. As previously said, these regions are characterized by high population density and extensive urban areas, which naturally generate greater mobility needs. However, is important to notice that while the Northern area dominate both new and used markets in absolute terms, the South plays now a more prominent role in respect to previous analysis. This difference suggests that used motorcycles represent a more accessible and economically convenient option in areas with lower average income levels, where affordability strongly influences purchasing decisions.
The second part of the graph shows the distribution of ownership transfers by cubic capacity. The data confirm that smaller motorcycles dominate the this market. Vehicles with an engine capacity up to 125 cc represent the largest share, with more than 120,000 transfers during 2023, followed by 126–250 cc and 251–400 cc. This suggests that lightweight and mid range motorcycles are the most traded, probably because they are affordable, which is likely to be the first motivation an used vehicle purchasing. Although this, higher cubic capacities (above 600 cc) account for still relevant portion of the market, mainly linked to enthusiasts and long distance riders, who are generally more experienced and willing to invest in performance oriented models. These motorcycles are often used for leisure rather than daily commuting and tend to maintain a stronger emotional and brand driven appeal. As a result, their resale market remains stable and supported by a passionate community.

3.1.2 Selling modalities

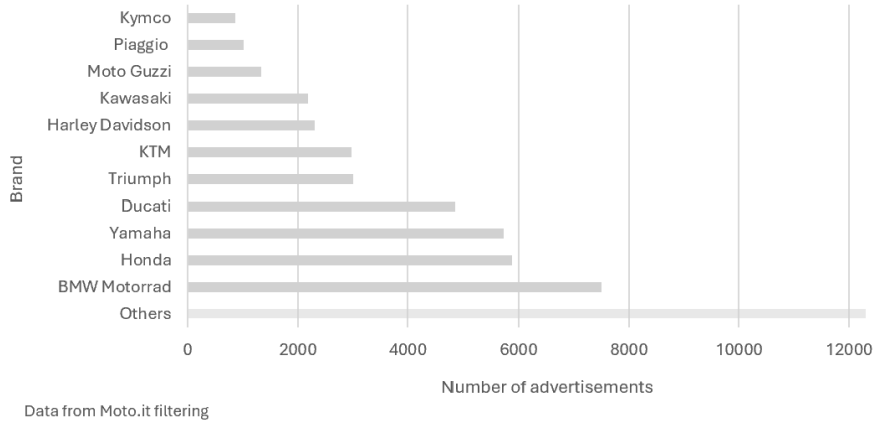
The Italian second-hand motorcycle market is composed of a wide range of sellers, each contributing to the overall structure and efficiency of the sector. The two main typologies are private sellers and professional dealers, differing in size, transaction methods, and target customers.
Private sales represent a large portion of the market. These transactions typically occur through online classified platforms, specialized forums, or social media groups, allowing direct interaction and price negotiation between individuals. This modality offers flexibility and competitive prices, although it may involve higher risks due to the absence of warranties. Dealerships and professional resellers, instead, provide a more structured and reliable service. They manage trade-ins and resales of used motorcycles, often including inspection and after-sale support.
In recent years, the growth of digital platforms and certified marketplaces has reduced geographical barriers and improved transparency, making users able to compare offers and complete much of the buying process remotely. Overall, the coexistence of traditional dealers and digital channels has created a hybrid market structure where convenience, reliability, and accessibility coexist, confirming the growing maturity and modernization of the Italian second-hand motorcycle sector.

3.2 ONLINE PLATFORMS

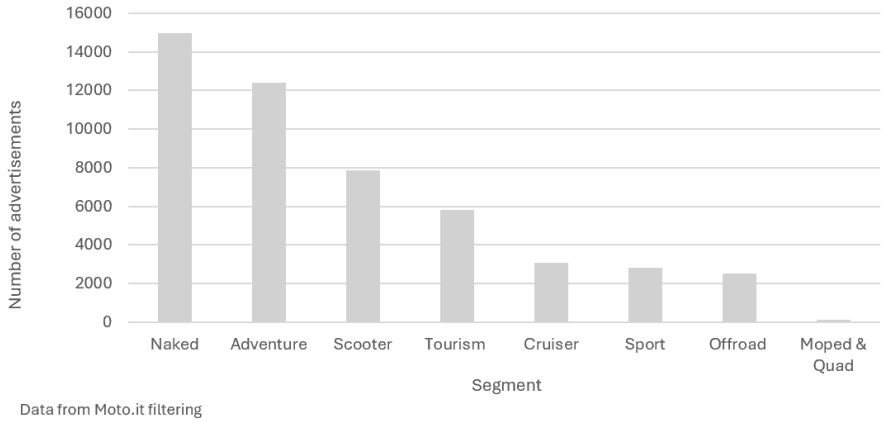
The rise of digital platforms has profoundly transformed the dynamics of the reselling market. Websites such as Moto.it, Subito, AutoScout24, and DueRuote have become the main reference points for buyers, offering accessible and user friendly environments for trading used vehicles. These platforms combine large databases with advanced search filters, allowing users to compare prices, mileage, and seller reputation in real time.
From an operational point of view, their functioning is relatively straightforward: sellers create advertisements by uploading photos, technical specifications, and pricing details, while buyers can browse available offers, contact sellers directly, and often use integrated tools to estimate the market value or verify a vehicle's history.
Among them, Moto.it and DueRuote are specialized in the two-wheeler sector, often integrating editorial content, reviews, and technical insights that support users during the purchasing process. Subito, instead, operates as a general marketplace, where motorcycles represent one of the most active categories due to the high number of private listings. AutoScout24 maintains a more professional approach, focusing on verified ads and dealer collaborations, which contributes to greater trust and transparency in transactions.
The diffusion of these digital tools has not only increased market visibility but also enhanced competitiveness and accessibility. Buyers can reach offers from all over the country, while sellers benefit from a broader audience and quicker transactions.
In the following section, the analysis will focus specifically on Moto.it, which between these sources is the most "easy to use" and reliable. By exploiting its online search filters and publicly available data, descriptive statistics will be developed to outline the main distribution and characteristics of motorcycles currently offered on the platform.

Figure 3.3: *Platforms' logos*

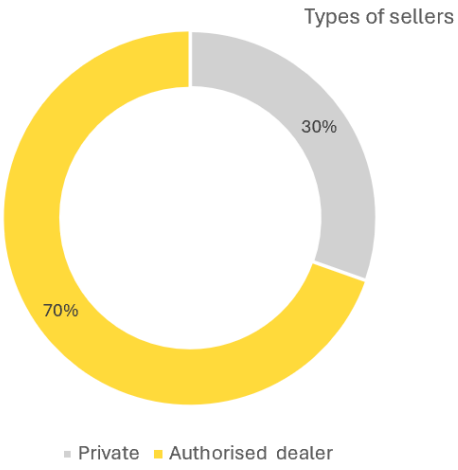
3.2.1 Moto.it descriptive analysis



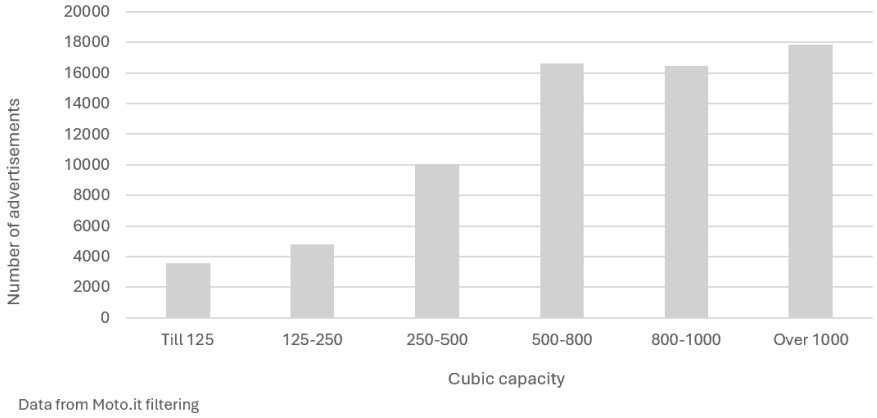
Graphic 3.4: *Number of advertisements divided by brand*



Graphic 3.5: *Number of advertisements divided by segment*



Graphic 3.6: *Number of advertisements divided by type of seller*



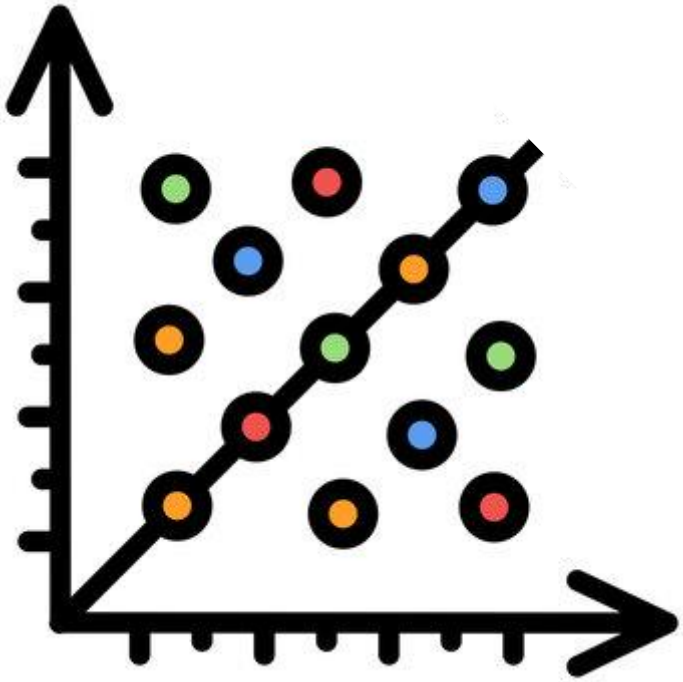
Graphic 3.7: *Number of advertisements divided by cubic capacity*

The data gathered from Moto.it provide a detailed overview of the composition and dynamics of the Italian second-hand motorcycle market. By exploiting the platform's filtering tools, it was possible to extract descriptive statistics regarding the distribution of advertisements by brand, segment, cubic capacity, and type of seller. These indicators allow for a better understanding especially of supply, giving some hints regarding also consumers preferences.
Starting from brand segmentation, the advertisements collected show a clear prevalence of established manufacturers such as BMW Motorrad, Honda, and Yamaha, which together account for a large share of total listings. These brands are traditionally associated with reliability and wide model ranges, elements that sustain their value even in the second-hand market. Ducati and Triumph also maintain a relevant presence, reflecting the appeal of premium and performance oriented motorcycles. The consistent representation of brands like KTM, Harley-Davidson, and Moto Guzzi indicates that niche markets and brand loyalty play a considerable role, as many users seek specific models or distinctive styles.
When analyzing the type of motorcycle in Graph 3.3, the data reveal that naked and adventure models dominate the listings, followed by scooters and touring bikes. These categories represent versatile and practical solutions, suitable for both urban mobility and leisure medium distance travels. The lower share of cruisers, sport, and off-road motorcycles suggests that these segments address more specialized audiences. This distribution aligns with the general composition of the Italian motorcycle fleet, confirming that the market is largely driven by everyday usability.
Regarding engine displacement, advertisements are concentrated in the medium / high cubic capacity range, particularly between 500 and 1000 cc. This indicates that most used motorcycles offered online are not entry level models, but rather medium sized bikes with balanced performance and comfort, appealing to experienced riders. Although this, smaller displacements still represent a consistent portion of listings, mainly targeted at commuters and new riders looking for affordable options.
The analysis of seller typology (Graph 3.6) highlights that about 70% of advertisements come from authorized dealers, while 30% are published by private individuals. This predominance of professional sellers shows the increasing role of dealerships and intermediaries in structuring the online second-hand market. Their presence ensures higher levels of reliability, vehicle inspection, and post sale support, contributing to the professionalization of what was once a mostly informal exchange network.
Overall, the descriptive results obtained from Moto.it highlight the main features of the Italian second-hand motorcycle offer and while the data are not a direct reflection of demand, they remains strongly correlated with it. The predominance of well known brands such as Honda, BMW Motorrad, and Yamaha indicates that reputation and reliability continue to drive both offering and purchasing behaviours. The focus on medium and large displacements suggests that most available motorcycles target experienced riders, while smaller models likely circulate faster or have lower resale margins. The strong presence of professional dealers further shows the increasing organization and transparency of the online offer, where inspections and warranties strengthen buyer trust. Altogether, Moto.it provides a realistic representation of the market's structure, capturing the interaction between supply, perceived demand, and the growing role of digital platforms in shaping this balance.

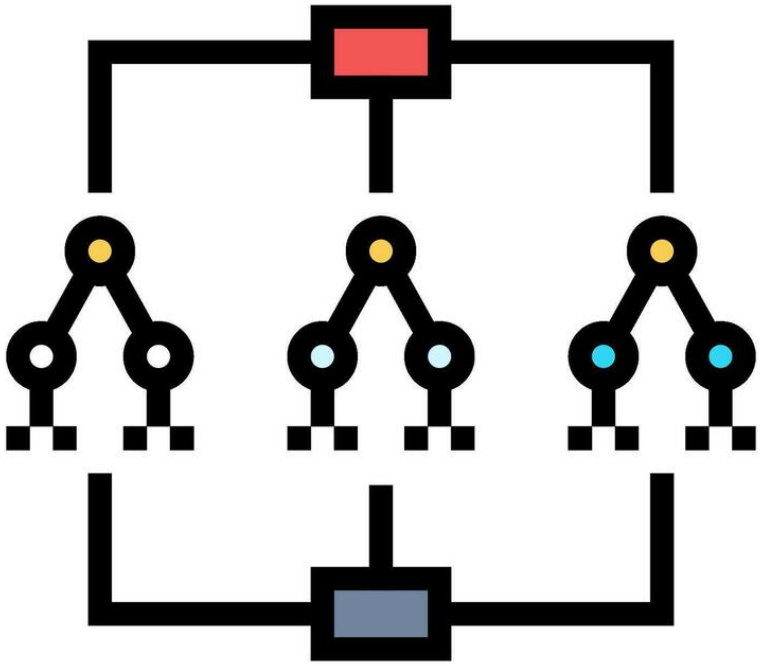
3.3 MARKET ANALYSIS RECAP and CONCLUSIONS

The analysis developed throughout this chapter provides a comprehensive overview of the Italian second-hand motorcycle market, highlighting its structure, evolution, and connection with the broader mobility context. Data from official sources and digital platforms together outline a sector that has become a vital component of the two-wheeled industry and a strategic complement to the new vehicle market.
Ownership transfer statistics confirm the growth and stability of the used market over the last two decades. Even during periods of economic uncertainty, the number of transactions has remained consistently high, showing that consumers perceive used motorcycles as a flexible and affordable solution. From a regional perspective, Lombardia clearly stands out as the leading area in terms of transfers, followed by Sicilia, Campania, and Lazio. Northern regions, with higher population density and purchasing power, dominate the market in absolute terms; however, the South shows a stronger relative weight in the used segment. This indicates that second-hand motorcycles represent a more accessible and cost effective alternative in areas with lower income levels, where affordability significantly influences mobility choices.
At the same time, the analysis of Moto.it data provides a complementary view focused on the supply side of the market. The listings available on the platform reveal a predominance of medium and high displacement models (between 500 and 1000 cc), often associated with experienced riders and leisure oriented usage. Most advertisements are published by professional dealers, confirming the growing role of intermediaries in structuring the online market and ensuring higher levels of reliability and post sale support. The presence of renowned brands such as Honda, BMW Motorrad, and Yamaha further emphasizes the importance of reputation and perceived quality in shaping the online offer.
A comparison between ownership transfer data and online advertisements highlights an interesting contrast: while low displacement motorcycles dominate real world transactions, the online supply tends to focus on more advanced and higher value models. This divergence reflects the dual nature of the market: on one side, a mass demand driven by practicality and cost efficiency; on the other, a professionalized online offer aimed at riders seeking performance, prestige, or specialization.
In conclusion, the Italian second-hand motorcycle market appears mature, heterogeneous, and increasingly digitalized. It combines accessibility for everyday users with a structured and transparent environment for enthusiasts and experienced riders. Regional variations, together with the coexistence of private and professional sellers, demonstrate the adaptability and resilience of this sector, which continues to evolve as a fundamental component of Italy's mobility ecosystem. Building on these findings, the next chapter will focus on the development of a predictive model designed to analyze and quantify market dynamics, offering a data driven approach to better understand the factors influencing motorcycle prices.

CH. 4



DATA ANALYSIS and MODELING



Chapter 4

DATA ANALYSIS and MODELING

Following the descriptive analysis of the Italian second-hand motorcycle market presented in the previous chapter, this section aims to develop a model capable of estimating the price of used motorcycles based on their main technical and commercial characteristics. The objective is to identify how specific features like mileage, engine displacement, brand and type of seller contribute to determining market prices, assessing also how accurately these relationships can be captured through different analytical approaches.
To achieve this goal, two complementary methodologies were applied. The first adopts an econometric perspective, implemented in Stata, which allows the estimation of a non-linear regression model to quantify the relationship between explanatory variables and price while preserving interpretability. The second employs a machine learning approach, developed in Orange, based on the Gradient Boosting algorithm, which focuses on maximizing predictive accuracy by capturing complex and non-linear dependencies within the data.
By comparing the results of these two models, it becomes possible to integrate the interpretive strength of econometrics with the predictive power of machine learning.

4.1 DATA COLLECTION and PREPARATION

The dataset used for this analysis was manually compiled using advertisements published on Moto.it, one of the main Italian platforms previously introduced in Chapter 3. This website was selected as the primary source due to its extensive coverage of the national motorcycle market and the reliability of its listings, which often include verified technical and commercial information. Data collection was carried out progressively over several weeks, with the support of ChatGPT for information retrieval, validation, and consistency checks where applicable. This approach allowed to streamline repetitive searches, cross-check details such as original retail prices, ensuring that all entries were standardized before inclusion in the dataset. To guarantee the quality and representativeness of the data, only featured advertisements were selected. A total of 1,000 observations were compiled. Among them,

approximately 700 were intentionally chosen to maintain a balanced representation across brands, models, engine displacements, and registration years. This deliberate selection focused on the most iconic and widely represented motorcycles on the Italian market, ensuring that the dataset captured the structure of the sector's most active segments. The remaining 300 records were instead collected through random sampling, incorporating a broader range of less common models and minor brands. This mixed sampling strategy aimed to enhance diversity within the dataset, allowing the predictive models to generalize effectively not only for mainstream motorcycles but also for those less frequently represented in the market.
Each record included detailed information describing both technical and commercial characteristics of the motorcycle, integrating aspects related to performance, configuration, and transaction conditions. In this way, the dataset mirrors the actual composition of the Italian second-hand market while providing a solid empirical base for statistical and predictive analysis. Specifically, the variables collected were:

Brand – *manufacturer of the motorcycle (e.g., Honda, Ducati, Yamaha...).*

Model – *specific commercial model name.*

Trim – *version or configuration of the model, when available.*

Segment – *motorcycle category (e.g., Naked, Sport, Adventure, Touring...).*

Price of new – *retail price at the time of launch, retrieved through online sources.*

Actual price – *price reported in the second-hand listing.*

Year of immatricolation – *year the motorcycle was first registered.*

Lifespan – *motorcycle's age, calculated.*

Mileage (Km) – *total kilometers reported by the seller.*

Color – *main color of the motorcycle as stated in the listing.*

Engine displacement (Cc) – *engine size in cubic centimeters.*

Horsepower (Hp) – *nominal engine power output.*

Fuel – *type of fuel used (e.g., petrol, electric).*

Seller type – *whether the listing was published by a private, reseller or official dealer.*

Optional features – *additional equipment, encoded as a binary "yes/no" variable.*

Damages – *declared presence defects, also encoded as a "yes/no" variable.*

Number of previous owners – *total number of past proprietors.*

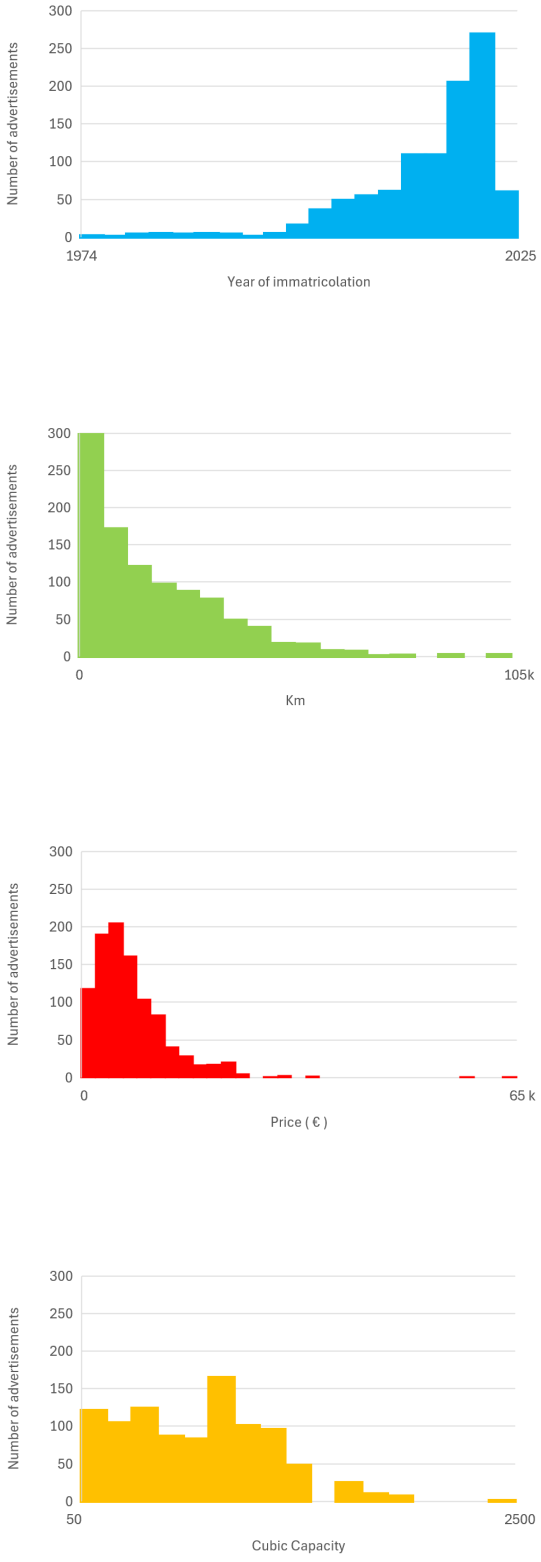
Region – *geographical area in Italy where the motorcycle was listed for sale.*

Before modeling, the dataset underwent a careful cleaning process. Duplicates, incomplete listings, and implausible values, such as unrealistic mileage and prices, were replaced with coherent estimates derived from comparable motorcycles of the same brand. Outliers, on the other hand, were preserved whenever they represented genuine cases, including premium motorcycles or limited editions. This choice ensured that the dataset retained its natural heterogeneity, accurately reflecting the diversity and complexity of the market rather than imposing artificial uniformity.

The resulting distributions of year, mileage, cubic capacity, and price (shown in Graphic 4.1) confirm the coherence and realism of the collected data. The histogram of registration years shows a major presence of newer motorcycles, reflecting the higher turnover of recent models. The mileage distribution is, as expected, right-skewed: most motorcycles record moderate usage, while only a few exceed 50,000 km, probably corresponding to long distance models.

Price follows a similar pattern, with most listings concentrated between €3,000 and €10,000, and a smaller share above €30,000 representing premium motorcycles. Engine displacement, instead, shows distinct peaks around 125cc, 600cc, and 1,000cc, highlighting how demand clusters around standard licensing categories and performance ranges.

Overall, these patterns confirm that the sample is both representative and diversified, an essential foundation for the predictive models developed in the following sections, as it allows them to learn from real market variability and generate valid estimates.



Graphics 4.1: *Variables distribution*

4.2 REGRESSION MODEL

Regression analysis is a statistical technique used to examine the relationship between a dependent variable and one or more independent variables. It allows researchers to identify how changes in explanatory variables are associated with variations in the outcome variable and to quantify the strength and direction of these relationships. In this particular study, the dependent variable is the *Actual price*, representing the selling price of used products.
Starting from a linear regression model, the analysis aims to provide an interpretable and explanatory framework capable of highlighting the main factors that influence the resale price. However, since real world relationships between variables are often complex and non linear, additional model specifications with higher complexity will be considered to improve explanatory power and causal interpretation.
All regression analyses were conducted using Stata, a statistical software widely employed in academic and professional research for data management, econometric modeling, and hypothesis testing. Stata provides a comprehensive suite of tools for performing regression analysis, evaluating model assumptions, and generating robust statistical inferences. Its flexibility and command-based interface make it particularly suitable for reproducible and transparent empirical research.

4.2.1 Data entry, checking, cleaning and modifications

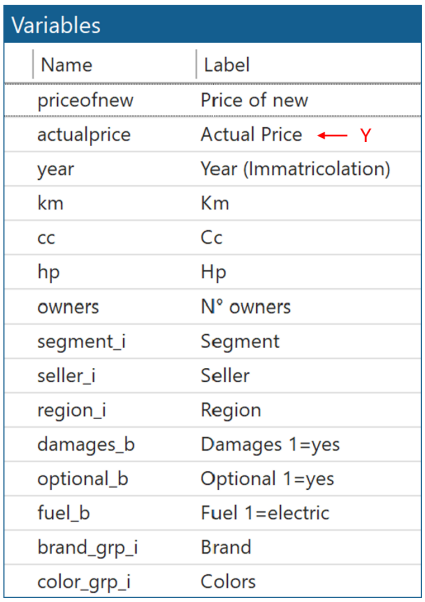


Figure 4.2: *Stata variables visualisation*

The dataset used for the regression analysis was imported into Stata from the Excel file where the data collection was performed. After loading the dataset, additional modifications were applied to improve consistency.
Variables such as *Model* and *Trim* were excluded, as they introduced excessive granularity without adding meaningful explanatory power. Categorical variables like the *Segment*, *Color*, *Region*, and *Brand* were recoded: several minor category levels were grouped to mitigate sparsity and improve coefficient stability. Furthermore, variables such as *Fuel*, *Optional* and *Damages* were transformed into binary indicators to simplify interpretation while preserving informational content. Finally *Year* was transformed into *Age* for better interpretation.
After these transformations, variables were ready for the regression analysis.

4.2.2 Primary regression and correlation problems

Starting from a multiple linear regression, all the previously selected variables (without expanding the categorical ones into their dummy components) were included in the first trial model to predict the dependent variable *Actual price*. The purpose of this initial specification was to obtain a preliminary understanding of the underlying relationships within the dataset and to identify potential structural issues before refining the model. However, the first estimation revealed several important problems affecting the model's validity, interpretability, and statistical reliability.

```
. reg actualprice priceofnew age km cc hp owners i.segment_i i.seller_i i.region_i i.brand_grp_i i.color_grp_i
> damages_b optional_b fuel_b
note: fuel_b omitted because of collinearity.
```

Source	SS	df	MS			
Model	1.7368e+10	46	377565957	Number of obs	=	391
Residual	1.3515e+09	344	3928812.33	F(46, 344)	=	96.10
Total	1.8720e+10	390	47998834.5	Prob > F	=	0.0000
				R-squared	=	0.9278
				Adj R-squared	=	0.9181
				Root MSE	=	1982.1

```
. corr hp cc
(obs=973)
```

	hp	cc
hp	1.0000	
cc	0.8182	1.0000

Graphic 4.3: *First regression and correlation results*

The initial output, whose main results are reported in Graph 4.3, showed excessively high values for the Adjusted R-squared (0.9181) and related fit statistics. Although a high R-squared is often interpreted as a sign of good explanatory power, such an extreme value in the context of used vehicle pricing, raised clear concerns of overfitting. This suggests that the model might have been capturing noise rather than genuine structural relationships.
A second issue emerged regarding the final sample size. The number of valid observations was drastically reduced (391 compared to the initial 1000) due to the presence of missing values in the *Owners* variable. Since Stata performs listwise deletion by default, each row with a missing entry in any variable is excluded from the estimation. As a result, the inclusion of *Owners* restricted the usable dataset, potentially introducing bias and compromising the generalizability of the model.
Further analysis identified additional sources of instability, particularly related to correlation among independent variables. Stata automatically dropped the variable *Fuel* because it was mutually exclusive with *Cc*: electric vehicles, by definition, do not possess an engine displacement, leading to perfect separation between the two categories. Moreover, the correlation matrix confirmed a very strong linear association between *Hp* and *Cc* (corr = 0.8182). This was expected, as horsepower and engine displacement are closely related technical attributes, yet such high correlation introduces significant multicollinearity, making coefficient interpretation unreliable.
Overall, these findings clearly indicated that the initial model specification was not suitable for drawing meaningful conclusions. The combination of overfitting, reduced sample size, variable redundancy, and multicollinearity necessitated a systematic refinement of the model to ensure statistical robustness and interpretability.

To address these issues and develop a more reliable specification, several corrective actions were implemented. The first intervention concerned the removal of the variable *Cc*. Given its very strong correlation with *Hp*, retaining both variables would have perpetuated the multicollinearity problem and compromised the stability of the regression coefficients. Removing *Cc* allowed the model to retain the more informative and commonly used performance indicator, *Hp*, while mitigating the inflation of variance associated with redundant predictors.
A second modification involved the exclusion of the variable *Owners*. As previously noted, this variable contained a substantial number of missing values, which significantly reduced the sample size available for estimation. Since the inclusion of *Owners* did not provide essential explanatory contribution and had the undesirable effect of discarding more than half of the dataset, removing it enabled the restoration of the full sample of nearly 1000 observations. This step improved both the representativeness of the data and the robustness of the statistical analyses.

```
. reg actualprice priceofnew age km hp i.segment_i i.seller_i i.region_i i.brand_grp_i i.color_grp_i damages_b optional_b fuel_b
```

Source	SS	df	MS	Number of obs	=	968
				F(46, 921)	=	149.25
Model	2.7361e+10	46	594811671	Prob > F	=	0.0000
Residual	3.6705e+09	921	3985296.21	R-squared	=	0.8817
				Adj R-squared	=	0.8758
Total	3.1032e+10	967	32090790.8	Root MSE	=	1996.3

actualprice	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
priceofnew	.7770143	.0199313	38.98	0.000	.7378982	.8161304
age	-64.36917	12.25353	-5.25	0.000	-88.41725	-40.3211
km	-.0540386	.0040462	-13.36	0.000	-.0619794	-.0460978
hp	.6811563	2.689243	0.25	0.800	-4.5966	5.958912
segment_i						
Adventure	1159.45	233.7903	4.96	0.000	700.6263	1618.273
Cruiser	978.4632	288.1686	3.40	0.001	412.9199	1544.006
Offroad	215.0141	327.3685	0.66	0.511	-427.4607	857.489
Scooter	421.1514	258.3922	1.63	0.103	-85.95446	928.2573
Sport	169.0623	282.4107	0.60	0.550	-385.1808	723.3054
Touring	-441.4853	282.817	-1.56	0.119	-996.5259	113.5552
seller_i						
Authorized dealer	185.9464	155.093	1.20	0.231	-118.4303	490.3231
Reseller	-283.945	254.4331	-1.12	0.265	-783.281	215.391
Others ...						

```
. corr actualprice priceofnew hp
(obs=968)
```

	actual~e	priceo~w	hp
actualprice	1.0000		
priceofnew	0.8904	1.0000	
hp	0.6755	0.7842	1.0000

```
. estat vif
```

Variable	VIF	1/VIF
priceofnew	4.01	0.249489
age	1.80	0.556957
km	1.87	0.534948
hp	4.64	0.215444

Graphic 4.4: *Second regression and multicollinearity test results*

After applying the initial corrections, a second run of the regression model was performed. Although the new estimation produced more consistent and stable values compared to the first attempt, signs of overfitting still appeared to persist. To understand the source, a closer inspection of the correlation structure was carried out. The first observation concerned the strong linear relationship between *Actualprice* and *Priceofnew*. Such a high correlation suggested that the model was relying excessively on *Priceofnew* to explain the variation in the dependent variable, thus limiting the contribution of the other predictors. In addition to this, the expected correlation between this variable and *Hp* introduced a second issue. The multicollinearity test, based on the Variance Inflation Factor (VIF), confirmed this dependency: *Price-*

ofnew showed an inflated VIF value above conventional thresholds, indicating that its information overlapped with that of other vehicle characteristics, especially *Hp*. For these reasons, and despite being aware of the substantial reduction in predictive power that would follow, the variable *Priceofnew* was removed from the model. This choice made it possible to better evaluate the causal contribution of the remaining variables and to obtain a more interpretable and statistically balanced specification.

```
. reg actualprice age km hp i.segment_i i.seller_i i.region_i i.brand_grp_i i.color_grp_i damages_b optional_b fuel_b
```

Source	SS	df	MS	Number of obs	=	1,000
				F(46, 953)	=	43.99
Model	2.1664e+10	46	470960085	Prob > F	=	0.0000
Residual	1.0203e+10	953	10705734.6	R-squared	=	0.6798
				Adj R-squared	=	0.6644
Total	3.1867e+10	999	31898627.6	Root MSE	=	3272

```
. estat vif
```

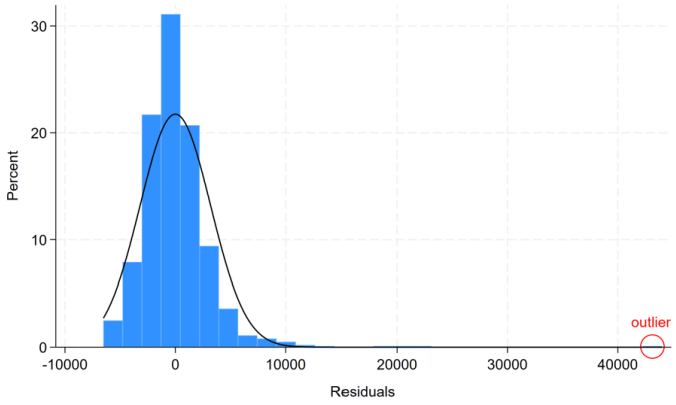
Variable	VIF	1/VIF
age	1.75	0.572718
km	1.67	0.597225
hp	2.57	0.388590

actualprice	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
age	-97.81444	16.85317	-5.80	0.000	-130.8881	-64.74083
km	-.0662374	.0061705	-10.73	0.000	-.0783467	-.054128
hp	72.61839	3.176619	22.86	0.000	66.38442	78.85237
segment_i						
Adventure	2832.72	374.9943	7.55	0.000	2096.81	3568.63
Cruiser	4180.07	453.7354	9.21	0.000	3289.634	5070.506
Moped	2517.85	2006.737	1.25	0.210	-1420.285	6455.985
Offroad	2159.679	528.339	4.09	0.000	1122.837	3196.521
Scooter	2417.375	414.519	5.83	0.000	1603.9	3230.851
Sport	1145.983	460.2597	2.49	0.013	242.7433	2049.222
Touring	3260.103	437.0673	7.46	0.000	2402.378	4117.829
seller_i						
Authorized dealer	-827.0027	246.6889	-3.35	0.001	-1311.119	-342.8865
Reseller	-1124.906	401.4423	-2.80	0.005	-1912.718	-337.0926
Others ...						

Graphic 4.5: *Third regression and multicollinearity test results*

A third regression was run. As expected, the predictive power of the model decreased compared to the previous specifications, with The Adjusted R-squared, previously above 0.87, dropping to a noticeably lower level (0.66). However, this reduction is not of concern for the primary objective of the analysis, which wants to focus on the identification of an econometric model, majorly capable of explaining the relationships between the dependent variable and its determinants.
The definition of a more accurate predictive model is intentionally postponed to the next subchapter, 4.3, where Machine Learning algorithms will be employed. These methods are better suited for prediction, as they can capture more complex patterns in the data than a linear econometric model.
In the following subsection, before moving to model presentation and results, robustness and significance diagnostics will be implemented. This includes the assessment of residual normality, tests for heteroskedasticity, and additional specification tests aimed at verifying the validity of the underlying assumptions. These analyses ensure that the final regression model is statistically suitable for causal interpretation.

4.2.3 Robustness tests and model developing

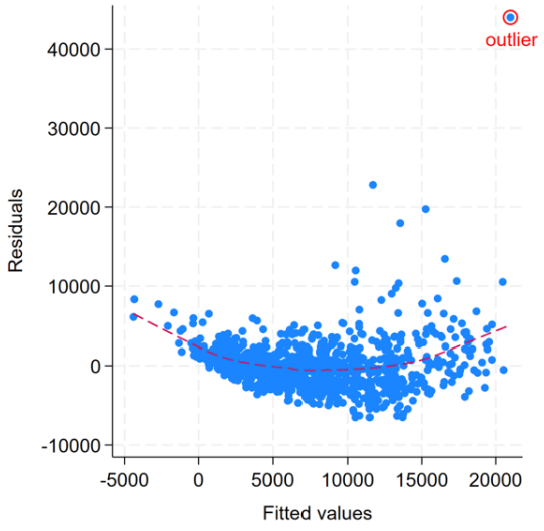



```
swilk residuals

                    Shapiro-Wilk W test for normal data

    Variable |   Obs        W           V          z       Prob>z
-------------+--------------------------------------------------
   residuals |  1,000    0.79949     126.461    11.986     0.00000
```

Graphic 4.6: *Residuals distribution*

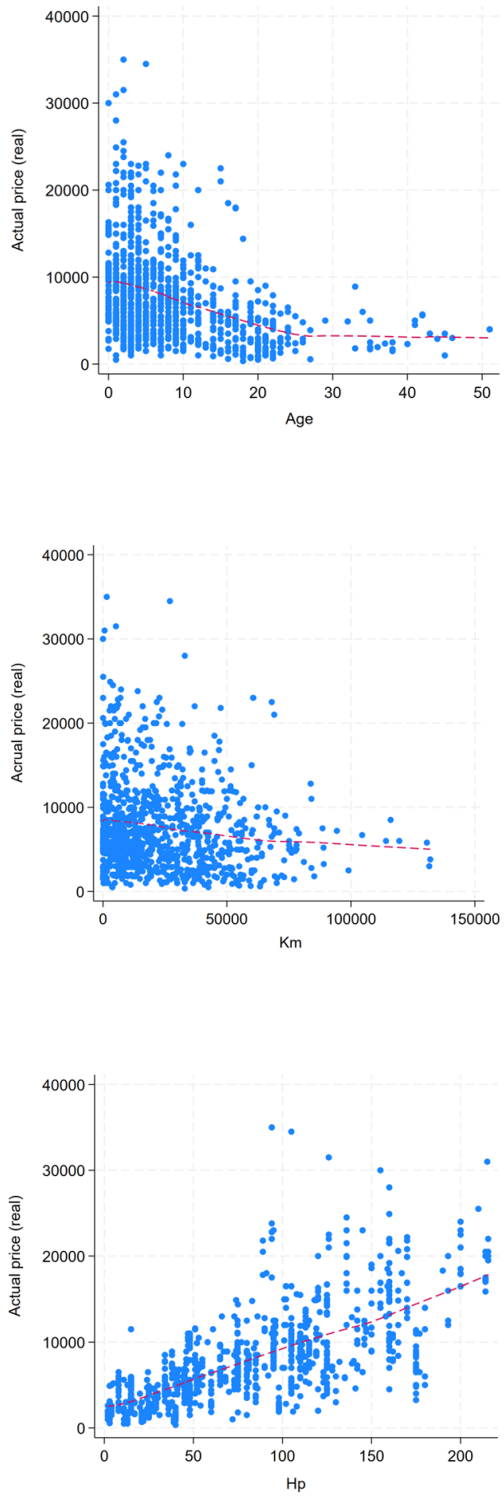



```
. estat ovtest

Ramsey RESET test for omitted variables
Omitted: Powers of fitted values of actualprice

H0: Model has no omitted variables      F(3, 950) =  79.89
                                        Prob > F =  0.0000
```

Graphic 4.7: *Scatterplot residuals–fitted values*



Graphics 4.8: *Variables correlation*

In order to assess the reliability of the initial regression model, a series of robustness checks were performed. The analysis of residuals (Graph.4.6) showed a clear violation of the normality assumption: the distribution exhibited a pronounced right tail driven by the presence of outliers, corresponding to premium motorcycles with exceptionally high prices. Graph.4.7 confirmed substantial heteroskedasticity, further amplified by the model's difficulty in handling high price values. The Lowess curve provided additional evidence of model misspecification: the curvature of the fitted residual trend suggested that the linear structure of the model was inadequate for capturing the true relationship between the variables.

To better understand the source of these issues, the correlations between the continuous regressors and the dependent variable were explored. The analysis revealed that *Km* and *Hp* exhibited reasonably linear relationships with price, whereas *Age* displayed a distinctly nonlinear pattern, characterized by a strong price decline during the first years, followed by a progressively flatter slope. This behavior indicated that a simple linear term for age is insufficient.

Based on these findings, corrective measures were implemented. First, the extreme outlier underlined in the graphs was removed due to its disproportionate influence on the model's error structure. Second, a quadratic term for age was introduced to properly capture the observed parabolic relationship between *Age* and *Actualprice*. Finally, the dependent variable was transformed using the natural logarithm. The log transformation improved the model by reducing heteroskedasticity, mitigating deviations from normality, and stabilizing the variance of the residuals, producing a more robust and interpretable specification.

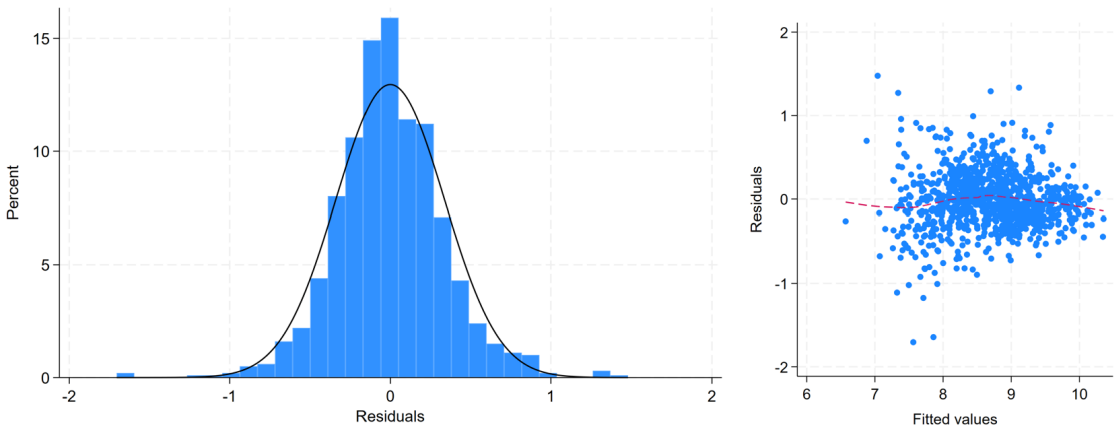
4.2.4 Final model overview

```
. reg log_actualprice age age_2 km hp i.segment_i i.region_i i.brand_grp_i i.color_gr
> p_i damages_b optional_b fuel_b seller_b, vce(robust)
```

log_actualprice	Coefficient	Robust std. err.	t	P>|t|	[95% conf.	interval]
age	-.0662329	.0045065	-14.70	0.000	-.0750768	-.057389
age_2	.0014227	.0001264	11.26	0.000	.0011747	.0016708
km_thousands	-.0045969	.0007078	-6.49	0.000	-.0059859	-.0032079
hp	.0084198	.0002496	33.73	0.000	.0079299	.0089097
segment_i						
Adventure	.2880643	.0314291	9.17	0.000	.2263859	.3497427
Cruiser	.4483161	.0477714	9.38	0.000	.3545666	.5420656
Moped	-.6446545	.3036538	-2.12	0.034	-1.240563	-.0487464
Offroad	.2994129	.043661	6.86	0.000	.2137299	.3850959
Scooter	.1054333	.045986	2.29	0.022	.0151877	.1956789
Sport	.0976599	.0386294	2.53	0.012	.0218514	.1734685
Touring	.358107	.0497224	7.20	0.000	.2605288	.4556852
region_i						
Abruzzo	-.1218289	.0847034	-1.44	0.151	-.2880559	.044398
Basilicata	.6802389	.5266912	1.29	0.197	-.3533709	1.713849
Calabria	-.0944914	.1654541	-0.57	0.568	-.4191883	.2302054
Campania	-.0304204	.0697636	-0.44	0.663	-.1673287	.1064878
Emilia Romagna	.0616392	.0345959	1.78	0.075	-.0062539	.1295322
Friuli Venezia Giulia	-.0993448	.1100229	-0.90	0.367	-.3152601	.1165706
Lazio	.1625475	.0477267	3.41	0.001	.0688858	.2562092
Liguria	.0776263	.0558908	1.39	0.165	-.0320572	.1873097
Marche	.0641248	.0560684	1.14	0.253	-.0459071	.1741567
Molise	-.0130767	.0566811	-0.23	0.818	-.124311	.0981576
Piemonte	.0877952	.0447241	1.96	0.050	.000026	.1755643
Puglia	-.025632	.0864998	-0.30	0.767	-.1953844	.1441204
Sicilia	.0290397	.1322998	0.22	0.826	-.2305933	.2886727
Toscana	.028084	.0367703	0.76	0.445	-.0440761	.1002442
TrentiNo Alto Adige	.0951543	.0805447	1.18	0.238	-.0629113	.25322
Umbria	-.1166328	.0660313	-1.77	0.078	-.2462165	.012951
Valle d'Aosta	.558819	.067834	8.24	0.000	.4256975	.6919405
Veneto	.1046163	.0520808	2.01	0.045	.0024098	.2068228
brand_grp_i						
bmw	.2299539	.0410093	5.61	0.000	.1494748	.3104329
ducati	.1231871	.0398317	3.09	0.002	.045019	.2013553
kawasaki	-.2050235	.0505668	-4.05	0.000	-.3042587	-.1057882
ktm	.1375934	.0511149	2.69	0.007	.0372825	.2379043
moto guzzi	.1693031	.0531371	3.19	0.001	.0650237	.2735826
other	-.0623611	.0573448	-1.09	0.277	-.174898	.0501757
piaggio	-.2468671	.0673563	-3.67	0.000	-.3790512	-.1146831
triumph	.2061565	.0532742	3.87	0.000	.1016081	.3107048
yamaha	.1170029	.0438658	2.67	0.008	.0309181	.2030878
color_grp_i						
colors	-.0236073	.0317036	-0.74	0.457	-.0858244	.0386098
grey	-.037213	.0360635	-1.03	0.302	-.1079861	.03356
multi	-.0125434	.0356401	-0.35	0.725	-.0824857	.0573989
white	-.0578183	.0400739	-1.44	0.149	-.1364617	.0208251
damages_b	-.4846652	.0748907	-6.47	0.000	-.631635	-.3376953
optional_b	.1009053	.0250454	4.03	0.000	.0517547	.1500559
fuel_b	-.2606527	.0677458	-3.85	0.000	-.393601	-.1277044
seller_b	-.0554979	.0266545	-2.08	0.038	-.1078063	-.0031895
_cons	8.288642	.056334	147.13	0.000	8.178088	8.399195

Graphics 4.9: *OLS - Regression model results*

The final regression model reflects the cumulative set of adjustments introduced throughout the diagnostic and refinement phase and represents the specification used for the conclusive analysis. These steps significantly enhanced the model capability, both in terms of fit and compliance with regression assumptions.
From a global perspective, the regression output shows that the model achieves a satisfactory level of explanatory power. The R-squared value (0.7930) indicate that a substantial share of the variation in motorcycle prices is explained by the included predictors, with a Root MSE at 0.34592. The diagnostic assessment of residuals in Graph.4.10 provides additional evidence of the improved model adequacy. The histogram reveals that residuals now approximate a normal distribution, with no excessive skewness or heavy tails. The log transformation of price played a crucial role in correcting this imbalance, compressing extreme values and yielding more symmetrical errors. Complementary insights arise from the residuals–fitted scatterplot. The dots pattern exhibits a broadly homogeneous cloud around zero, with no marked curvature or systematic deviation that would suggest functional misspecification. A slight increase in the spread of residuals at higher fitted values remains visible. The strong heteroscedasticity detected in the preliminary model has been reduced; the more uniform distribution of points confirms that the combination of transformation and model respecification successfully corrected the primary weaknesses highlighted during the robustness checks.
Overall, the final regression model integrates all necessary refinements and demonstrates consistent improvement across fit metrics, statistical significance, and diagnostic indicators. The outcome is a more reliable and interpretable specification, suitable for drawing considerations across the determinants of motorcycle prices.



Graphics 4.10: *Residual distribution and residual-fitted scatter*

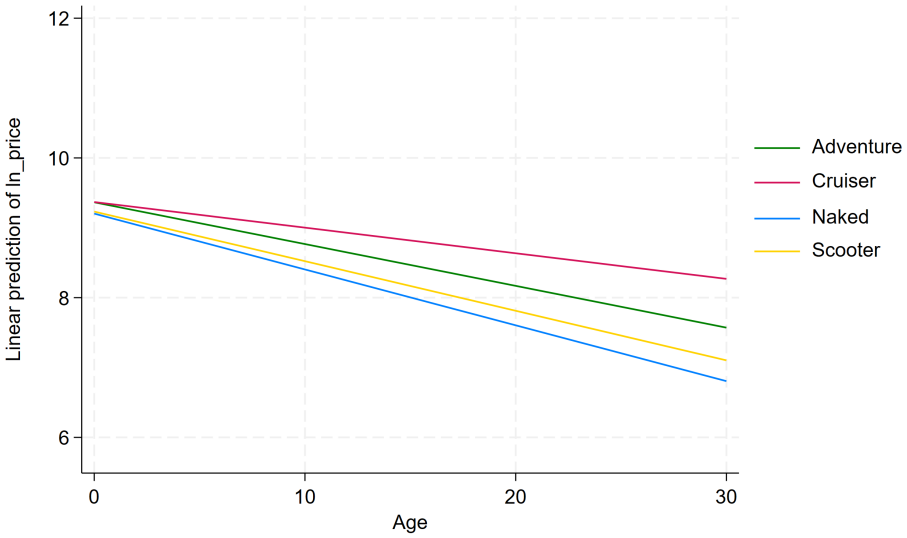
4.2.5 Results and considerations

$$
\begin{aligned}
\ln(\text{price}_i) \;&= \beta_0 + \beta_1 \text{Age}_i + \beta_2 \text{Age}_i^2 + \beta_3 \text{Km}_i + \beta_4 \text{Hp}_i \\
&\quad + \sum_{s=1}^{S-1} \gamma_s \, \text{Segment}_{is} + \sum_{r=1}^{R-1} \delta_r \, \text{Region}_{ir} + \sum_{b=1}^{B-1} \theta_b \, \text{Brand}_{ib} + \sum_{c=1}^{C-1} \eta_c \, \text{Color}_{ic} \\
&\quad + \beta_5 \text{Damages}_i + \beta_6 \text{Optional}_i + \beta_7 \text{Fuel}_i + \beta_8 \text{Seller}_i + \varepsilon_i
\end{aligned}
$$

Regression model formula

The final regression model provides a comprehensive explanation of the determinants of motorcycle prices, or in other terms, describes how the variables in examination compound into determining the price of a motorcycle in the used market. All the necessary considerations could be done observing the Graph.4.9 in the previous page. Starting from continuous variables, these show coherent patterns supported by strong statistical significance. *Age* has a negative linear coefficient (–0.0662, $p < 0.001$) and a positive quadratic term (0.001422, $p < 0.001$). In a log-linear model, this means that each additional year initially reduces the predicted price by about 6.4%, but the quadratic term progressively attenuates this effect as the motorcycle becomes older. In practical terms, depreciation is steep in the first years, reflecting rapid loss of value for nearly new motorcycles, but gradually stabilizes for older.
Km have a small but statistically strong effect ($p < 0.001$). Every additional 1,000 km reduces the predicted price by approximately 0.46%. Thus, a motorcycle with 20,000 km more than another comparable model would be priced roughly 9% lower, illustrating the economic relevance of usage even when the marginal coefficient appears numerically small.
Hp shows a strong and highly significant positive coefficient (0.00842, $p < 0.001$). Interpreting this value implies that each additional horsepower increases the predicted price by about 0.84%. This effect accumulates rapidly across engine classes: a 30 horsepower difference between two models corresponds to an approximate 28–30% higher predicted price, confirming that performance oriented motorcycles are priced higher that the others segments.
Shifting to the binary variables, also these translate into clear and significant effects. The coefficient for *Damages* (–0.4847, $p < 0.001$) implies that motorcycles reporting defects or repairs experience a 38% lower predicted price on average . This is one of the largest effects and highlights how buyers heavily penalize uncertainty.
Optional equipment instead increases predicted value by 10.6%, confirming the market relevance of accessories, enhanced features, and added comfort.
Seller dummy is also significant: motorcycles sold by private individuals have a predicted price approximately 5.4% lower than those sold by professionals, consistent with differences in guarantees, reliability, and negotiation power.
Fuel type shows an unpredicted negative coefficient (–0.26065, $p < 0.001$), which corresponds to a 23.4% lower predicted price for electric vehicles. This unexpected negative effect is likely driven by the composition of the sample. Most electric mo-

torcycles in the dataset belong to entry level or low performance categories, which naturally have lower prices compared to the petrol models included in the analysis. The categorical variables coefficients support the market analysis done in previous chapters. Using Naked as the baseline segment and Honda as the baseline brand, the results confirm the expected price hierarchy: premium segments and brands display positive and significant coefficients, while lower categories show minor valuations.
When examining regional effects using Lombardia as the baseline category, only two regions show statistically significant differences. Lazio exhibits a sizeable premium, with predicted prices approximately 17.6% higher, while Piemonte shows a smaller and borderline significant increase of around 9.2%. All other regions display p-values above 0.05, indicating no statistically detectable difference from Lombardia. This could be caused by the fact that most regions are represented by a relatively small number of observations in the dataset, which reduces statistical power and makes it harder to detect significant price differences compared to the baseline.
Finally, color categories exhibit no explanatory power. Most color dummies are statistically insignificant, indicating that this characteristic probably has no impact.
More interesting considerations can be drawn by introducing interaction terms as in Graphics 4.11-12 showed in the next page. The interactions between age and motorcycle segments for example, allow a more precise evaluation of how the relationship between age and price varies across different categories. In the current specification, the baseline age effect corresponds to the Naked segment, which acts as the omitted category. Its coefficient indicates that, within the cross-section of used motorcycles listed on the market, an additional year of age is associated with an average price reduction of approximately 8% (coefficient = –0.07994, $p < 0.001$).
When comparing other segments to this reference, clear heterogeneity in the age–price gradient emerges. Cruiser motorcycles display a substantially weaker sensitivity of price to age, with an interaction effect of +0.04327, which reduces the magnitude of the baseline slope to approximately –3.67% per additional year ($p < 0.001$). This suggests that, in the current used market, the price difference between newer and older Cruisers is smaller than for Naked motorcycles, likely reflecting greater durability, more stable demand, and a customer base less influenced by model-year differences. Adventure models also show a milder age effect relative to Naked motorcycles. Their interaction term (+0.02012, $p = 0.025$) yields an effective slope of roughly –6% per additional year, rather than –8%. This attenuated gradient may reflect stronger market demand, broader usability, and higher initial prices, which tend to stabilise valuations even for older units. Scooters, despite exhibiting a statistically significant interaction effect (+0.00895, $p = 0.041$), remain close to the baseline, with an implied age effect of approximately –7.1%. This is coherent with their utilitarian nature, where price variation is driven predominantly by age and usage rather than segment-specific attributes.
Other segments, such as Offroad, Sport, Touring and Moped, do not present statistically significant interaction effects (all $p > 0.10$). This implies that their age–price relationship is statistically indistinguishable from that of the Naked segment.
Same thing could be done for segments. The interaction analysis between brand and age reveals in fact differences in how price varies with age across manufacturers. The baseline category is Honda, meaning that all coefficients are interpreted relative



Graphic 4.11: *Differences in price reduction between segments*

log_actualprice	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
age	-.0729013	.0067985	-10.72	0.000	-.0862429	-.0595598
brand_grp_i#c.age						
bmw	.0173677	.0065225	2.66	0.008	.0045678	.0301675
ducati	.006291	.0072915	0.86	0.388	-.008018	.0205999
kawasaki	.0183806	.0071253	2.58	0.010	.0043978	.0323635
ktm	-.0147261	.0151338	-0.97	0.331	-.044425	.0149728
moto guzzi	.0020234	.0058695	0.34	0.730	-.0094951	.013542
other	.0345064	.0109519	3.15	0.002	.0130142	.0559987
piaggio	.0188614	.0049775	3.79	0.000	.0090934	.0286294
triumph	.0050971	.0107035	0.48	0.634	-.0159078	.0261019
yamaha	-.0122886	.0060039	-2.05	0.041	-.0240708	-.0005064

Graphic 4.12: *Differences in price reduction between brand*

to Honda's age slope (approximately –0.073 per year). Other brands ?
Yamaha exhibits the strongest age sensitivity (interaction = –0.0123, p = 0.041), producing an effective slope of –0.0852. This indicates that the price gap between newer and older Yamaha motorcycles widens more rapidly than for Honda. Piaggio shows an even steeper decline (interaction = –0.0189, p ¡ 0.001), yielding the highest age sensitivity in the sample (–0.0918). This pattern is consistent with scooter-oriented brands, where older age tends to strongly depress used-market valuations. KTM also shows a relatively steep effective slope, although its interaction coefficient is not statistically significant. In contrast, BMW exhibits a much milder decline with age (interaction = +0.0174, p = 0.008), corresponding to an effective slope of –0.0555. Kawasaki also shows a flatter profile (interaction = +0.0184, p = 0.010), with an effective slope of –0.0545. Moto Guzzi presents an interaction coefficient close to zero (+0.0020, p = 0.730), indicating an age–price relationship broadly comparable to Honda's. It's important to note that these effects do not represent depreciation from new vehicle retail prices, but rather differences in how used-market valuations respond to ageing. The interaction terms capture relative age sensitivity across brands: Yamaha and Piaggio display the strongest age effects, whereas BMW and the "Other" group maintain more stable used-market valuations over time.

4.2.6 Regression conclusions

The regression model provides a coherent and economically meaningful explanation of the determinants of second-hand motorcycle prices. Continuous variables behave as expected: age represents the strongest driver of price differences, with an average reduction of approximately 8% per additional year, while mileage shows a weaker but still significant negative effect. Power contributes positively and consistently, confirming the premium associated with higher-performance engines.
Categorical variables further refine this picture. Damage history leads to substantial price discounts, optional equipment increases valuations, and professional sellers are associated with slightly higher prices than private ones. Colour has no significant impact, while some regional markets exhibit mild differences relative to Lombardia.
Introducing interaction terms reveals a clearer structure in how prices are formed. Segments and brands do not simply differ in their average price levels, they differ in how sensitive their prices are to age. Cruiser and Adventure models show a notably flatter age–price gradient, meaning that the price gap between newer and older units is smaller. Conversely, Naked and Scooter follow steeper profiles. A similar pattern emerges among brands: manufacturers associated with premium positioning, heritage identity or strong reputation (such as BMW) show weaker age sensitivity, while brands serving the commuter (such as Piaggio) exhibit faster price declines.
These findings highlight how both functional characteristics and perceived brand positioning jointly shape market valuations in the second-hand motorcycle sector.

4.3 MACHINE LEARNING MODEL

The use of machine learning techniques, thanks to their ability to detect nonlinear relationships, has become one of the most widespread and effective approaches for tackling complex prediction problems. Broadly speaking, machine learning can be defined as a collection of algorithms and methods that enable a computer system to "learn" from data, gradually improving its predictive accuracy without being explicitly programmed with fixed rules. This makes machine learning particularly suitable for forecasting tasks, where the main objective is to maximise predictive performance rather than interpret the contribution of each individual variable.
However, this characteristic also represents one of the major limitations of machine learning when the goal is to understand the underlying relationships among variables. Unlike linear regression, they often behave as black boxes: they generate highly accurate predictions but do not provide a transparent explanation of how each predictor influences the outcome. For this is the reason why this thesis used both, the regression model to underline major causal effects, and this machine-learning model to optimize prediction capacity.
The platform used to build the model was Orange, a visual data-mining and machine-learning platform built in Python. Orange allows the construction of analytical workflows through an intuitive graphical interface, enabling the combination of algorithms, data transformations, and diagnostic tools without writing code. This flexibility makes it especially useful for rapidly comparing different models, evaluating performance metrics, and optimising training and testing procedures.
In the following section, the selected models will be presented, along with the structure of the workflow, the evaluation metrics adopted, and the results obtained.

4.3.1 Model developing

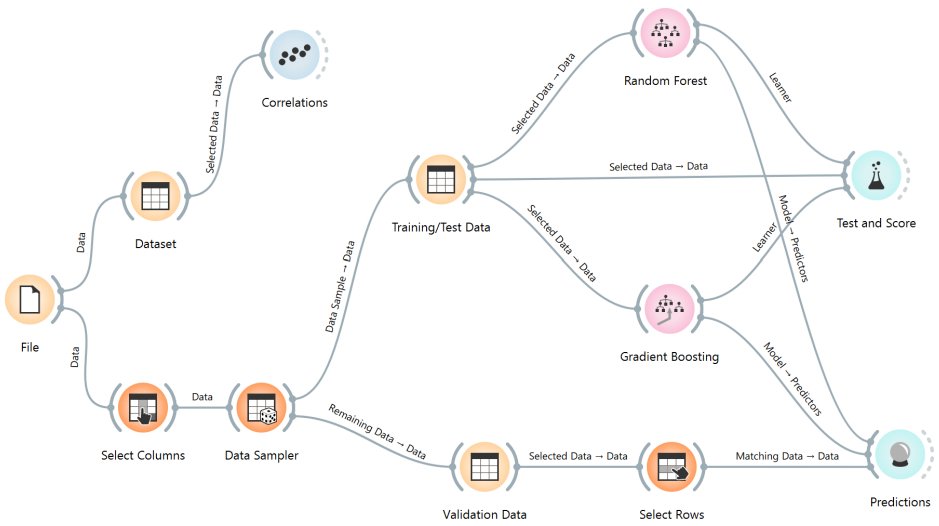


Figure 4.13: *Orange's graphic interface*

As already said, the analysis was carried out using Orange's graphical interface, following the workflow illustrated in Figure 4.13. First, the dataset was imported and all variables were inspected to ensure their format (continuous, categorical or meta) and that the target variable, *Actual Price*, was properly defined.
After this stage, some predictors were excluded from the modelling phase. In particular, *Trim* was removed because it generated an extremely high number of categories with very few observations each, introducing instability and limited interpretative value. Moreover, *Cc* and *Price of new* were discarded due to their very high Pearson correlations with *Actual Price*, which would have led the model to rely heavily on information that is either conceptually redundant or not easily available in real world prediction scenarios. In contrast, the variable *Number of owners* was retained even though it contained missing values, since the selected learners in Orange are able to handle incomplete entries without eliminating the corresponding rows.
Subsequently, a Data Sampler widget was used to split the original dataset into two subsets: an 80% sample employed for model training and internal testing, and the remaining 20% reserved as an external validation set. This procedure makes it possible to train and tune the models on one portion of the data while assessing their predictive performance on observations that were not used in the learning phase.
Two machine-learning models were selected: Random Forest and Gradient Boosting. These algorithms are among the most widely used ensemble methods for regression tasks, and they were chosen due to their ability to capture complex nonlinear relationships between predictors and target variable. Random Forest works by constructing a large number of de-correlated decision trees and averaging their predictions, which reduces variance and increases robustness against noise and overfitting. Gradient Boosting, in contrast, builds trees sequentially, each one correcting the errors of the previous one, allowing the model to approximate complex functions and achieve strong predictive performance even with relatively simple base learners.
Both models were tuned using Orange's interface, following the settings shown in Figure 4.14. For Random Forest, the number of trees was set to 100, a value high enough to ensure stable predictions without excessively increasing computation time. Tree growth was controlled by preventing splits on subsets smaller than 5 observations, which helps reduce overfitting by avoiding branches created from very small groups of data. No limit was imposed on tree depth, allowing the model to fully exploit the available structure in the dataset. For Gradient Boosting, the ensemble was also trained with 100 trees, combined with a learning rate of 0.10, a standard compromise that balances model flexibility and generalisation. The depth of individual trees was limited to 3, encouraging the model to learn small, incremental improvements rather than overly complex splits. Additionally, minimum leaf size was set to 2, and the full training sample (100% of instances) was used at each boosting iteration, ensuring consistent optimisation.
Once both models were trained, their predictive performance was evaluated through the "Test and Score" widget, applying a 5 cross-validation procedure. This method provides a reliable assessment of how the models generalise to unseen data by repeatedly training on different subsets and testing on the remaining folds.
To conclude validation has been performed on the relative subset using the "Predictions" widget. Both testing and validation will be discussed in the next paragraph.

4.3.2 Model results

Model	MSE	RMSE	MAE	MAPE	R2
Gradient Boosting	5989631.795	2447.372	1441.766	25.889	0.804
Random Forest	5850460.224	2418.772	1291.046	21.985	0.808

Figure 4.14: *Testing results*

	MSE	RMSE	MAE	MAPE	R^2
General (all data)	7549671,61	2747,667	1661,565	27,205	0,797
Adventure	9552936,1	3090,782	2182,413	14,358	0,645
Cruiser	12653327,2	3557,152	1775,907	17,199	0,732
Naked	2610354,05	1615,659	1230,532	30,247	0,722
Offroad	2502526,65	1581,938	1228,033	28,072	0,611
Scooter	1269879,57	1126,889	933,81	39,933	0,808
Sport	6267102,25	2503,418	2004,913	25,925	0,805
Touring	25645176,2	5064,107	3053,394	24,523	0,613

Figure 4.15: *Validation results*

The results from the testing are shown in figure 4.14. Both algorithms achieve comparable accuracy, with Random Forest providing slightly better average error metrics. Specifically, Random Forest reached an RMSE of approximately 2,418 and an MAE of 1,291, while Gradient Boosting reported an RMSE of 2,447 and an MAE of 1,442. The corresponding coefficients of determination were 0.808 and 0.804, respectively. These values indicate that both methods explain around 80% of the variability in used-motorcycle prices and achieve error magnitudes that align with the inherent heterogeneity of the second-hand market.
To better understand the comparative behaviour of the models, Orange's Compare Models tool was used to analyse their performance fold-by-fold. Interestingly, despite Random Forest having slightly lower average errors, Gradient Boosting outperformed it in the vast majority of cross-validation folds. For example, when comparing Mean Absolute Error, Gradient Boosting achieved a relative score of 0.957, meaning that it produced lower MAE in almost 96% of the folds, whereas Random Forest outperformed it in only 4%. This result reflects a difference in model behaviour: Gradient Boosting is more stable, providing consistently good performance across folds, whereas Random Forest is more variable, occasionally achieving very low error but also performing less accurately in most iterations.
As already said an independent evaluation was conducted using the 20% external validation set that had been kept aside during sampling. Given its more stable behaviour in cross-validation, only the Gradient Boosting model was subjected to this final prediction test. The results confirm the model's ability to generalise to unseen data: Gradient Boosting achieved an RMSE of approximately 2,747, an MAE of

1,662, and an R^2 of 0.797. Although the metrics are slightly weaker than those obtained before, as expected when evaluating on new observations, the performance remains solid and coherent with the model's behaviour during testing.
Filtering by segment, predictive accuracy varies substantially across motorcycle categories. Scooters achieve the best performance, with the lowest RMSE and the highest R^2 (0.808), indicating that their market prices follow more regular and homogeneous patterns. In contrast, Adventure, Cruiser, and especially Touring motorcycles exhibit higher errors and lower explanatory power, reflecting greater variability in price drivers such as engine size, equipment, and customisation. Naked, Offroad, and Sport segments show intermediate performance, with moderate R^2 but relatively high MAPE, suggesting notable dispersion in actual prices. Overall, the results confirm that some segments, particularly premium or highly customisable ones, are intrinsically harder to predict, while more standardised categories yield more reliable estimates.

4.3.3 Machine-learning conclusions

The results obtained from the machine-learning analysis clearly show that ensemble methods, and Gradient Boosting in particular, offer superior predictive performance compared to the regression model developed in the previous section. While the econometric approach provides interpretability and allows the identification of causal relationships, its predictive accuracy is limited by the linear structure of the model and by the assumptions required for inference.
In contrast, the machine-learning models demonstrated a strong ability to capture nonlinear patterns and complex interactions among variables, achieving substantially lower prediction errors and higher explanatory power. Gradient Boosting proved especially effective, showing remarkable stability across cross-validation folds and maintaining solid performance even when applied to the external validation set. This consistency confirms its robustness and suitability for real world prediction scenarios, where the priority is the accuracy of the estimated price rather than the interpretability of individual coefficients.

Conclusions

This thesis examined the motorcycle market with the aim of describing it and identify the main economic determinants that shape used motorcycle prices, assessing the reliability of predictive tools based on statistical and machine-learning models. The work combined a structured descriptive analysis of the market with an empirical investigation built on a dataset of listings collected from the platform Moto.it.
The results of Chapters 2 and 3 provide a clear and structured picture of the motorcycle sector and its second-hand market, forming the foundation for the empirical work that follows. Chapter 2 shows that the global motorcycle market is highly heterogeneous: in Asian countries, two-wheelers remain essential for daily mobility, while in Europe, and particularly in Italy, they increasingly represent leisure oriented products. Italy stands out as one of the largest and most dynamic European markets, with steady growth in registrations over the last decade and strong demand for medium and large displacement motorcycles, especially in the Naked and Adventure segments. At the same time, the adoption of electric models remains limited, constrained by high prices, infrastructure gaps and the continued optimization of internal combustion vehicles under Euro 5bis regulations.
Chapter 3 confirms the centrality of the used motorcycle market in Italy. ACI data show that ownership transfers consistently exceed new registrations, demonstrating the resilience of the second-hand segment even in periods of economic uncertainty. Regional differences are pronounced: Northern regions dominate in absolute volumes thanks to higher purchasing power, while Southern regions show a higher relative dependence on used vehicles. Smaller and mid-sized motorcycles (up to 400 cc) are the most frequently transferred, reflecting affordability and practicality, whereas online listings—particularly on Moto.it—are dominated by medium and large displacement models from brands such as Honda, BMW Motorrad and Yamaha. The strong presence of professional sellers, accounting for around 70% of listings, highlights the increasing professionalization and transparency of the digital market.
Building on this foundation, Chapter 4 introduced the empirical core of the thesis through the development of two complementary methodological approaches: a non-linear regression model, designed to identify and interpret the main drivers of price formation, and a machine-learning model, aimed at maximizing predictive accuracy. The results highlight that age, mileage, and horsepower are among the most influential variables in determining second-hand prices. Regression analysis also revealed significant differences across segments and brands in terms of age dependency: Cruiser and Adventure motorcycles, as well as brands with strong heritage or premium positioning, tend to lose value more slowly increasing the age of the vehicle, whereas scooters and commuter-oriented manufacturers display steeper declines. Additional factors such as optional equipment, seller type, and reported damages showed effects consistent with economic intuition and with the descriptive findings. While regression provide effective causal explanation on price variables, the Gradient Boosting model achieve substantially higher predictive performance compared to the first one, thanks to its ability to capture non-linear relationships and complex variable interactions. With an R^2 close to 0.80 on the external validation set, the

model demonstrates that, despite the intrinsic heterogeneity of the used motorcycle market, it is possible to build predictive tools that deliver reliable and actionable estimates. This opens the door to potential applications such as automated valuation tools, support systems for private buyers and retailers, and algorithms for online marketplaces capable of identifying anomalies or highlighting advantageous listings. Despite the encouraging results, some limitations must be acknowledged. The manually collected dataset, although carefully constructed, may suffer from selection biases, particularly in the representation of brands and models. The market's inherent variability also makes it difficult to fully account for subjective or non-observable factors such as actual maintenance conditions or the presence of non declared modifications. In addition to this, the parabolic relation imposed on the Age variable, doesn't fit perfectly, supposing an increase in prices when the age of a motorcycle exceeds a certain amount. But the more important limitation is the fact that the analysis conducted in this thesis focuses on price levels rather than on true depreciation trajectories. Since reliable and complete "price of new" information was not consistently available for all models, the study could only infer relative depreciation patterns by comparing price differences across segments and brands while controlling for age and mileage. This approach is useful for identifying systematic differences in value retention, but it does not allow the estimation of an absolute depreciation curve. Obtaining accurate and comprehensive data on the original retail price would make it possible to compute absolute depreciation, which could be more informative from an economic and managerial perspective. Future research could improve upon these aspects by automating the data collection process through web scraping. Extending the analysis to other platforms, comparing international markets, or tracking price changes over time could also provide valuable longitudinal insights.