

THE IMPACT OF INFLATION ON THE U.S.
AUTOMOTIVE INDUSTRY

BY

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ABSTRACT

In recent years, global inflationary pressures have intensified, and the high costs of raw materials, energy, and logistics for production have made the automotive industry face severe challenges in both the supply chain and market demand. Against this backdrop, it is crucial for industry practitioners and policymakers to quantitatively assess the impact of inflation on the automotive industry and find strategies to deal with it. Hence, this study examines the impact of inflation on the U.S. automotive industry, focusing on the short-run and long-run impact of the dynamics of inflation and other macroeconomic variables such as the Producer Price Index (PPI), energy prices, and interest rates on the U.S. automotive industry. In examining the objectives, this study employs the Autoregressive Distributed Lag Model (ARDL) with quarterly data from the third quarter of 2004 to the third quarter of 2024. The findings of the study reveal that inflation has a significant negative impact on the U.S. automotive industry in the long run, indicating that when the aggregate price level continues to rise, consumers' disposable income and consumer confidence weaken, which in turn suppresses the demand for auto purchases. However, the study finds that inflation does not significantly impact the industry in the short run. In addition, changes in energy prices and interest rates also have different degrees of impact on car sales in different periods: in the short term, fuel price fluctuations can magnify the cost of car purchases or prompt consumers to switch to more energy-efficient models; while interest rate increases tend to increase financing costs, but to a certain extent, they also go hand in hand with economic expansion and job growth, which may have a double effect on car demand.

Keywords: Inflation, U.S. Automotive Industry, ARDL, Cointegration

ملخص البحث

في السنوات الأخيرة، اشتدت الضغوط التضخمية العالمية، كما أدت التكاليف المرتفعة للمواد الخام والطاقة والخدمات اللوجستية اللازمة للإنتاج إلى جعل صناعة السيارات تواجه تحديات شديدة في كل من سلسلة التوريد والطلب في السوق. وعلى هذه الخلفية، من الأهمية بمكان أن يقوم ممارسو الصناعة وصناع السياسات بتقييم تأثير التضخم على صناعة السيارات كميًا، وإيجاد استراتيجيات للتعامل معه. ومن ثم، تدرس هذه الدراسة تأثير التضخم على صناعة السيارات الأمريكية، مع التركيز على التأثير القصير والطويل الأجل لديناميكيات التضخم والمتغيرات الاقتصادية الكلية الأخرى، مثل مؤشر أسعار المنتجين وأسعار الطاقة وأسعار الفائدة على صناعة السيارات الأمريكية. في دراسة الأهداف، تستخدم هذه الدراسة نموذج الانحدار التلقائي الموزع ((Autoregressive Distributed Lag (ARDL)) مع بيانات ربع سنوية من الربع الثالث من عام 2004م إلى الربع الثالث من عام 2024م. تكشف نتائج الدراسة أنّ التضخم له تأثير سلبي كبير على صناعة السيارات الأمريكية في الأمد البعيد، مما يشير إلى أنه عندما يستمر مستوى السعر الإجمالي في الارتفاع، فإنّ الدخل المتاح للمستهلكين وثقة المستهلك يضعفان، مما يؤدي بدوره إلى قمع الطلب على مشتريات السيارات. ومع ذلك، وجدت الدراسة أنّ التضخم لا يؤثر بشكل كبير على الصناعة في الأمد القريب. بالإضافة إلى ذلك، فإنّ التغيرات في أسعار الطاقة وأسعار الفائدة لها أيضًا درجات مختلفة من التأثير على مبيعات السيارات في فترات مختلفة: في الأمد القريب، يمكن أن تؤدي تقلبات أسعار الوقود إلى تضخيم تكلفة شراء السيارات أو دفع المستهلكين إلى التحول إلى نماذج أكثر كفاءة في استخدام الطاقة؛ في حين تميل زيادات أسعار الفائدة إلى زيادة تكاليف التمويل،

ولكن إلى حد ما، فإنها تسير جنبًا إلى جنب مع التوسع الاقتصادي ونمو الوظائف، مما قد يكون له تأثير مزدوج على الطلب على السيارات.

الكلمات المفتاحية: التضخم، صناعة السيارات في الولايات المتحدة، ARDL،

التكامل المشترك



APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Finance

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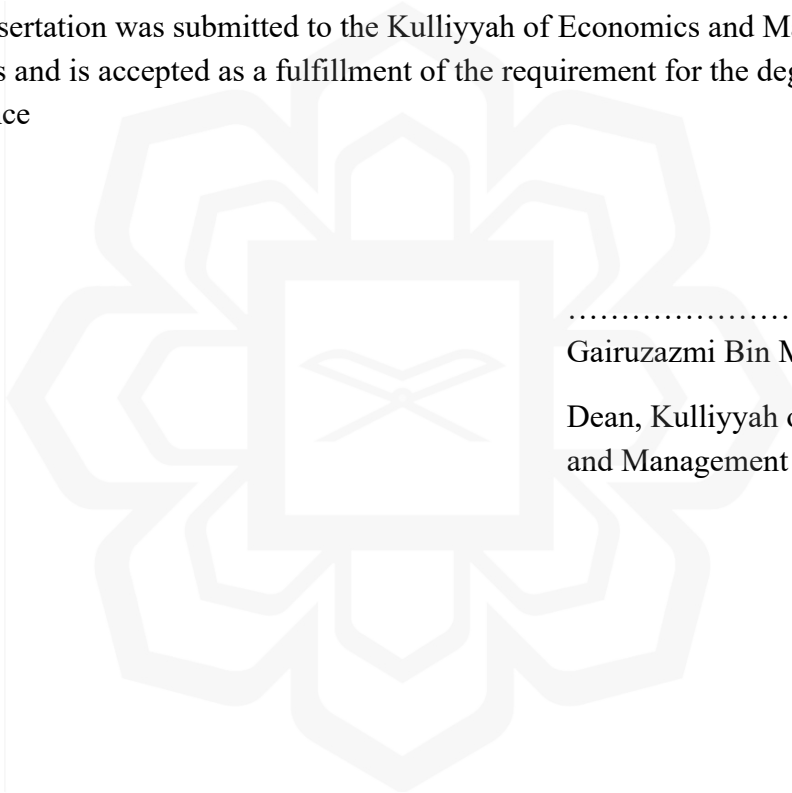
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and Management Sciences

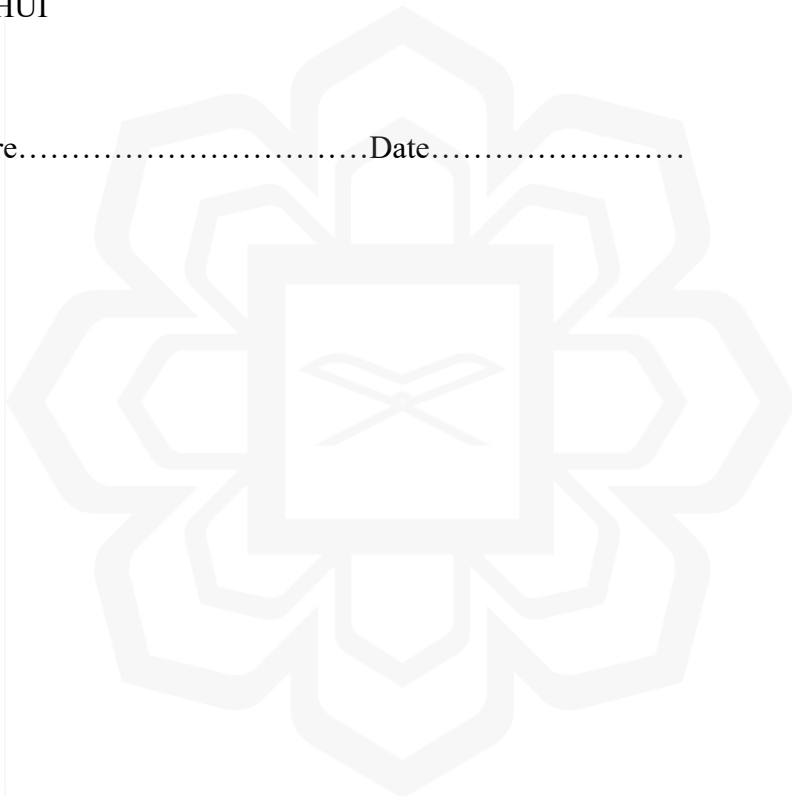


DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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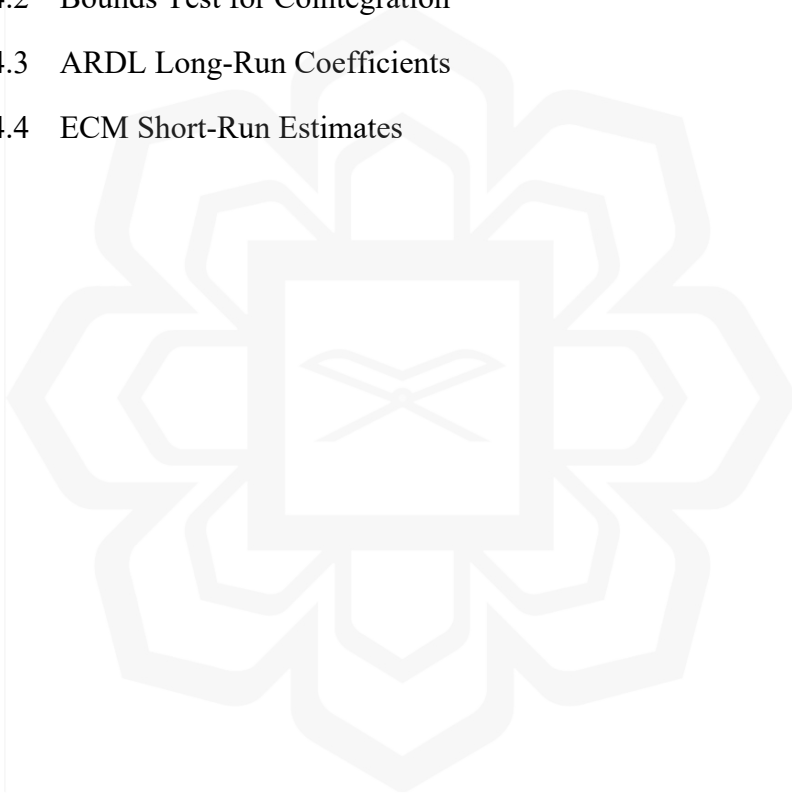
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LIST OF SYMBOLS

α_0	quad Baseline vehicle sales in the absence of external macroeconomic influences (intercept term)
β_1	quad Estimated coefficient measuring the effect of inflation on total vehicle sales (TVS)
β_2	quad Estimated coefficient measuring the effect of interest rates on TVS
β_3	quad Estimated coefficient measuring the effect of energy prices on TVS
β_4	quad Estimated coefficient measuring the effect of the Producer Price Index (PPI) on TVS
β_5	quad Estimated coefficient measuring the effect of the COVID-19 pandemic (Dummy2020) on TVS
ε_t	quad Error term accounting for unobserved factors, model discrepancies, and random shocks
TVS_t	quad Total Vehicle Sales at time t
CPI_t	quad Consumer Price Index at time t , representing inflation
$InterestRate_t$	quad Interest rate at time t
$EnergyPrice_t$	quad Energy price at time t
PPI_t	quad Producer Price Index at time t
$Dummy2020$	quad Binary variable representing the COVID-19 pandemic (1 for 2020, 0 otherwise)
Δ	denotes the first-difference operator
$TVSt$	are total vehicle sales
CPI_t	is the consumer price index for new vehicles
IRt	is the interest rate

GPt	is the gasoline price
PPI_t	is the producer price index
$Dummy_{2020t}$	is the binary variable controlling for pandemic effects
τ	is the coefficient of the error correction term $ECT_{(t-1)}$



ARDL	Autoregressive Distributed Lag Model
CPI	Consumer Price Index
DXY	U.S. Dollar Index
ECM	Error Correction Model
EV	Electric Vehicle
GDP	Gross Domestic Product
IR	Interest Rate
IMF	International Monetary Fund
PPI	Producer Price Index
TVS	Total Vehicle Sales



CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Inflation is one of the most critical macroeconomic indicators affecting the global economy, industrial costs, and consumer purchasing behaviour. In recent years, inflationary pressures have intensified due to multiple factors. The International Monetary Fund (2022) highlighted that global inflation in 2022 was among the most severe since the 1970s. The ongoing geopolitical crisis, supply chain disruptions, and expansionary monetary policies have collectively fueled inflation (IMF, 2022). Rising energy and raw material costs have significantly increased production expenses across industries, including the automotive sector (OECD, 2021).

From a production standpoint, inflation influences the automotive industry mainly through cost-push inflation (Blanchard, 2018; Mankiw, 2020). Higher input prices—such as raw materials, logistics, and labour—directly increase manufacturing costs (Handfield & Nichols, 1999; Christopher, 2016). As production expenses rise, manufacturers may adjust pricing strategies or seek cost-cutting measures, which can affect vehicle affordability and overall market supply (OECD, 2021). Additionally, persistent inflation can alter aggregate demand; when consumers experience higher living costs, their discretionary spending capacity declines, which may impact purchasing durable goods, including automotive (IMF, 2022).

In this study, we focus on the U.S. automotive industry, in which major domestic manufacturers such as General Motors, Ford, and Stellantis, as well as global brands like Toyota, Honda, and Volkswagen, are significantly impacted by inflation. The automotive industry plays a crucial role in national economic output and employment—contributing nearly US \$1 trillion to U.S. GDP and supporting about 9.6 million jobs—while spanning manufacturing, assembly, distribution, retailing, and after-sales services (Alliance for Automotive Innovation, 2022). According to the Alliance for Automotive Innovation (2024), the industry supports approximately 9.6 million direct and indirect jobs and contributes nearly 5% to the U.S. GDP, amounting to over \$1 trillion in total economic output. Furthermore, industry data show that U.S. auto sales reached about 15.4 million units in 2023, reflecting a 9% year-over-year increase (Cox Automotive, 2024). These figures underscore the sector’s central role in both employment and consumer spending. However, the industry remains highly sensitive to macroeconomic fluctuations, particularly inflation. As it relies heavily on raw materials such as steel and aluminium, inflation-driven increases in input costs reduce profit margins and disrupt supply chain efficiency. In addition, energy prices—especially oil—directly affect manufacturing expenses and the affordability of vehicle ownership, making fuel costs a key determinant of consumer demand.

In a market environment where auto consumption is highly dependent on loans, rising prices not only compress corporate profit margins, but also directly undermine the ability of ordinary families to purchase cars. Taking the Federal Reserve Board (2022) policy movement as an example, when the inflation index climbs, the central bank will often raise interest rates by means of suppressing prices. The knock-on effect of such regulatory measures is obvious - higher interest rates can put a heavier interest burden on consumers who take out loans to buy cars, a situation that can both delay the decision-making time of potential buyers and prompt them to switch to more affordable

budget models. After all, buying a car is a big expense for most families that requires careful consideration compared to everyday necessities.

In short, we examine the impact of inflation on the automotive industry as well as the dynamics of multiple economic variables in depth by focusing on short-run and long-run impacts. By analysing the interactions among these factors, we aim to provide a complete picture of how inflationary pressures impact the total U.S. automotive industry.

1.2 BACKGROUND OF U.S. AUTOMOTIVE INDUSTRY

The automotive industry in the U.S. accounts for more than 9.6 million jobs in manufacturing, sales, and related sectors, contributing about 3% of the U.S. GDP (Harp & Prasad, 2024). The industry includes major domestic manufacturers such as General Motors, Ford, and Stellantis, as well as global brands like Toyota, Honda, and Volkswagen. Strong demand for light trucks and SUVs—which comprised over 75% of total sales in 2023—drove U.S. auto sales to 15.4 million units, a 9% year-on-year increase (J.D. Power, 2024). However, despite this growth, inflationary pressures and rising interest rates have significantly impacted vehicle affordability. Over 85% of new car purchases in the U.S. involve financing, meaning higher borrowing costs are dampening demand (Federal Reserve, 2024). In 2023, the average interest rate on new car loans rose above 7.0%, up from 4.5% in 2021, resulting in higher monthly payments and weaker consumer purchasing power (Federal Reserve Bank of St. Louis, 2024). In response, automakers have extended loan terms and offered more leasing incentives to offset higher financing costs and sustain market demand (Alliance for Automotive Innovation, 2024).

On the production side, the U.S. automotive sector is heavily reliant on global supply chains, making it vulnerable to disruptions in raw material availability and pricing. The semiconductor shortage of 2021–2022 led to a production decline of over 2.2 million vehicles, causing widespread inventory shortages and price surges (Burkacky et al., 2022). Although supply conditions have improved since then, ongoing geopolitical tensions and volatility in key raw materials such as steel, aluminium, and lithium continue to challenge automakers (International Energy Agency, 2024). Moreover, fuel prices and regulatory policies significantly shape consumer preferences. The average gasoline price in 2023 was \$3.60 per gallon, up from \$2.50 per gallon in 2020, prompting a shift toward fuel-efficient and electric vehicles (EVs) (U.S. Energy Information Administration, 2024). As a result, EV market share in the U.S. rose to 8.6% in 2023 (up from 6.1% in 2022), bolstered by incentives such as the Inflation Reduction Act’s tax credits for EV purchases and domestic battery production (International Energy Agency, 2024). Facing stricter environmental regulations, major automakers like General Motors, Ford, and Tesla have increased investment in EV and battery production to meet new Environmental Protection Agency emissions and efficiency standards (EPA, 2024). Looking ahead, advancements in autonomous driving, digital transformation, and sustainability present new opportunities for the U.S. automotive industry—but these are also accompanied by considerable challenges. Simultaneously, inflation, interest rate fluctuations, and changing regulatory policies will continue to influence market stability and long-term growth (Harp & Prasad, 2024).

1.3 PROBLEM STATEMENT

The U.S. automotive industry is a key driver of economic activity, significantly contributing to both employment and GDP (OICA, 2023; IMF, 2023). However, in an environment of rising inflation, the sector faces mounting challenges that threaten production costs, consumer demand, and overall market stability. The impact of inflation on the industry is multifaceted, affecting four critical areas: rising production costs, supply chain stability, consumer purchasing power, and long-term industry adjustments.

Rising production costs resulting from inflation are an immediate concern for automakers. Inflation has driven up prices of key raw materials; for example, steel prices surged by about 50% and aluminium by 30% during 2021–2022 (Kliesen, 2021). Additionally, producer price inflation reached its highest level in a decade, further squeezing industry profit margins (IMF, 2023). Automakers face a dilemma of whether to absorb these higher costs or pass them on to consumers, potentially affecting vehicle affordability and demand (World Bank, 2022). This price pressure also extends to energy costs, which significantly impact manufacturing and logistics expenses.

Next, inflation has exacerbated supply chain disruptions, complicating production schedules and inventory management. The COVID-19 pandemic has already strained global supply chains, and inflation has amplified these challenges. Semiconductor shortages alone resulted in production losses exceeding 21 million vehicles in 2021 (Sudan & Taggar, 2022), while rising transportation costs and other bottlenecks have delayed vehicle deliveries and contributed to price volatility (World Economic Forum, 2022). The industry's reliance on stable and efficient supply chains makes it particularly vulnerable to inflation-driven disruptions, necessitating strategic adjustments to mitigate risks.

In addition, consumer purchasing power has been significantly eroded by inflation, leading to a weakening demand for new vehicles. As inflation increases the cost of living, households face reduced discretionary spending, making major purchases like cars less feasible. J.D. Power (2022) reports that U.S. new car sales declined by 8.1% in 2022 due to rising costs and economic uncertainty. Moreover, central banks often respond to inflation by raising interest rates, which increases borrowing costs for consumers (Federal Reserve Board, 2022). Since the majority of U.S. car purchases rely on financing, higher interest rates make loans more expensive, reducing demand for new vehicles. This link between inflation, interest rates, and vehicle affordability is crucial for understanding broader market fluctuations.

Finally, beyond these immediate issues, inflation has longer-term effects on market trends and industry structure. Persistently high production and financing costs might push consumers toward smaller, more affordable models or even used cars instead of new ones (McKinsey & Company, 2023). Inflationary pressure could also slow the adoption of electric vehicles, since key inputs like lithium became about 70% more expensive in 2022 (International Energy Agency, 2022). Costlier materials drive up Electric Vehicle (EV) production costs, potentially making EVs less affordable and hindering the shift toward sustainable transportation. These longer-term shifts highlight the importance of ongoing monitoring and strategic adaptation to inflationary pressures.

Considering the above challenges, a thorough analysis of inflation's impact on the U.S. automotive industry is clearly needed. Besides this, the dynamic relationship between macroeconomic variables and the industry cannot be ignored. By combining a macroeconomic modelling approach with industry-specific analysis, the research seeks to offer practical insights for policymakers, automakers, and other stakeholders. Clarifying how inflation influences production costs, financing conditions, and

consumer purchasing power can help devise strategies to cushion the industry against inflation-driven disruptions and support its long-term stability.

The United States is selected as the exclusive focus of this study because it represents one of the largest and most influential automotive markets globally, accounting for approximately 10.1 million direct and indirect jobs and contributing nearly 4.8% to the nation's GDP, with an annual economic output of \$1.2 trillion (Alliance for Automotive Innovation, 2024). Furthermore, U.S. automakers are highly integrated into global supply chains, rendering the industry especially vulnerable to global economic shocks and inflationary pressures (Moffat & Poitiers, 2024; International Energy Agency, 2024). Moreover, the automotive market in the U.S. is uniquely dependent on consumer financing, with over 85% of new vehicle purchases involving loans or leases (Zabritski, 2025). This financing reliance significantly enhances the industry's sensitivity to monetary policy adjustments and inflation-driven changes in interest rates (Federal Reserve Board, 2024). Given these distinct characteristics, focusing exclusively on the U.S. automotive industry provides a meaningful context to deeply analyze inflation's sector-specific effects, yielding practical insights and robust policy implications.

1.4 OBJECTIVES OF THE STUDY

This study primarily investigates the impact of inflation on the U.S. automotive industry. While recognizing that inflation often interacts with other macroeconomic factors—such as interest rates, energy prices, and production costs—these variables are treated as control variables or mediating channels through which inflation exerts its influence. Therefore, the core objective is to assess how inflation, in both the short-run and long-

run, affects vehicle sales and industry dynamics, while accounting for the influence of related macroeconomic conditions.

More specifically, the research objectives of the study are as follows:

1. To investigate the impact of inflation, focusing on the interaction between other key macroeconomic factors on U.S. automotive industry
2. To examine the short-run effects of inflation and related macroeconomic variables on the U.S. automotive industry
3. To examine the long-run effects of inflation and related macroeconomic variables on the U.S. automotive industry.

1.5 RESEARCH QUESTIONS

Based on the research objectives, this study aims to answer the following questions:

1. Is there a cointegration between inflation, other macroeconomic variables and the U.S. automotive industry?
2. What are the short-run and long-run effects of inflation on the U.S. automotive industry, considering related macroeconomic variables such as fuel prices and interest rates as control factors?
3. What are the long-run effects of inflation and other macroeconomic variables on the U.S. automotive industry?

1.6 SIGNIFICANCES OF THE STUDY

This study primarily makes an empirical rather than theoretical contribution. Specifically, it focuses on how inflation affects demand in the U.S. automotive industry, investigating how factors such as overall price increases, rising energy costs, changes in production costs, and adjustments in interest rates collectively impact automotive market demand. Unlike previous studies that emphasize broader macroeconomic trends, this research conducts an in-depth analysis of factors unique to the automotive sector, such as fuel price fluctuations and rising production expenses, and examines the differing short- and long-run effects of inflation through the ARDL model. It also treats interest rates as a moderating variable, highlighting the crucial role of financing costs in consumer vehicle purchase decisions and market demand.

From an empirical perspective, the study uses recent quarterly data encompassing the significant economic fluctuations following the COVID-19 pandemic, delivering updated quantitative insights tailored to the U.S. automotive context. These findings provide practical guidance for policymakers and industry stakeholders. For example, government authorities and central banks can utilize the empirical evidence to better understand how elevated inflation and interest rate changes affect automotive production and sales, informing more targeted monetary and fiscal policies. Similarly, automotive manufacturers, suppliers, and financial institutions can draw on these insights to optimize product positioning, pricing strategies, supply chain management, and financing solutions.

Although this study does not directly advance new theoretical frameworks, it strengthens and contextualizes existing economic theories on inflation transmission mechanisms within the automotive industry by providing rigorous empirical evidence.

Therefore, its primary value lies in empirical rigor and practical relevance rather than theoretical innovation.

Overall, this research addresses a notable gap in empirical studies on the relationship between inflation and the automotive industry. While it does not develop new theoretical frameworks, it provides clear and practical strategies to mitigate inflation-related challenges—such as stabilizing energy costs, controlling production expenses, and adjusting interest rates appropriately—to help maintain the industry’s competitiveness and promote sustainable development.

1.7 SUMMARY

In summary, this chapter has outlined the background, research problem, objectives, and significance of examining the impact of inflation on the U.S. automotive industry. We established inflation’s critical role as a macroeconomic force affecting industrial costs, consumer purchasing power, and market stability. Given the increasing inflationary pressures in recent years—driven by supply chain disruptions and rising material and energy costs—the need to understand inflation’s effects on the automotive sector is clear. The problem statement identified four key areas of concern: rising production costs, supply chain disruptions, consumer affordability challenges, and long-term industry shifts. Inflation has led to sharp increases in raw material prices, intensified supply chain constraints, and reduced household purchasing power, all of which shape vehicle sales trends. Overall, this chapter has framed the research in a broad macroeconomic context and defined the key challenges facing the automotive industry, specifically in the U.S. context. The next chapter will provide an in-depth review of relevant literature on inflation’s economic impact and specifically on the automotive sector.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents an overview of existing academic and industry research on how inflation and related macroeconomic variables influence the automotive sector. Given that vehicle manufacturing draws on extensive global supply chains and depends heavily on consumer financing, the industry is especially sensitive to price fluctuations. Various strands of literature have analysed the interplay between rising production costs, energy prices, and interest rates to determine how these forces shape vehicle demand, firm strategies, and longer-term structural shifts. Considering these studies, this chapter synthesizes key insights regarding the ways inflationary pressures manifest in supply chains and consumer spending behaviour, as well as how interest rate movements and energy costs can either moderate or worsen these effects.

The chapter begins by examining how inflation heightens raw material, and labour expenses and disrupts supply chain operations. It then explores how price shocks affect household purchasing power and consumer confidence, often driving buyers toward used cars or smaller, more efficient models. Subsequent sections delve into the role of energy prices, interest rates, and other macroeconomic factors that can either strengthen or weaken the link between inflation and automotive sales. By reviewing both historical and recent empirical evidence, the chapter aims to clarify which drivers are most influential in shaping short-run and long-run industry outcomes. Ultimately, understanding these mechanisms offers valuable perspectives for policymakers and

manufacturers seeking to manage inflation-related uncertainties and maintain the stability of the U.S. automotive market.

2.2 IMPACT OF INFLATION ON THE ECONOMY AND THE AUTOMOTIVE INDUSTRY

Inflation significantly influences the broader economy as well as specific industries like automotive manufacturing. When the prices of raw materials, labour, or energy rise, production costs climb, which can erode firms' competitiveness and profit margins. Because the automotive sector relies heavily on these cost-sensitive inputs, it is especially vulnerable to inflationary pressures.

From a theoretical standpoint, inflation impacts economic sectors primarily through two classic mechanisms: cost-push and demand-pull inflation (Blanchard, 2018; Mankiw, 2019). The cost-push theory posits that increased prices of key production inputs, such as raw materials and energy, directly elevate manufacturing costs, forcing firms to raise their product prices. Conversely, demand-pull inflation occurs when excessive monetary supply or credit availability stimulates consumer spending, increasing overall demand and consequently pushing up prices (Mishkin, 1995). Within the automotive industry context, these mechanisms frequently operate simultaneously. For example, rising costs for materials like steel, aluminium, and petroleum directly increase automotive production expenses. Meanwhile, loose monetary policies and low-interest rates can temporarily boost vehicle demand, further exerting upward pressure on prices (Bernanke & Blinder, 1992). Understanding these theoretical channels is critical to accurately interpret how inflation propagates through the automotive sector.

One immediate channel through which inflation hits the automotive industry is the cost of raw materials like steel and plastics. Kliesen (2021), Musarat et al. (2020), and Przekota and Szczepańska-Przekota (2022) note that surging commodity prices drive inflation by raising both consumer expenditures and production costs. In car manufacturing, steel is a critical input; thus, swings in steel prices can have a substantial impact on overall manufacturing expenses. Ashby and Jones (2019) further point out that persistently high steel and other material costs pose challenges for automakers, complicating their pricing strategies and squeezing profit margins.

Beyond materials, labour costs are another important component of inflation-driven expenses. Wage increases improve workers' living standards but can also raise manufacturing costs if not accompanied by gains in efficiency (Qian & Wang, 2022). Mendoza-Velázquez et al. (2018) highlight that rapid wage growth can lead to tight labour markets or bottlenecks in certain regions, further driving up operational expenses. While such observations are often drawn from international contexts, they are equally applicable to the U.S. automotive industry, where labour costs are a major factor in production efficiency.

Energy price swings also connect inflation with industrial performance. The growing use of renewable energy has added extra variability to electricity markets, which affects energy-intensive industries such as automotive manufacturing (Mureddu & Meyer-Ortmanns, 2016). Higher energy costs influence many aspects of car production—from the electricity used in factories to transportation and fuel expenses. Furthermore, Bombelli et al. (2019) argue that stricter climate policies and environmental regulations can amplify inflationary pressures by increasing compliance costs for automakers, adding yet another layer of uncertainty.

Recent evidence underscores these challenges. Havlin (2023) reports that dealership markups accounted for roughly 35% to 62% of the total increase in new vehicle prices between 2019 and 2022. Such a large contribution to vehicle price inflation shows how supply chain constraints and rising input costs were passed on to consumers, which in turn worsened inflation's overall effect on the automotive sector. Likewise, J.P. Morgan (2023) noted that the average price of a new vehicle in the U.S. rose to \$46,437 in January 2023, a 4.2% increase from the previous year. This uptick reflects the dual impact of higher production costs and supply chain disruptions. The same report, however, predicted that new vehicle prices might decrease by about 2.5% to 5% later in 2023 as supply problems ease and production levels normalize.

Inflation raises costs on multiple fronts—raw materials, labour, and energy—which in turn affects supply chain operations, vehicle pricing strategies, and what consumers can afford. These dynamics lay the groundwork for examining how inflationary pressures feed into supply chain costs (Section 2.2.1) and influence the demand side (Section 2.2.2), thereby driving broader industry trends. By examining these interconnections, one can better assess inflation's effects on vehicle pricing, sales, and trade, underscoring the importance of macroeconomic stability for the automotive industry's long-term sustainability.

2.2.1 Supply Chain Costs as An Inflationary Transmission Path

Inflation can substantially alter the cost structure of automotive supply chains, driving up the prices of raw materials, transportation, and inventory management. Such inflation-driven disruptions often lead to component shortages, logistics bottlenecks, and greater operational risks, all of which undermine production efficiency and push up final vehicle prices. In the highly globalized automotive supply network, rising costs at

any single stage can cascade throughout the entire chain, ultimately impacting the industry worldwide.

One immediate effect of inflation is the surge in input costs and transportation expenses. Because the automotive sector depends on a complex global network of parts suppliers, it is especially prone to inflation-driven cost spikes throughout its supply chain. Kliesen and Werner (2022) observe that recent semiconductor shortages—aggravated by rising input prices—have severely constrained vehicle production worldwide. Similarly, Ivanov and Dolgui (2022) highlight that escalating material costs combined with supply chain inefficiencies lead to sharp price increases and inventory challenges. Higher fuel and logistics costs add to these pressures by making the transport of raw materials and finished vehicles more expensive. Furthermore, Masoumi et al. (2019) argue that efforts to implement environmentally sustainable practices (for example, sourcing low-emission steel) impose additional financial burdens on automakers. Gao and Zhu (2022) likewise emphasize that emerging urban mobility trends can drive up logistics fees and fuel costs, placing even more stress on automotive supply chains.

Beyond material and transportation costs, inflation amplifies external shocks—such as the COVID-19 pandemic—on inventory management. The semiconductor shortage, initially triggered by the pandemic, was further exacerbated by inflationary pressures. Sudan and Taggar (2022) report that supply chain disruptions in the Indian automotive sector resulted in sharp declines in production and sales, a phenomenon mirrored in the U.S. market. Rising component costs, coupled with uncertain delivery schedules, have complicated automakers' production planning and lean inventory strategies. Jiang, Shu, and Song (2022) propose a robust optimization model for vehicle manufacturing under supply chain disruptions, demonstrating how rising costs and logistical uncertainties hinder just-in-time inventory practices. Similarly, Ivanov (2021)

finds that unexpected inflation can destabilize post-pandemic inventory recovery strategies and long-term production forecasting.

Empirical evidence highlights the profound impact of supply chain disruptions on the automotive industry, particularly as inflationary pressures intensified post-COVID-19. Naimy et al. (2024) analyzed 73 European automotive companies (2013–2022), finding that a 1% rise in industrial material costs increased stock returns by 99.5%, as firms passed higher costs onto consumers. Similarly, a 1% rise in precious metal prices led to a 17.3% drop in return on equity (ROE) and a 55.5% decline in stock returns, underscoring the volatility of raw material costs. Eldem et al. (2022) found that firms using digital supply chain monitoring reduced procurement delays by 27%, while supplier diversification improved supply chain resilience by 15%, mitigating inflationary disruptions. However, Frieske and Stieler (2022) reported that global automotive production fell by 9.6% (7.7 million vehicles) in 2020 due to semiconductor shortages, with Germany alone losing 970,000 units in 2021, contributing to an 18% rise in U.S. new vehicle prices from 2020 to 2022 and extending delivery times from 6–8 weeks to over 20 weeks. Additionally, Manley et al. (2022) found that lithium and cobalt prices surged by 70% and 38% in 2022, respectively, driving EV battery production costs up by 18.6% and forcing automakers to either absorb or transfer costs. Sudan and Taggar (2022) highlighted similar supply chain disruptions in India, where Maruti Suzuki saw domestic sales collapse in April 2020 (only 632 exports) and a 24% production decline in 2021, leading to an 8.9% price hike between 2021 and 2022 to counter rising costs. Collectively, these studies show that supply chain disruptions, compounded by semiconductor and raw material shortages, have driven higher production costs, rising vehicle prices, and constrained global market supply, reshaping the automotive industry. Firms that adopted digitalized logistics and multi-sourcing procurement strategies proved more resilient, highlighting the importance of robust supply chain management in mitigating future inflationary pressures.

Studies such as those by Kliesen and Werner (2022), Ivanov and Dolgui (2022), and Masoumi, Kazemi, and Abdul-Rashid (2019) underscore the fact that inflation does not merely raise costs at the individual firm level but also introduces systemic vulnerabilities across the entire supply chain (Kliesen & Werner, 2022; Ivanov & Dolgui, 2022; Masoumi et al., 2019). They collectively highlight how rising input and transportation costs triggered by inflationary pressures can cascade through supply chain networks, amplifying industry-wide disruptions. Di Giovanni et al. (2022) reinforce this view by showing how supply chain bottlenecks contribute to inflationary pressures in the euro area, highlighting parallels for the U.S. automotive industry. Additionally, higher supply chain costs influence consumer perceptions of vehicle affordability and economic security, ultimately affecting demand. Rising inflationary pressures on supply chains are thus interconnected with consumer behaviour, a crucial factor examined in Section 2.2.2. Understanding these dynamics is essential for automakers and policymakers seeking to mitigate the impact of inflation on production efficiency, pricing strategies, and long-term market stability.

2.2.2 Demand Side and Inflationary Pressures in The Automotive Industry

Consumer demand for automotive is shaped by broad macro-economic conditions as well as the purchasing power of individual households. When inflation rises, consumers suffer from eroding real incomes and greater financial uncertainty. This deterioration in purchasing power often dampens consumer sentiment and leads households to reconsider or delay major purchases like vehicles (Rondinelli & Zizza, 2020; Bonab, 2019).

Arguably the most immediate consequence of inflation for consumers is the erosion of purchasing power and, by extension, vehicle affordability. High inflation

diminishes the real value of disposable income, making it harder for consumers to afford expensive items such as cars. Bonab (2019) found that during extended periods of inflation, households tend to reprioritize their expenses by postponing or even cancelling plans to buy new vehicles. Even in advanced economies such as the U.S., relatively stagnant wages in the face of inflation have been linked to shifts in buyer preferences—consumers gravitate toward smaller, more fuel-efficient car models as a cost-saving measure.

Consumers' sensitivity to inflation can vary across segments and demographics, which in turn affects overall market demand. Weber (2019) showed that in Switzerland, car-buying decisions were largely driven by factors like vehicle performance and fuel efficiency, and that the responsiveness to price changes (i.e., price elasticity of demand) differed by demographic segment. These findings imply that income level plays a key role in how consumers adjust their vehicle preferences under inflationary pressure, ultimately influencing which types of cars remain in demand.

Aside from affordability, broader economic uncertainty and shocks to consumer confidence can also hold back car sales. El Massah and Hassanein (2020) documented that major crisis—such as the COVID-19 pandemic—significantly curtailed consumer spending in the U.S., an effect that inflation fears only exacerbated. Correspondingly, Wen et al. (2022) found in Pakistan that when policy uncertainty rose, household consumption fell, illustrating how economic instability translates into reduced spending on big-ticket items like cars. Interestingly, Wang, Geng, Xia, and Wang (2022) noted that heightened uncertainty even had an indirect environmental effect: by depressing overall economic activity (and thus emissions), it hinted at a similar mechanism whereby concerns about inflation could lead to fewer car purchases (and by extension, potentially lower emissions from the transport sector).

Several more recent studies shed additional light on consumer behaviour under inflationary stress. Talay et al. (2023), examining 1 071 new car launches in the U.S. between 1946 and 2008, found that vehicles introduced during recessionary periods (when consumer confidence was low) had an 18 % longer market survival but saw 12.4 % lower initial adoption rates. This implies that during times of economic uncertainty, many consumers delay purchasing new models even though those models might stay available longer. Meanwhile, Bhutto et al. (2022) surveyed 732 prospective hybrid-car buyers in Pakistan and observed that greater price sensitivity driven by inflation significantly dampened their purchase intentions. In that study, 48 % of respondents said rising inflation made them reconsider buying a hybrid vehicle, and a 5 % increase in the vehicle's price led to a 9.3 % drop in purchase likelihood. Notably, lower-income households in the sample were 63 % more likely to postpone buying a car during inflationary periods, whereas wealthier consumers were comparatively more resistant to such pressures. In a different approach, Dasgupta et al. (2022) analysed more than 50 000 consumer reviews and social-media posts and found a 62 % surge in discussions of affordability concerns from 2020 to 2022. Over the same period, there was a 14.8 % decline in expressed intent to buy new cars and a 34 % rise in online searches for used cars, suggesting that many consumers were actively seeking cheaper alternatives to new vehicles.

Collectively, these findings indicate that inflation tends to erode consumer confidence and financial security, heighten consumers' sensitivity to prices, and push many buyers toward lower-cost vehicle options (or out of the market entirely). Such shifts in consumer behaviour present long-term challenges for automakers and policymakers alike, who must adapt to an environment of more cautious and cost-conscious car buyers.

Inflation-driven supply-chain pressures, as outlined in Section 2.2.1, often result in higher showroom prices for vehicles, which in turn heighten consumers' concerns about their future income stability (Di Giovanni et al., 2022). In other words, inflation doesn't just squeeze affordability—it also darkens consumer expectations about the economy, leading people to postpone purchases, dampen demand, and ultimately contribute to lower overall vehicle sales and exports. The following section (2.3) will consider how macro-economic factors like energy prices and interest rates can moderate or intensify these inflation-driven trends.

2.3 THE IMPACT OF OTHER MACROECONOMIC VARIABLES ON THE AUTOMOTIVE INDUSTRY

Inflation's impact on the automotive industry is shaped by other macro-economic variables, particularly energy prices and interest rates, which influence both production costs and consumer-demand dynamics. These factors interact with inflationary pressures, either amplifying or mitigating their effects, ultimately shaping the industry's overall response to economic fluctuations.

Energy prices significantly affect the automotive sector, influencing both manufacturing costs and consumer behaviour. Automakers rely on petroleum-based materials, electricity, and transportation logistics, all of which become more expensive when energy prices rise (Storm & Breman, 2023). Higher fuel prices increase operational costs, leading to higher vehicle prices, particularly for fuel-intensive models (EIA, 2022). Additionally, fluctuations in fuel prices influence consumer preferences, with a shift toward fuel-efficient and electric vehicles during periods of high energy costs. However, the transition to alternative-energy vehicles remains constrained by

affordability concerns and limited charging infrastructure (Grigolon, Reynaert, & Verboven, 2018).

Interest rates play an equally significant role in shaping automotive demand, particularly in markets where vehicle financing is prevalent. As central banks raise interest rates to counter inflation, borrowing costs increase, making auto loans less affordable for consumers (McKinsey & Company, 2023). Higher interest rates also discourage capital investment among automakers, limiting production expansion and technological development (Bernanke & Blinder, 1992). Additionally, rising interest rates combined with inflationary pressures on production costs create a double constraint on the industry, reducing both supply-side production capabilities and demand-side affordability. In Turkey, Ustabas and Buyun (2024) showed that a one-percentage-point rise in funding costs led to a significant drop in domestic vehicle sales, underscoring the sensitivity of auto demand to financing conditions.

Recent quantitative studies further illustrate the influence of these macro-economic drivers. For example, Guo et al. (2023) found that in China, a 16.32 % rise in crude-oil prices led to roughly a one-unit decline in crude-oil imports—a sign of reduced fuel consumption in the automotive sector as energy costs increase. Interestingly, the same study noted that a 15.53 % increase in the market share of new-energy vehicles (NEVs) was associated with an extra unit of crude-oil imports, suggesting that even as NEVs gain traction, overall oil demand can remain high due to persistent fossil-fuel needs in the automotive supply chain and related industries.

Overall, these findings confirm the pivotal role that energy costs and interest rates play in shaping the automotive industry's resilience or vulnerability to inflation. As fuel and financing costs rise, automakers are pressed to improve supply-chain efficiency, design more cost-effective vehicle models, or adjust pricing strategies. Understanding

these interactions is essential for automakers and policymakers when formulating pricing models, supply-chain strategies, and monetary policies to stabilise the industry amid inflationary uncertainties.

2.4 EMPIRICAL EVIDENCE ON DYNAMIC RELATIONSHIPS AND INDUSTRY TRENDS

Against the backdrop of an increasingly complex global economic landscape, the impact of inflation on the development of various industries has become a common focus of academic and industry circles. As a capital-intensive and consumption-oriented industry, the automotive industry is highly sensitive to inflation fluctuations. With the fluctuations in raw material, energy and financial costs, companies' production decisions and consumers' willingness to buy cars will change accordingly. Based on cases from different countries and periods, this section focuses on how inflation affects the automotive industry through both the production and demand sides and explores the possible response strategies that companies and policy departments may take in a high-inflation environment. The following will start from recent data from the United States, expand to the unique experiences of other countries, and then go back to historical events, striving to show the impact of inflation on the automotive industry in multiple dimensions and its deep-seated laws.

The empirical data presented in Table 2.1 fully illustrate the multiple impacts of inflation on the automotive industry in different regions and periods. Taking the United States as an example, the consumer price index (CPI) for new cars rose by 11.8% in 2021, while the price of used cars soared by 37.3% (Bureau of Labor Statistics, 2022). Behind this is not only the reason why the shortage of chips under the epidemic has

limited the production capacity of new cars but also the surge in consumer demand and supply chain chaos. Especially between 2019 and 2022, the markups made by dealers on new cars accounted for 35% to 62% of the total price increase (Havlin, 2023), highlighting the "seller's market" formed after a serious imbalance between supply and demand. However, the price increase did not bring about a simultaneous increase in sales. In 2022, new car sales in the United States fell by about 8.1% (J.D. Power, 2022). This was mainly due to the fact that consumers chose to postpone consumption or turn to the used car market when faced with higher car purchase costs under the rise in inflation and interest rates, which weakened overall demand.

Compared with the United States, the situation in Turkey emphasizes the linkage between inflation and monetary policy. Studies have shown that for every one percentage point increase in the average financing rate, domestic car sales in Turkey will drop significantly (Ustabaş & Buyun, 2024). The reason is that after the central bank raised the benchmark interest rate to curb inflation, the loan costs of commercial banks rose accordingly, and the burden on car buyers increased immediately. For emerging markets where loans are the mainstream way to buy cars, the inhibitory effect of rising interest rates on car sales is particularly obvious.

At the same time, China's case pays more attention to the transformation of energy prices and consumption patterns. The data shows that when the oil price rises by 16.3%, China's crude oil imports will decrease by nearly 1 unit, while the market share of new energy vehicles can increase by 15.5% (Guo et al., 2023). It can be seen that rising energy costs will not only inhibit the purchase or use of fuel vehicles but also drive the growth of electric vehicle demand to a certain extent. However, this substitution effect has not completely offset the impact on overall oil demand, making the future market trend more complicated.

Historical episodes of energy-driven price shocks show how specific forms of inflation have reshaped the automotive industry. During the 1970s oil crises, fuel prices quadrupled in a short period, triggering an inflation spike that immediately shifted U.S. consumers toward smaller, fuel-efficient cars, while large-displacement models remained unsold (Ramey & Vine, 2010). Automakers at the time were unable to retool quickly, causing inventories of big cars to swell. Likewise, in the high-inflation period of 1980-1981, the U.S. prime rate exceeded 20 percent, new-car sales dropped by roughly 20 percent compared with 1979, and many dealerships were forced to close (UPI News, 1981). These historical cases underscore that when energy costs drive overall price levels higher, both consumer demand patterns and manufacturers' production decisions adjust dramatically.

Recent empirical research shows that oil-price volatility continues to reshape both consumer demand and manufacturers' product strategies. Klier and Linn (2010), using monthly U.S. new-vehicle sales data from 2002–2008, find that a \$1-per-gallon increase in gasoline prices raises the average fuel economy of new cars sold by roughly 1.4 mpg, confirming that higher fuel costs push consumers toward more efficient vehicles. Busse, Knittel, and Zettelmeyer (2013) extend this insight to the used-car market, showing that a sustained \$1 gasoline-price increase reduces market prices of low-fuel-economy vehicles by approximately \$3,000 relative to high-efficiency models, indicating a sizable demand penalty for fuel-intensive cars. Conversely, when fuel prices fall, buyers gravitate back toward larger, less fuel-efficient vehicles. Allcott and Wozny (2014) document that the 2008–2009 collapse in gasoline prices led to a measurable shift in new-car purchases toward lower-mpg models; they estimate consumers internalize only about 60–70 percent of expected gasoline costs, so cheaper fuel relaxes the effective cost of owning inefficient vehicles. Together, these studies reveal that the effect of oil prices on automotive demand is bidirectional and context-dependent—higher prices dampen sales of fuel-intensive models and stimulate interest in fuel-efficient or

alternative-energy vehicles, whereas lower prices have the opposite effect. Incorporating both historical events and contemporary evidence thus provides a more nuanced understanding of how energy costs interact with inflation and consumer behaviour in the automotive sector.

Combining the earlier cases—namely the 2021-2022 U.S. inflation surge that depressed new-car sales, Turkey’s interest-rate hikes that curtailed loan-financed purchases, China’s oil-price shocks that spurred a shift toward new-energy vehicles, and the 1970s oil crises that forced U.S. consumers to down-size—it becomes clear that inflation often impacts the automotive industry through a “dual path”. On the one hand, soaring vehicle prices and higher financing costs weaken consumer demand; on the other hand, simultaneous increases in upstream input prices such as parts, steel and energy compress corporate profit margins. Although specific national conditions differ, balancing supply and demand, stabilising market prices, and maintaining industrial vitality in the face of high inflation remain common priorities. For decision-makers, continuous monitoring of macro-economic conditions and moderate policy intervention can mitigate inflation’s impact on the industry; for firms, flexible adjustments in production capacity and model mix are pragmatic choices for preserving competitiveness in a turbulent environment. Overall, macro-economic stability is still a prerequisite for the healthy development of the automotive industry.

Table 2.1 Key empirical evidence of inflation’s impact on the automotive industry

Context	Observation	Implication	Source
U.S. Vehicle Prices (2021)	New vehicle CPI +11.8%; Used vehicle CPI +37.3% (record high increase)	Supply shortages and strong demand led to sharp inflation in car prices.	BUREAU OF LABOR STATISTICS, (2022)
U.S. Dealership Markups (2019–22)	Dealer markups caused ~35–62% of new car price increase	The inflationary environment enabled sellers to significantly raise prices.	Havlin (2023)
U.S. Auto Sales (2022)	New vehicle sales –8.1% in 2022 amid rising prices	High inflation and uncertainty curtailed vehicle demand.	J.D. Power (2022)
Turkey Interest Rates (2011–2023)	+1% interest rate → significant drop in car sales	Higher rates (often to fight inflation) directly reduce auto purchases.	Ustabaş & Buyun (2024)
China Oil Prices & Consumption	+16.3% oil price → ~1 unit decline in crude oil imports; NEV share +15.5% → +1 unit oil imports	Rising energy costs reduce fuel use (hints at lower driving/consumption), though EV growth can complicate oil demand trends.	Guo et al. (2023)

1970s Oil Shock (USA)	Fuel price surge → rapid shift to small cars; large car inventories piled up	Energy inflation swiftly changed consumer preferences and outpaced automakers' production adjustments.	Ramey & Vine (2010)
1980–81 High Inflation (USA)	Prime rate ~20%; 1980 auto sales –20% (vs 1979); Many dealerships closed	Extreme inflation and interest rates severely depressed auto sales and business viability.	UPI News (1981)

2.5 CONCEPTUAL FRAMEWORK

This study examines the impact of inflation on the U.S. automotive industry by constructing a conceptual framework that links macroeconomic variables to key industry dynamics. In this framework, inflation (CPI) is the central independent variable influencing the automotive sector's performance. Inflation affects total vehicle sales through two main channels: production costs and consumer affordability. When inflation rises, the costs of raw materials, logistics, and labour increase, leading to higher production expenses for automakers. Manufacturers may respond by raising vehicle prices or reducing output, either of which can dampen sales. At the same time, inflation erodes consumers' purchasing power, making vehicles less affordable for households (especially in a market where financing is crucial for purchases). This dual-channel effect means that inflation puts pressure on both the supply side (via higher costs) and the demand side (via reduced real income) of the automotive market.

The framework also includes energy prices and interest rates as additional explanatory variables that operate alongside inflation. Energy prices—particularly

gasoline—affect both production and consumption in the auto industry: higher fuel costs raise manufacturers’ operating and logistics expenses and simultaneously squeeze consumers’ disposable income, often shifting demand toward smaller or more-efficient vehicles. Interest rates, frequently adjusted by central banks in response to inflation, influence vehicle-loan affordability for buyers and financing costs for producers; higher rates can dampen demand and constrain capital investment, whereas lower rates may partially offset inflation’s strain. Although the model does not specify interaction (cross) terms, these variables enter the ARDL equation as separate regressors, allowing their direct effects on automotive demand to be quantified while still acknowledging their potential to reinforce—or occasionally counteract—the impact of rising prices.

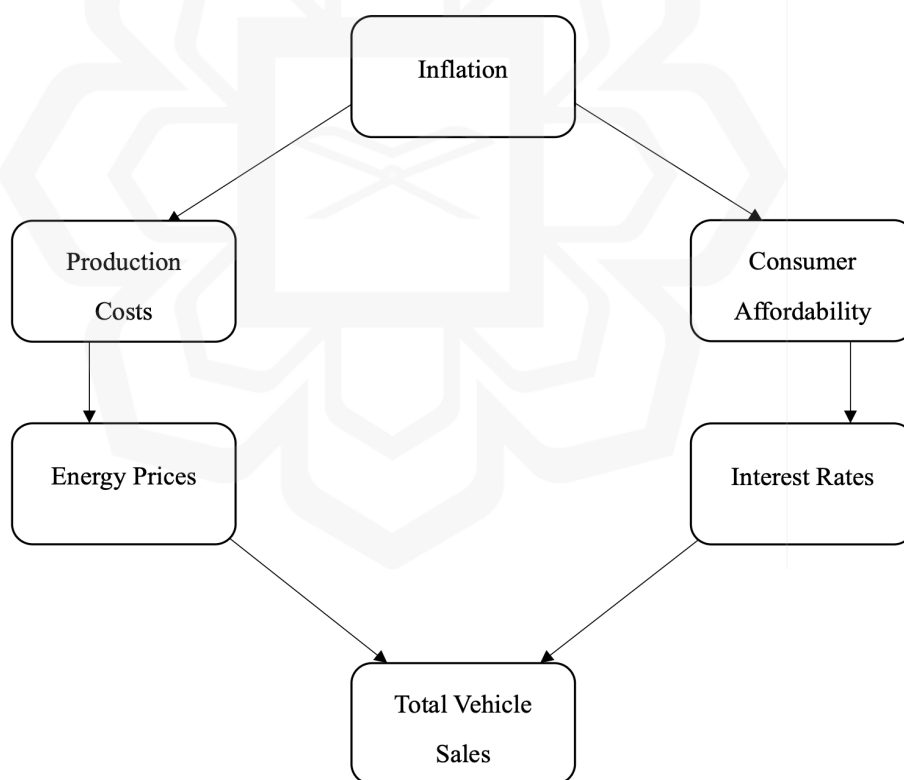


Figure 2.1 Conceptual Framework: The Impact of Inflation On The U.S. Automotive Industry

2.6 RESEARCH GAPS

In summary, the literature indicates that inflation exerts a complex and multifaceted influence on the U.S. automotive industry. On the one hand, rising production costs—driven by more expensive raw materials, labour, and energy—coupled with tighter financing conditions (e.g. higher interest rates) can significantly curtail vehicle sales by raising prices and suppressing demand. This kind of cost-push inflation disrupts production efficiency and forces automakers to rethink their pricing strategies. On the other hand, macroeconomic factors like energy prices and interest rates can modulate these impacts, sometimes intensifying the challenges or, in other cases, providing temporary relief. At the same time, long-term structural adjustments (such as a gradual shift toward electric vehicles or changes in consumer preferences) are critical to understanding the industry's response to sustained inflationary pressures. These structural trends need to be considered to fully grasp the automotive sector's performance under inflation.

However, despite this extensive body of research, several gaps remain in the literature. First, many existing studies focus on the broad economic effects of inflation without drilling down into how, specifically, inflation-induced cost increases (such as sudden spikes in raw material or energy prices) directly affect vehicle affordability and sales in the U.S. context. In other words, the precise pathways by which higher production costs are passed through to car prices and then to consumer purchase decisions in the U.S. market are not yet fully understood. Additionally, although factors like energy prices and financing conditions (interest rates) are recognized as important, there is a lack of research examining their joint short-run and long-run impacts on vehicle sales under inflationary conditions. The literature would benefit from a more systematic analysis that considers how these variables interact over time to influence car buying.

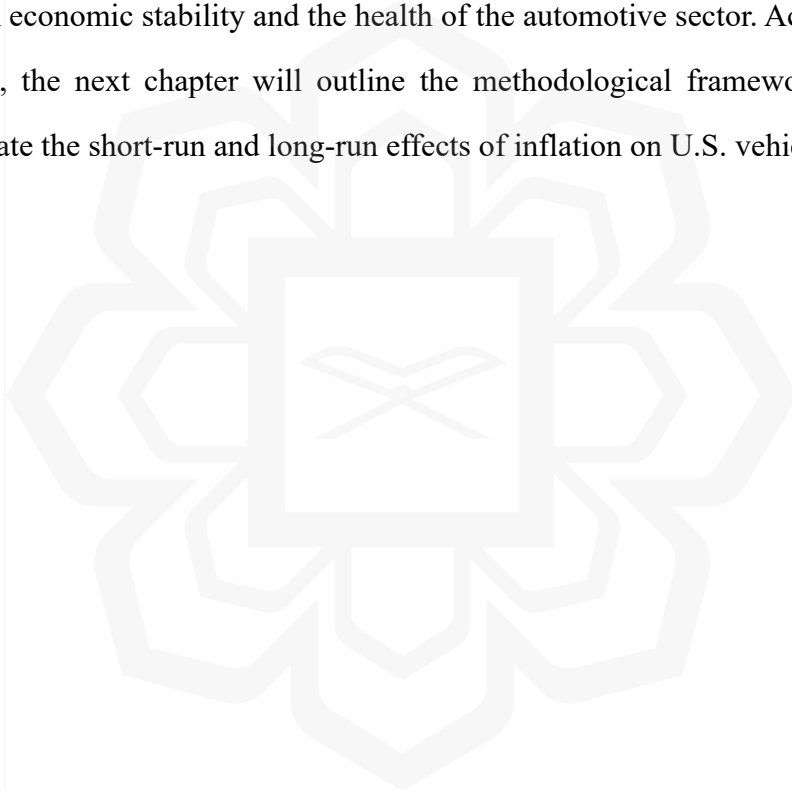
Another gap is that a large portion of prior studies have been cross-national or focused on emerging markets, often overlooking distinctive features of the U.S. automotive market. For example, car buying in the U.S. is heavily tied to consumer financing (auto loans), and U.S. manufacturers often utilize just-in-time supply chain logistics (which minimize inventory storage). These factors may alter how inflation impacts the U.S. market compared to others. Thus, more research specifically targeting the U.S. automotive industry is necessary to capture these unique dynamics.

Finally, there is a tendency in existing research to examine short-term shocks (like sudden price jumps or supply disruptions) in isolation from long-term trends (like gradual shifts in technology or consumer behaviour). This separation means we know less about how short-run and long-run effects of inflation interact in the automotive sector. To fully understand inflation's impact on vehicle sales, future studies should adopt an integrated approach that accounts for both immediate disruptions and evolving longer-term responses simultaneously.

2.7 SUMMARY OF THE CHAPTER

In summary, Chapter Two has shown that inflation affects the automotive industry through multiple channels, notably by increasing production costs and constraining consumer demand. Rising raw material expenses, higher energy prices, and wage pressures can drive up vehicle manufacturing costs and disrupt delicate supply chain networks. These cost increases often filter through to retail car prices, influencing the affordability of new vehicles and prompting shifts in consumer behaviour.

On the demand side, the research indicates that households feel the strain of inflation in reduced purchasing power and greater financial caution, ultimately weighing on decisions related to major purchases such as automobiles. This effect becomes more pronounced when central banks respond to inflation with interest rate hikes, which elevate borrowing costs for car buyers and manufacturers alike. Furthermore, the chapter highlights how macroeconomic factors such as energy prices and exchange rates interact with inflation to shape both production strategies and market trends. Collectively, the studies reviewed in this chapter underscore the interdependence between economic stability and the health of the automotive sector. According to these findings, the next chapter will outline the methodological framework employed to investigate the short-run and long-run effects of inflation on U.S. vehicle sales.



CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This chapter details the methodology used to examine the short-run and long-run effects of inflation, producer prices, interest rates, and energy prices on total vehicle sales (TVS) in the U.S. automotive industry. The primary objective is to quantify how inflation— together with its key transmission channels such as energy prices, interest rates, and producer costs—shapes U.S. new-vehicle demand in both the short and the long run.

The study adopts an Autoregressive Distributed Lag (ARDL) model to investigate these relationships. ARDL is a well-established econometric approach that can capture dynamic relationships among variables even when they have different orders of integration (Pesaran & Shin, 1995). This method is advantageous compared to traditional cointegration techniques like the Engle-Granger two-step procedure or Johansen's method because it works well with small sample sizes and does not require all variables to be integrated of the same order. In an ARDL framework, both short-run and long-run dynamics are estimated together in a single equation, simplifying the analysis by avoiding the need for multiple separate steps.

Furthermore, the ARDL approach is flexible in that it can include both stationary ($I(0)$) and non-stationary ($I(1)$) variables without losing reliability. It reduces the biases associated with pre-testing for unit roots since it does not impose a strict requirement on the integration order of each variable. Another benefit is the clear separation it provides between short-term fluctuations and long-term equilibrium trends in the results,

ensuring that both temporary and persistent effects of the economic variables on TVS are captured.

These events introduce significant variability into the data, providing a rich context for observing how the automotive industry responds to changing macroeconomic conditions. Understanding the nature of these responses is crucial for policymakers, industry leaders, and financial analysts who aim to forecast market trends and formulate effective strategies.

3.2 MODEL SPECIFICATION

3.2.1 Empirical Model

Prior research highlights those macroeconomic variables, such as inflation, interest rates, producer price index (PPI), and energy prices, exert significant effects on the performance of the automotive sector. The demand for vehicles is closely linked to consumer purchasing power, financing costs, and production expenses, all of which fluctuate due to macroeconomic variations. A robust empirical model is necessary to quantify these relationships.

While both the Consumer Price Index (CPI) and the Producer Price Index (PPI) are measures of inflation, they capture distinct aspects of its transmission mechanism. CPI reflects changes in retail prices paid by households and therefore directly influences consumer purchasing decisions, particularly vehicle affordability. In contrast, PPI tracks the input costs faced by manufacturers, such as raw materials and parts, and serves as a proxy for cost-push inflation pressures. Including both indicators allows the model to distinguish between demand-side and supply-side inflationary effects on the automotive

market. This approach is consistent with prior literature that separates producer versus consumer inflation channels in sectoral demand studies (Blanchard, 2018).

The functional form of the model is defined as follows:

TVS

$= f(\text{Inflation}, \text{Interest Rates}, \text{Energy Prices}, \text{Producer Price Index}, \text{Dummy2020})$

Where:

TVS: Total Vehicle Sales, serving as the dependent variable that reflects consumer demand for new vehicles.

Inflation (CPI): Measured using the Consumer Price Index (CPI) for new vehicles, representing the overall change in vehicle prices and consumer purchasing power.

Interest Rates: The Federal Funds Effective Rate influences borrowing costs for vehicle financing.

Energy Prices: U.S. Regular All Formulations Gas Price, which affects operating costs and vehicle preferences.

Producer Price Index (PPI): Reflects input costs associated with automotive manufacturing, thereby influencing production costs and vehicle pricing.

Dummy2020: A binary variable (1 for 2020, 0 otherwise) to control for the impact of the COVID-19 pandemic on vehicle sales.

3.2.2 Log-Linear Model

A log-linear transformation is applied to all continuous variables, except *Dummy2020*, to improve estimation accuracy and facilitate elasticity-based interpretations. *Dummy2020* is excluded from the log transformation because it is a binary variable,

representing a categorical distinction (whether the COVID-19 pandemic occurred in a given period). Log-transforming such variables does not provide meaningful interpretations and could distort the results. The econometric model is expressed as follows:

$$\begin{aligned} \ln(TVS_t) = & \alpha_0 + \beta_1 \ln(CPI_t) + \beta_2 \ln(InterestRate_t) \\ & + \beta_3 \ln(EnergyPrice_t) + \beta_4 \ln(PPI_t) + \beta_5 Dummy2020 \\ & + \varepsilon_t \end{aligned}$$

Where:

α_0 : The intercept term representing baseline vehicle sales in the absence of external macroeconomic influences.

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$: The estimated coefficients of the explanatory variables, measuring the respective effects of inflation, interest rates, energy prices, PPI, and the COVID-19 pandemic on TVS.

ε_t : The error term, accounting for unobserved factors, model discrepancies, and random shocks.

3.3 DATA SOURCES AND VARIABLES

This study analyses quarterly data from 2004 Q3 to 2024 Q3, a span that captures the 2007–2009 financial crisis, multiple oil-price swings, the COVID-19 pandemic, and the recent inflation surge. Data sources and variable definitions are summarised in Table 3.1. This study utilizes quarterly time-series data spanning from 2004 Q3 to 2024 Q3, sourced primarily from Federal Reserve Economic Data (FRED). Table 3.1 below shows the Data Sources and Variable Description:

A binary variable (Dummy 2020 = 1 for 2020 Q1–Q4, 0 otherwise) is included to capture the acute disruption caused by the COVID-19 pandemic. According to the U.S. International Trade Commission (2022), 2020 marked the most severe contraction in U.S. automotive production and demand in decades: manufacturing plants were shut down for nearly two months, dealer operations were curtailed, and supply chains experienced widespread breakdowns. Although the pandemic began in late 2019 and continued into 2021, its most concentrated economic and industrial effects were felt in 2020. Using a single-year dummy allows the model to isolate this sharp external shock without overlapping it with the subsequent partial recovery observed in 2021.

Table 3.1: Variable Definitions and Data Sources

Variable	Description	Measurement / Transformation	Data Source
TVS	Total Vehicle Sales, measuring changes in overall vehicle demand	Percent Change, Quarterly, Not Seasonally Adjusted	Federal Reserve Economic Data (FRED)

Variable	Description	Measurement / Transformation	Data Source
CPI	Consumer Price Index for All Urban Consumers: New Vehicles in U.S. City Average	Percent Change, Quarterly, Not Seasonally Adjusted	FRED, updated quarterly
PPI	Producer Price Index by Industry: Motor Vehicle Manufacturing, tracking production cost changes	Percent Change, Quarterly, Not Seasonally Adjusted	FRED, updated quarterly
GP	U.S. Regular All Formulations Gas Price, reflecting fluctuations in fuel costs	Percent Change, Quarterly, Not Seasonally Adjusted	FRED, updated quarterly

Variable	Description	Measurement / Transformation	Data Source
IR	Federal Funds Effective Rate, indicating changes in borrowing costs	Percent Change, Quarterly, Not Seasonally Adjusted	FRED, updated quarterly
Dummy2020	COVID-19 Impact Variable, capturing the effects of the pandemic on vehicle sales	Binary (1 for 2020, 0 otherwise)	Defined in study

3.4 RESEARCH HYPOTHESES

Table 3.2 summarizes the study's key variables, detailing their definitions, units of measurement, and the expected direction of their relationship with total vehicle sales (TVS). These variables were selected for their strong theoretical and empirical relevance to the automotive market, ensuring that the model captures the principal macro-economic factors that drive vehicle demand (Klier & Linn, 2010; Busse, Knittel, & Zettelmeyer, 2013).

In particular, the independent variables include inflation (measured by the Consumer Price Index, CPI), producer prices (PPI), gasoline prices (GP), and interest rates (IR). CPI represents overall consumer price inflation and is used to gauge how rising living costs might affect car affordability. PPI serves as an indicator of changes in production costs that could influence how automakers price their vehicles. Gasoline price is included because it can alter consumer preferences—for example, higher fuel prices might steer buyers toward more fuel-efficient or alternative-energy vehicles. Interest rate reflects the cost of borrowing money, influencing both consumers' car loan expenses and manufacturers' capital costs. Alongside these, a dummy variable for 2020 (DUMMY2020) is incorporated to account for the extraordinary impact of the COVID-19 pandemic, which disrupted supply chains and consumer spending patterns.

Each variable comes with an expected effect on vehicle sales, based on theory and prior evidence. CPI and PPI are both anticipated to have negative impacts: when consumer prices or production costs rise, consumers' purchasing power falls and vehicles become more expensive, likely reducing sales. The impact of interest rates is nuanced. Higher interest rates generally raise borrowing costs, reducing consumer affordability and thereby dampening automotive demand (Copeland, Hall, & Maccini, 2015). However, if rising rates coincide with robust economic growth, including higher employment and income levels, stronger consumer confidence can partially offset the negative effect of increased borrowing costs, thus helping sustain vehicle sales (Hall & Copeland, 2015). Gasoline prices may also have a mixed effect: expensive fuel can discourage purchases of less fuel-efficient vehicles, yet it can simultaneously encourage demand for more economical or alternative-energy models. Finally, the COVID-19 dummy variable is expected to capture a significant negative shock to vehicle sales due to the pandemic's disruptions.

Table 3.2 Research Hypotheses

Hypothesis	Null (H_0)	Alternative (H_1)
Inflation (CPI)	Inflation has no significant effect on TVS	Inflation significantly affects TVS
Interest Rate (IR)	Interest rates do not significantly impact TVS	Interest rates significantly impact TVS
Energy Prices (GP)	Energy prices have no significant effect on TVS	Energy prices significantly affect TVS
Producer Price Index (PPI)	PPI has no significant effect on TVS	PPI significantly affects TVS
Dummy2020(COVID-19)	The COVID-19 pandemic had no effect on TVS	The COVID-19 pandemic significantly affected TVS

3.5 ESTIMATION METHOD: ARDL COINTEGRATION

The estimation process involves several key steps. First, the time-series properties of each variable are examined using the Augmented Dickey-Fuller (ADF) test to determine their stationarity or order of integration (MPRA, 2023). Next, the ARDL bounds testing procedure is applied to check for a long run cointegrating relationship among the variables (Alimi, 2014). If the bounds test confirms cointegration, the ARDL model is then estimated to obtain both the long-run coefficients and the short-run dynamics (including an error-correction term linking the two). Finally, a series of diagnostic tests is conducted on the fitted model to check for any remaining issues (such as serial correlation or heteroskedasticity), ensuring the model's results are reliable.

ARDL is chosen for this study because of its flexibility and efficiency in handling time-series data. It can accommodate variables that are a mix of $I(0)$ and $I(1)$ while still yielding valid results in small- or medium-sized samples (Pesaran & Shin, 1995; Kripfganz & Schneider, 2023). Traditional cointegration methods like the Engle-Granger two-step procedure or Johansen's VAR-based approach require all variables to be integrated of the same order, but the ARDL method imposes no such restriction (Pesaran & Shin, 1995; Shin et al., 2011). This advantage allows us to include both stationary and first-difference stationary variables in the model together.

However, the ARDL approach is not without limitations. It can produce misleading results if any variable is integrated in order two or higher ($I(2+)$) since the bounds testing technique is only valid for up to $I(1)$ series. Additionally, using ARDL with a large number of variables or lag terms can become computationally intensive, so model selection criteria like the Akaike Information Criterion (AIC) or Schwarz Bayesian Criterion (SBC) must be applied carefully to choose a parsimonious model and avoid overfitting. Despite these considerations, ARDL remains a robust tool for capturing both short-run and long-run relationships in time-series data, making it well-suited for the present analysis.

The Autoregressive Distributed Lag (ARDL) bounds-testing framework proposed by Pesaran, Shin, and Smith (2001) is particularly well-suited to this study for several reasons. First, ARDL can handle a mixture of $I(0)$ and $I(1)$ variables, thereby avoiding the pre-test bias that arises when all regressors are forced to share the same order of integration. Second, simulation evidence shows that the estimator performs reliably even with modest sample sizes—an important advantage given the 80 quarterly observations used here. Third, the technique allows each explanatory variable to enter the equation with its own optimal lag length, which is essential when inflation, fuel prices, or interest-rate shocks reach vehicle demand with different delays. Once a long-

run relationship is confirmed by the bounds F-test, the model automatically yields an error-correction term whose coefficient measures the quarterly speed of adjustment back to equilibrium. Together, these features enable the simultaneous estimation of short-run dynamics (through differenced lagged terms) and long-run elasticities (through level terms) for inflation, energy prices, interest rates, and producer costs, providing a comprehensive view of how macro-economic forces shape U.S. vehicle sales.

3.5.1 ARDL bounds testing approach and unrestricted Error Correction Model (UECM)

To examine whether a long-run relationship exists among the variables in the study, this research employs the bounds-testing approach proposed by Pesaran, Shin, and Smith (2001). The procedure starts by setting up an Unrestricted Error Correction Model (UECM), which incorporates both the levels and the first differences of the variables in a single equation. The general form of the UECM for this study can be outlined as follows:

$$\begin{aligned} \Delta TVS_t = & \beta_0 + \sum_{i=1}^p \beta_i \Delta TVS_{t-i} + \sum_{j=0}^q \lambda_j \Delta CPI_{t-j} + \sum_{k=0}^r \delta_k \Delta IR_{t-k} + \sum_{l=0}^s \phi_l \Delta GP_{t-l} \\ & + \sum_{m=0}^t \varphi_m \Delta PPI_{t-m} + \sum_{n=0}^u \sigma_n \Delta dummy2020_{t-n} + \theta_1 TVS_{t-1} \\ & + \theta_2 CPI_{t-1} + \theta_3 IR_{t-1} + \theta_4 GP_{t-1} \\ & + \theta_5 PPI_{t-1} + \theta_6 dummy2020_{t-1} + \varepsilon_t \end{aligned}$$

Where:

Δ denotes the first-difference operator.

TVS_t are total vehicle sales.

CPI_t is the consumer price index for new vehicles.

IRt is the interest rate.

GPt is the gasoline price.

$PPIt$ is the producer price index.

$Dummy2020t$ is the binary variable controlling for pandemic effects.

ε_t is the error term.

The essence of the Bounds Testing method is to check the joint significance of the level variables $TVSt - 1, CPIt - 1, IRt - 1, GPt - 1, PPIt - 1, Dummy2020t - 1$. Specifically, one tests the null hypothesis of “no cointegration,” which can be written as:

$$H_0: \theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = \theta_6 = 0$$

Under the alternative hypothesis (that there is a long-run relationship), at least one of the δ -coefficients is non-zero. Pesaran et al. (2001) provide two sets of critical values: one set assumes all variables are integrated of order zero (I(0)), and another set assumes they are integrated of order one (I(1)). If the computed F-statistic from the joint significance test lies above the upper critical bound, we reject H_0 and conclude that the variables are cointegrated. If it lies below the lower bound, we fail to reject H_0 . If it falls between the two bounds, the result is inconclusive without further tests.

If the long-run relationship is confirmed, the UECM formulation conveniently yields both short-run and long-run estimates in a single framework. The significance of the coefficients on the lagged-level terms indicates how the variables adjust toward their long-run equilibrium path. This flexible approach offers a strong advantage over older cointegration methods, as it functions even with a mixture of I(0) and I(1) variables and is appropriate in samples of moderate size.

3.5.2 The short run and restricted ECM

Once a long-run relationship is established via the Bounds Test of Pesaran, Shin, & Smith (2001), the ARDL estimation produces an Error Correction Model (ECM) that links short-run dynamics to the long-run equilibrium. In this step, a critical component is the Error Correction Term (ECT_{t-1}), which represents the disequilibrium from the previous period (Engle & Granger, 1987; Narayan & Smyth, 2005). Formally, the Restricted ECM can be represented as follows:

$$\begin{aligned} \Delta LTVS_t = & \alpha_0 + \sum_{i=1}^p \alpha_{i+1} \Delta LTVS_{t-i} + \sum_{j=0}^q \Phi_{i+1} \Delta CPI_{t-j} + \sum_{k=0}^r \gamma_{i+1} \Delta IR_{t-k} \\ & + \sum_{l=0}^s \rho_{i+1} \Delta GP_{t-l} + \sum_{m=0}^t \Gamma_{i+1} \Delta PPI_{t-m} + \sum_{n=0}^u \eta_{i+1} \Delta dummy2020_{t-n} \\ & + \tau ECT_t \end{aligned}$$

Where:

τ is the coefficient of the error correction term ECT_{t-1} .

ECT_{t-1} is derived from the long-run equation.

In this restricted form, τ measures the speed of adjustment back to the long-run equilibrium after any short-run shock. A negative and significant τ implies that a portion of the previous period's disequilibrium is corrected in the current period, thus reinforcing the existence of a stable long-run relationship.

Under this framework, the coefficients on the first-differenced variables α_{i+1} , Φ_{i+1} , γ_{i+1} , ρ_{i+1} , Γ_{i+1} , η_{i+1} , etc., capture the immediate (short-run) effects of changes in each explanatory variable on $TVSt$. Meanwhile, the sign and magnitude of τ reveal how quickly the system converges to its steady-state path. This distinction between short-run and long-run effects is central to crafting policy responses and industry

strategies: while short-run changes in interest rates or gasoline prices can influence quarterly car sales, the error-correction mechanism sheds light on whether—and how fast—the market will revert to its underlying trend once these disruptions pass.

By integrating the ARDL bounds testing procedure with the restricted ECM, the study captures both transient fluctuations and sustained trends in the U.S. automotive industry. This comprehensive approach clarifies how inflation, interest rates, energy costs, and other factors reshape vehicle demand, not only from one quarter to the next but also in the broader, long-term context.

3.6 DIAGNOSTIC AND STABILITY TESTS

To verify that the model is statistically sound, several diagnostic and stability tests are performed. The Breusch-Godfrey LM test checks for serial correlation (autocorrelation of the residuals) (Godfrey, 1978), and the Breusch-Pagan test checks for heteroskedasticity (non-constant variance of the errors) (Breusch & Pagan, 1979). The Jarque-Bera test is used to assess whether the residuals are normally distributed (Jarque & Bera, 1987). Additionally, the stability of the model's coefficients over time is examined using cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests (Brown, Durbin, & Evans, 1975). Passing all these tests indicates that the model is well-specified and stable over the sample period, which adds confidence to the reliability of the results.

3.7 SUMMARY

This chapter has outlined the research methodology in detail, highlighting the use of the ARDL approach to capture both short-run and long-run relationships among the key variables. We described the model specification, the data set and sample period, the preliminary tests for stationarity, the cointegration testing approach, and the diagnostic checks employed to ensure model adequacy.

The next chapter will present the empirical results. Using the ARDL bounds testing framework (Alimi, 2014; Kripfganz & Schneider, 2023), it will estimate both the short-run and long-run linkages between total vehicle sales and the macroeconomic variables of interest. This includes examining how inflation, interest rates, energy prices, and the producer price index (along with the shock of COVID-19 captured by the 2020 dummy variable) have influenced vehicle sales over time. The findings will be interpreted in the context of existing economic theories and previous empirical studies, with an emphasis on their implications for policymakers and industry stakeholders.

CHAPTER FOUR

EMPIRICAL RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the quantitative findings of the study and discusses how key macroeconomic indicators—specifically inflation (CPI), producer price index (PPI), gasoline prices (GP), and interest rates (IR)—influence the U.S. automotive industry as measured by total vehicle sales (TVS). We begin by verifying the stationarity properties of each variable using Augmented Dickey-Fuller tests to ensure none of the series are integrated of order $I(2)$. Next, we identify the optimal lag lengths for the ARDL model based on the Schwarz Information Criterion. After establishing the model specification, we conduct the ARDL bounds test to determine whether a long-run cointegrating relationship exists among the variables. Upon finding cointegration, we estimate the long-run coefficients and the short-run dynamics (through an error correction model, ECM). We then carry out diagnostic tests to check for issues like serial correlation, heteroskedasticity, and model misspecification, and we assess model stability with CUSUM and CUSUMSQ tests. Finally, we integrate the results into a discussion, elaborating on the economic implications of the findings with regard to inflation control, energy pricing, financing costs, and the industry's resilience.

4.2 UNIT ROOT ANALYSIS

Before conducting the ARDL procedure, it is essential to verify that none of the variables are integrated at the order $I(2)$, as the ARDL bounds approach only accommodates the $I(0)$ and $I(1)$ series. Stationarity also helps prevent spurious regressions and ensures that subsequent inferences about cointegration and long-run relationships are valid.

As shown in Table 4.1, the Augmented Dickey-Fuller (ADF) test was performed on each series—TVS, CPI, PPI, GP, and IR—over the sample period from 2004Q3 to 2024Q3. EViews automatically determined a maximum lag length based on information criteria. The results indicate that TVS, PPI, GP, and IR are stationary at levels ($I(0)$), whereas CPI is non-stationary at level but becomes stationary after first differencing (D_CPI).

Table 4.1. Augmented Dickey-Fuller (ADF) Unit Root Test Results

Variable	ADF Statistic	p-Value	Order of Integration
TVS	-4.6506	0.0003	$I(0)$
CPI	-2.8674 (level)	0.0539	Non-stationary
D_CPI	-13.1167	0.0001	$I(1)$
PPI	-4.7257	0.0002	$I(0)$

GP	-9.1794	0.0000	I(0)
IR	-5.8951	0.0000	I(0)

From these results, no variable is integrated of order I(2). Consequently, the ARDL bounds testing framework is valid for determining long-run relationships among the variables. Furthermore, identifying the stationarity properties helps clarify whether changes in inflation or interest rates have transitory or persistent effects on automotive sales.

4.3 LAG SELECTION

Choosing the correct lag lengths is a critical step in ARDL modelling, as it influences both the short-run and long-run estimations. In this study, the Schwarz Information Criterion (SIC) was employed to balance model fit and parsimony. A broad range of ARDL specifications was examined automatically, and the top 20 models (ranked by SIC) were evaluated further.

Schwarz Criteria (top 20 models)

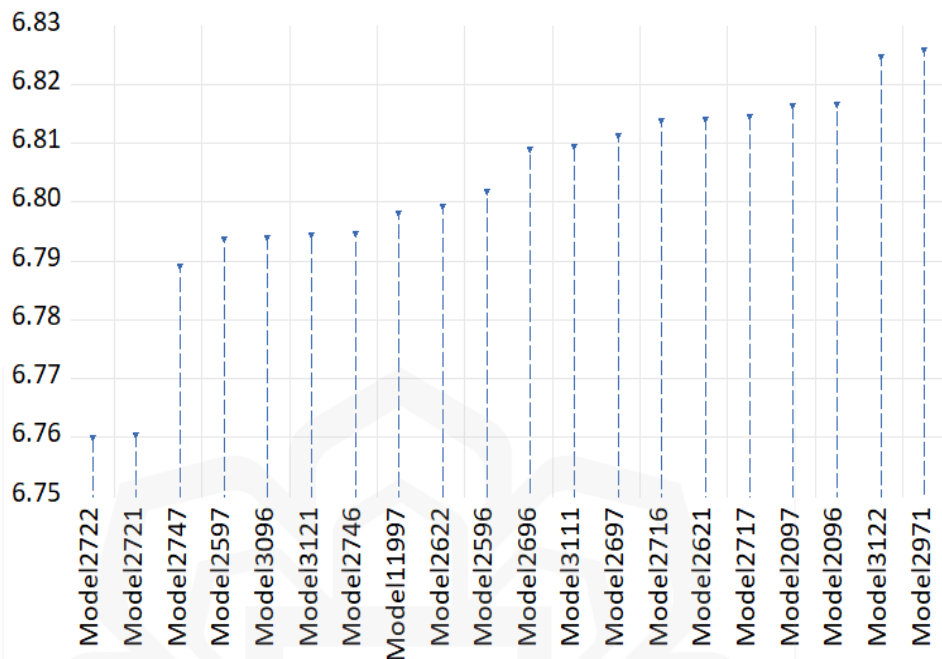


Figure 4.1. SIC-Based Lag Selection

The final selection is Model 2722, which is ARDL (4, 0, 3, 1, 0, 3), indicating:

TVS has four lags, reflecting potential inertia or cyclical patterns in consumer demand for automotive.

D_CPI requires no additional lag beyond differencing, suggesting inflation's immediate changes are sufficient to capture its impact.

GP has three lags, implying fuel price fluctuations may have a delayed yet multi-quarter influence on sales.

IR has one lag, indicating a relatively quick transmission of interest rate adjustments into vehicle financing dynamics.

PPI remains at zero lags, possibly reflecting that cost pressure from producers is quickly incorporated into market prices.

DUMMY2020 has three lags, accounting for staggered pandemic-related disruptions.

This systematic process ensures the final ARDL specification is not over-parameterized and that each macroeconomic variable's dynamics are properly accounted for.

4.4 BOUNDS TEST FOR COINTEGRATION

Having determined the integration orders and lag lengths, the next step is the bounds test to investigate whether the variables share a long-run equilibrium relationship. The test compares the computed F-statistic with critical bounds for I(0) and I(1) processes at various significance levels.

Table 4.2. Bounds Test for Cointegration

Statistic	Value	Signif.	I(0)	I(1)
F-statistic	4.7150	5%	2.39	3.38
k = 5		1%	3.06	4.15

Table 4.2 summarizes the bounds test result. The F-statistic is approximately 4.7150. At the 5% significance level, the critical bounds are 2.39 (I(0) bound) and 3.38 (I(1) bound). At the 1% level, the bounds are 3.06 (I(0)) and 4.15 (I(1)). Since our F-

statistic exceeds even the 1% upper bound, we reject the null hypothesis of no cointegration. This outcome affirms that a stable long-run relationship exists among TVS, CPI, GP, IR, PPI, and the pandemic dummy (Dummy 2020).

From a policy perspective, the existence of cointegration implies that these macroeconomic forces do not merely interact in the short term but maintain a systematic equilibrium relationship over time. This is an important insight when formulating long-term strategies for the automotive sector: it suggests that variables like inflation, interest rates, and energy costs collectively move with automotive sales in a way that keeps an equilibrium, despite short-term deviations.

4.5 LONG-RUN RELATIONSHIP

Table 4.3 summarizes the ARDL long-run coefficients derived from the selected model. These coefficients indicate how, in the long run, each independent variable influences total vehicle sales when the system is in equilibrium.

Table 4.3. ARDL Long-Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	p-Value
D_CPI	-2.9841	1.3082	-2.2812	0.0261
GP	-0.3180	0.2179	-1.4595	0.1496

IR	0.0406	0.0201	2.0180	0.0481
PPI	0.3898	0.6836	0.5702	0.5707
DUMMY2020	1.1693	4.9711	0.2352	0.8148
C	0.0702	0.9284	0.0756	0.9400

The coefficient for inflation (ΔCPI) is approximately -2.9841 ($p = 0.0261$), indicating that sustained inflation significantly suppresses automotive demand. This negative relationship aligns with existing economic literature, suggesting that persistent increases in inflation reduce real disposable incomes, thereby weakening consumer purchasing power and curtailing demand for durable goods such as automobiles (Kliesen, 2021; Duca, 2012; Ramey & Vine, 2010).

The gasoline price coefficient (GP), at about -0.3180 , is not statistically significant ($p = 0.1496$). The absence of significance here can be explained by previous studies showing consumers tend to adjust the type of vehicles they purchase rather than significantly reducing overall vehicle purchases in response to fuel-price volatility. Specifically, higher fuel prices typically result in consumer preferences shifting toward more fuel-efficient vehicles, leaving aggregate vehicle sales relatively stable in the long run (Klier & Linn, 2010; Busse, Knittel, & Zettelmeyer, 2013).

The coefficient for interest rate (IR) is approximately $+0.0406$ ($p = 0.0481$), which is statistically significant but carries a somewhat unexpected positive sign. Although higher interest rates are commonly anticipated to suppress automotive demand due to increased financing costs, this positive relationship may reflect periods when higher rates coincide with stronger economic growth, improved labor market conditions, and higher consumer confidence, which collectively support durable goods purchases despite higher financing costs (Bernanke & Blinder, 1992; Ustabaş & Büyün, 2024).

For the Producer Price Index (PPI), the coefficient is about +0.3898, and it is not statistically significant ($p = 0.5707$). Previous research indicates that moderate fluctuations in producer prices may often be absorbed by automakers through productivity enhancements, efficiency gains, or profit-margin adjustments, limiting the transmission of such cost pressures to end-consumer prices and, consequently, to consumer demand (Masoumi, Kazemi, & Abdul-Rashid, 2019).

Finally, the long-run coefficient for the pandemic dummy variable (DUMMY2020) is about +1.1693 and not statistically significant ($p = 0.8148$). This result indicates that although the COVID-19 pandemic caused substantial disruptions in the short run, it did not lead to lasting structural changes in the long-run equilibrium of automotive sales. Industry reports confirm that post-pandemic market dynamics are moving back toward pre-pandemic norms, suggesting the pandemic's impact is largely transient (Cox Automotive, 2023; 2024).

Overall, these long-run estimates confirm that inflation remains a major factor negatively influencing vehicle sales, whereas fuel-price changes primarily influence vehicle type rather than total sales volume. Interest rate effects appear context-dependent, influenced by broader economic conditions. Production costs, represented by the PPI, appear largely internalized within the industry, exerting minimal direct long-run impact on total sales. The pandemic's effects were notably severe in the short term but not persistent in altering long-run relationships.

4.6 SHORT-RUN DYNAMICS AND ERROR CORRECTION MODEL (ECM)

Although the long-run coefficients highlight equilibrium relationships, short-run fluctuations can deviate from this path. The error correction term (ECM) measures how quickly the system returns to equilibrium aftershocks.

Table 4.4. ECM Short-Run Estimates

Variable	Coeff.	Std. Error	t-Stat.	p-Value
D(TVS(-1))	-0.3578	0.1019	-3.5113	0.0009
D(TVS(-2))	-0.4053	0.0889	-4.5580	0.0000
D(TVS(-3))	-0.3623	0.0680	-5.3248	0.0000
D(GP)	0.2424	0.0525	4.6174	0.0000
D(GP(-1))	0.3164	0.0559	5.6614	0.0000
D(GP(-2))	0.2308	0.0582	3.9689	0.0002
D(IR)	0.0059	0.0081	0.7375	0.4637
D(DUMMY2020)	-0.3799	3.8396	-0.0989	0.9215
D(DUMMY2020(-1))	-20.9988	3.9570	-5.3067	0.0000
D(DUMMY2020(-2))	27.1041	4.0851	6.6348	0.0000
ECM(-1)	-0.7002	0.1162	-6.0254	0.0000

Table 4.4 presents the short-run (ECM) estimation results:

The error correction term, ECM(-1), has a coefficient of approximately -0.7002 ($p < 0.01$). This implies that about 70% of any deviation from the long-run equilibrium is corrected in the following quarter, a relatively high speed of adjustment. In practical terms, if auto sales are out of balance with the levels suggested by inflation, interest

rates, etc., the majority of that disequilibrium is resolved in the next quarter. This indicates a strong pullback to equilibrium—reflecting the automotive market’s resilience and the tendency for sales to stabilize relatively quickly after economic shocks.

Several lags of ΔTVS (quarterly changes in vehicle sales) are significant and negative (e.g., $\Delta TVS(-1) \approx -0.3578$, $\Delta TVS(-2) \approx -0.4053$, $\Delta TVS(-3) \approx -0.3623$, all $p < 0.01$). This suggests a short-term momentum or correction effect: a surge in sales in one quarter is often followed by a decline in subsequent quarters. Such dynamics could reflect inventory cycles or pent-up demand being satisfied, resulting in a pullback.

Changes in gasoline prices (ΔGP) and its lags have positive and significant coefficients in the short run. For instance, ΔGP (current quarter) $\approx +0.2424$, $\Delta GP(-1) \approx +0.3164$, $\Delta GP(-2) \approx +0.2308$, all $p < 0.01$. Counterintuitively, this indicates that increases in gas prices are associated with higher vehicle sales in the short run. One possible explanation is timing and consumer expectations: if gas prices are rising, consumers might accelerate vehicle purchases (especially fuel-efficient cars) expecting further price increases, or dealers might offer promotions to boost sales before higher costs fully hit. It could also reflect that gasoline price spikes often coincide with economic recoveries where consumers are more confident, partially offsetting the cost concern.

The immediate change in interest rates (ΔIR) has a small positive coefficient (+0.0059) that is not statistically significant ($p = 0.4637$), indicating that an interest rate hike or cut in a given quarter doesn’t instantaneously affect auto sales within that same quarter. This is reasonable because retail auto-loan rates, and thus consumers’ financing decisions, typically adjust only gradually after a change in the policy rate; this lagged

adjustment is consistent with the broader literature on the interest rate channel of monetary policy transmission (Mishkin, 1995).

The pandemic dummy shows an interesting pattern: the contemporaneous change ($\Delta\text{Dummy}_{2020}$) is negative but insignificant, while its first lag ($\Delta\text{Dummy}_{2020}(-1)$) is large and significantly negative (-20.9988 , $p < 0.01$), and the second lag is large and significantly positive ($+27.1041$, $p < 0.01$). This reflects the COVID-19 shock: auto sales didn't immediately plummet in early 2020 (many sales were already in the pipeline), but by the next quarter, they collapsed (hence the large negative lagged effect), and then by two quarters out there was a rebound (pent-up demand and adaptations, hence the large positive second lag). Essentially, the pandemic's effect on sales played out over multiple quarters rather than all at once.

The short-run dynamics of past sales and gas prices suggest some overshooting behaviour: a strong quarter is followed by a pullback (to correct over inventory or saturating demand), and higher fuel costs temporarily correlate with a flurry of activity (possibly due to substitution effects or timing of purchases).

To summarize the ECM results, about 70% of disequilibria in auto sales are corrected each quarter, indicating a quick reversion to long-run trend aftershocks. Short-run sales changes exhibit a "reversion to mean" pattern—big gains are partially reversed in subsequent quarters. Gasoline prices have a short-term positive relationship with sales, possibly due to consumer behaviour nuances and the timing of expectations. The COVID-19 shock had a staggered impact, with a sharp decline and rebound over a couple of quarters. These short-run findings highlight the automotive market's resilience and the importance of considering the timing and behavioural factors when examining immediate responses to economic changes.

4.7 DIAGNOSTIC TESTS

To ensure the reliability of the results, a battery of diagnostic tests was applied to the ARDL model's residuals. Serial correlation is examined using the Breusch–Godfrey LM test as proposed by Godfrey (1978), with an F-statistic of approximately 1.4921 ($p = 0.2169$), which indicates no evidence of autocorrelation in the residuals. This means our model has adequately captured the dynamic structure, and there aren't systematic patterns left in the residuals that could bias the standard errors or coefficients.

Heteroskedasticity is assessed using the Breusch–Pagan–Godfrey test (Breusch & Pagan, 1979). The test produces an F-statistic of approximately 0.3374 ($p = 0.9905$), suggesting that the variance of the residuals is constant (homoscedastic). In other words, there is no indication that the residual variance changes over time or with the level of any variable—implying the model's error terms are well-behaved in this regard.

Normality is evaluated with the Jarque–Bera test (Jarque & Bera, 1987). The JB statistic is approximately 3.6029 ($p = 0.1651$), which shows that we cannot reject the null hypothesis of normally distributed residuals. This is desirable for hypothesis testing, as many test statistics (and confidence intervals) rely on the assumption of normality in large samples.

The model's functional specification is tested using the Ramsey RESET test (Ramsey, 1969). The F-statistic obtained is approximately 1.9330 ($p = 0.1697$), indicating no significant functional-form misspecification. This suggests that our model likely includes the correct functional relationships, with no neglected non-linear transformations.

Collectively, these diagnostics provide confidence that the model is correctly specified and that the inference we draw—such as the significance of coefficients—is valid. No autocorrelation means past errors aren't predicting future errors; no heteroskedasticity means our standard errors are reliable; normal residuals and a correct functional form mean we haven't omitted key non-linear transformations.

4.8 STABILITY TESTS: CUSUM AND CUSUMSQ

Even when the diagnostic tests described above are satisfactory, it is still important to confirm that the model's parameters remain stable throughout the sample period, especially given the long timeframe (2004–2024) that spans major events. Following Brown, Durbin, and Evans (1975), cumulative-sum (CUSUM) and cumulative-sum-of-squares (CUSUMSQ) procedures are employed for this purpose.

For the CUSUM test, the plot of the cumulative sum of recursive residuals (see Figure 4.2) remains entirely within the 5 percent confidence band across the whole sample. This finding indicates the absence of structural breaks in the estimated coefficients; even shocks such as the 2008 financial crisis and the 2020 pandemic did not produce lasting shifts in the underlying long-run relationship, a pattern also reported for ARDL applications in Bahmani-Oskooee and Bohl (2000).

For the CUSUMSQ test, the companion plot (Figure 4.3) likewise stays within its critical limits, implying that the variance of the residuals is stable over time. No sudden changes in error volatility are detected, further supporting parameter constancy.

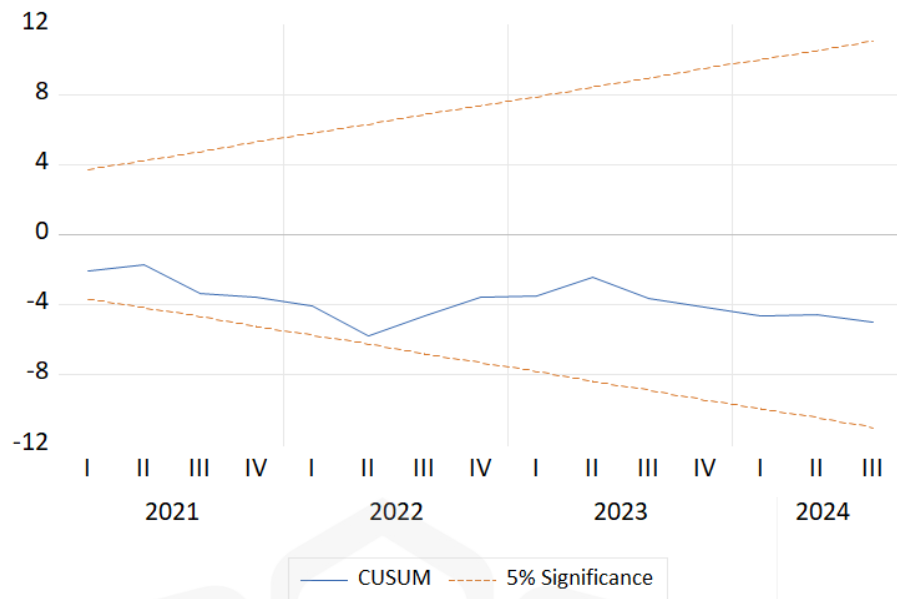


Figure 4.2. CUSUM Test

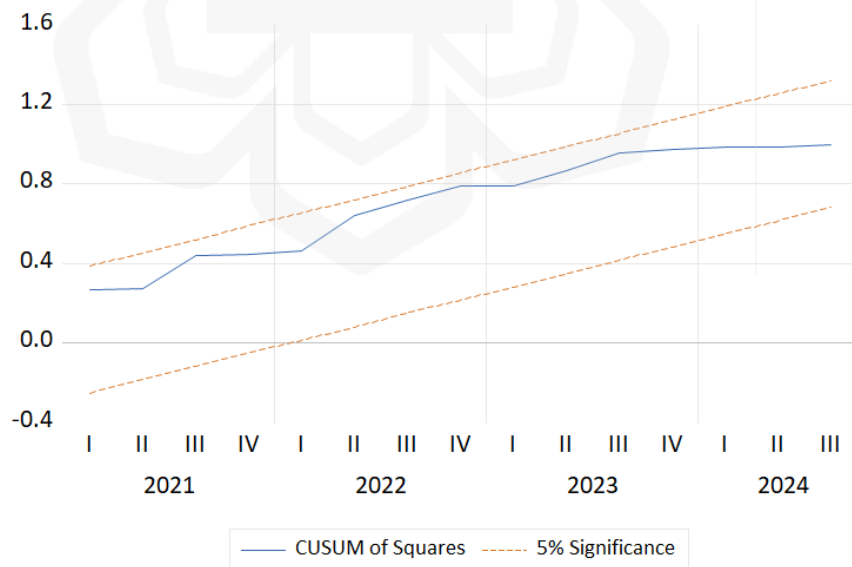


Figure 4.3. CUSUMSQR Test

Overall, the joint evidence from CUSUM and CUSUMSQ confirms that the short-run dynamics and long-run equilibrium estimated for the U.S. automotive market are robust across sub-periods, consistent with the stability results documented in prior ARDL studies (Bahmani-Oskooee & Bohl, 2000).

4.9 INTEGRATED FINDINGS AND DISCUSSION

The empirical estimations provide several key insights into the relationship between macroeconomic factors and total vehicle sales in the United States. The findings indicate that inflation is the most significant constraint on vehicle sales, with both short-run and long-run estimates confirming its negative impact. Rising inflation erodes consumers' purchasing power, leading to reduced demand for durable goods such as automobiles. In periods of high inflation, households are more likely to delay or cancel large purchases, contributing to fluctuations in the automotive market. This underscores the critical role of price stability in sustaining consumer confidence and demand within the sector. This finding aligns well with previous empirical studies such as Kliesen (2021), Duca (2012), and Ramey and Vine (2010), all of which highlight inflation as a key factor negatively influencing automotive sales through reduced real incomes and diminished consumer spending power.

The impact of interest rates is more complex than conventional wisdom might suggest. While higher borrowing costs are typically associated with lower vehicle sales, our results indicate a slightly positive long-run relationship between interest rates and vehicle demand. This may be explained by broader economic conditions: rising interest rates often coincide with economic expansions, increased household incomes, and greater consumer confidence, consistent with the findings of Bernanke and Blinder

(1992), who argue that higher interest rates can occur during periods of robust economic growth, partly offsetting the negative effect of borrowing costs. Ustabaş and Büyün (2024) also support the idea that context matters for interpreting the impact of monetary policy on auto sales. In the short run, interest rate changes did not have a significant immediate effect, suggesting that consumers do not respond instantly to rate fluctuations, especially when economic fundamentals are strong.

Regarding energy costs and producer constraints, gasoline prices do not appear to exert a significant long-term influence on vehicle sales, though they do show a strong short-term effect. This finding is consistent with earlier studies, such as those by Klier and Linn (2010) and Busse, Knittel, and Zettelmeyer (2013), indicating that consumers adjust their purchasing preferences—for instance, switching to fuel-efficient models rather than abandoning vehicle purchases entirely—when facing sustained fuel price volatility. Over the long run, these behavioral adaptations prevent fuel prices from fundamentally altering the total number of vehicles sold. However, in the short run, gasoline price increases show a positive and significant effect, suggesting that consumers may expedite vehicle purchases to avoid anticipated higher future prices, a behavior also observed by Allcott and Wozny (2014).

Moreover, the lack of a statistically significant relationship between producer costs (PPI) and vehicle sales indicates that fluctuations in production expenses are not directly transferred to consumers in a way that markedly affects demand. Automakers may be absorbing cost changes or finding efficiencies, and competitive pressures could be preventing cost-push inflation from fully impacting consumers. This interpretation aligns with Masoumi, Kazemi, and Abdul-Rashid (2019), who found that automotive manufacturers typically absorb moderate cost shocks internally rather than passing them on immediately to consumers.

The impact of the COVID-19 pandemic on vehicle sales reveals important insights. While the immediate effect in early 2020 was limited (sales didn't drop until the next quarter), the following quarter saw a severe decline, and subsequent quarters experienced a strong rebound. This pattern reflects the industry's ability to absorb shocks and the role of external support (such as fiscal stimulus and historically low interest rates) in reviving demand. Industry reports, including Cox Automotive (2023), also confirm the temporary nature of the pandemic's impact on automotive sales. The pandemic's effect was significant but transient; by the time we consider long-run relationships, the dummy variable for 2020 is insignificant, suggesting that the industry found a new equilibrium post-shock. This highlights the importance of viewing macroeconomic shocks not just for their initial impact but also for their lagged and recovery effects.

Finally, the speed of adjustment of the automotive market is notable. With roughly 70% of disequilibrium corrected each quarter, the market shows a strong tendency to revert to its long-run path. This indicates resilience: even when shocks like inflation spikes or supply chain disruptions push sales off track, the combination of market mechanisms (such as inventory adjustments and promotional activities) and policy responses (such as stimulus packages or monetary easing) helps sales bounce back quickly. However, this fast adjustment also means that policies intended to stimulate or cool the market need to be timely; delays in intervention could miss the window where they'd be most effective.

In summary, inflation control is paramount for maintaining healthy vehicle sales. High inflation is detrimental to auto demand, so central banks and governments should prioritize price stability to support consumer purchasing power for big-ticket items.

Economic context matters for interest rates. Policymakers should recognize that moderate rate hikes in a growing economy might not hurt auto sales much, but in a weaker economy, even small increases could have larger effects. Thus, interest rate policy should be calibrated considering the state of economic growth and consumer confidence.

The auto industry and consumers are adaptable to energy price swings in the long run, but short-term spikes can cause volatility. Policymakers might need to intervene (e.g., releasing oil reserves or providing temporary subsidies) if fuel costs surge too rapidly, to prevent short-run market disruption. Automakers, on their part, can mitigate long-run effects by diversifying their product mix (e.g., more EVs and hybrids) to reduce consumer fuel cost sensitivity.

Supply chain and cost issues (reflected in PPI) did not show up as demand changes, implying automakers have been managing these internally. However, sustained cost pressures could eventually require passing costs to consumers, so maintaining efficient production and exploring cost-saving technologies remains vital.

Resilience and policy agility: The quick error correction means the industry can recover swiftly, but it also means that supportive policies (like stimulus checks or tax breaks for car purchases) should be deployed promptly after a shock to be most effective. Conversely, if the market is overheating, delaying policy action might result in the market self-correcting (or overshooting) before measures take effect.

Overall, these results confirm a robust ARDL framework with a valid cointegrating relationship and a rapid speed of adjustment. They emphasize that stabilizing inflation and managing short-run shocks (such as fuel price spikes or sudden crises) are essential for sustained growth in the U.S. automotive industry.

4.10 SUMMARY

By combining data analysis with economic reasoning, this chapter showed that inflation is the most critical factor negatively affecting U.S. automotive sales in the long run. Interest rates have a more nuanced effect that often mirrors broader economic conditions. Gasoline price swings, while not a major long-term drag on sales, do influence the market in the short term—likely through consumer adaptation or automaker promotions. Producer cost changes (as reflected by the PPI) are mostly absorbed by the industry and do not consistently suppress vehicle demand. Overall, inflation emerges as the biggest threat to auto sales, but the industry’s ability to adapt quickly helps blunt the impact of other factors. With the right policies to keep prices stable and manage short-term shocks, the U.S. automotive market can continue to grow robustly.

CHAPTER FIVE

CONCLUSION

5.1 SUMMARY OF KEY FINDINGS

This study investigates the impact of inflation on total vehicle sales in the United States by employing an Autoregressive Distributed Lag (ARDL) model, using quarterly data covering the period from 2004 Q3 to 2024 Q3. The empirical findings indicate the presence of both short-run and long-run relationships between inflation and vehicle sales, confirming the theoretical expectation that rising inflation significantly reduces automotive demand. The results also underscore the complexity of interest-rate effects, demonstrating that the broader economic context matters substantially when interpreting monetary-policy impacts.

Additionally, gasoline-price fluctuations appear to influence vehicle sales primarily through short-term adjustments in consumer behavior rather than long-run aggregate demand. Producer price variations did not significantly influence vehicle sales, indicating that automakers are likely absorbing moderate cost fluctuations without immediate impacts on consumer pricing.

Finally, the COVID-19 pandemic had a noticeable short-run disruptive effect but did not produce a lasting structural shift in automotive sales. The diagnostic and stability tests confirm the robustness and structural stability of the estimated ARDL-ECM, thereby enhancing the reliability of the study's conclusions. Collectively, these findings provide valuable insights into how macroeconomic factors, particularly inflation, affect

vehicle sales dynamics, thereby informing relevant policy formulation and strategic planning in the automotive industry.

5.2 CONTRIBUTION OF STUDY

This study contributes significantly to the existing literature and provides meaningful insights for policy formulation in understanding how inflation and related macroeconomic factors influence total vehicle sales, particularly within the U.S. automotive market. From a theoretical standpoint, this research enriches economic literature by empirically verifying the dynamic interactions between inflation and automotive demand in both the short and long run, employing a robust Autoregressive Distributed Lag (ARDL) model. It bridges a gap in prior research by clearly demonstrating how inflation, gasoline prices, interest rates, producer costs, and specific shocks (such as the COVID-19 pandemic) interactively shape consumer and producer behaviors, and thus vehicle market outcomes. This study also extends existing discussions on monetary transmission by highlighting the complexity of interest rate impacts, demonstrating that macroeconomic context significantly affects how interest rate fluctuations influence vehicle demand.

In terms of policy, the study provides valuable insights that can inform decisions aimed at maintaining market stability and resilience. The significant negative impact of inflation on automotive demand underscores the importance of price stability, suggesting that policymakers should prioritize controlling inflation to sustain consumer purchasing power and overall market health. The nuanced relationship identified between interest rates and automotive sales implies that policymakers must carefully consider the broader economic context before implementing interest rate changes;

raising rates in a growing economy might yield minimal negative effects on auto demand, whereas similar measures in economic downturns could amplify adverse effects. Moreover, the short-run responsiveness of vehicle sales to gasoline price fluctuations indicates that proactive energy policy interventions, such as the strategic management of fuel reserves or temporary subsidies, could effectively moderate short-term market volatility. Lastly, the observed rapid market adjustments following economic disruptions imply that policy responses to economic shocks should be swift and targeted, ensuring timely and effective mitigation of adverse impacts. By clearly identifying these relationships, this research provides both theoretical enhancement and practical policy guidance, significantly advancing understanding of macroeconomic influences on the automotive market.

5.3 LIMITATION OF STUDY

Although this study provides insights into the link between macroeconomic variables and automotive sales, its scope is bounded by the availability and granularity of data. Quarterly data shed light on major market trends but do not fully capture rapid shifts that can occur within shorter intervals. The model also abstracts from regional differences within the United States, where local economic conditions could amplify or dampen the effects of inflation or energy price fluctuations. Moreover, external shocks—such as sudden policy changes or geopolitical events—were controlled using indicator variables, yet they might have additional implications that are not fully addressed in the current analysis.

5.4 SUGGESTION FOR FUTURE STUDY

Subsequent research might focus on finer-grained time frames, such as monthly data, to better understand how consumer purchase patterns respond to unanticipated shocks in inflation or interest rates. Examining the role of emerging technologies—such as electric and connected vehicles—would also offer a deeper view of how product innovation can mitigate or amplify the broader economic forces at work. Furthermore, regional or micro-level studies could unpack how demographic factors or local regulations influence automotive sales. By integrating these considerations into advanced modelling approaches, future inquiries can offer an even clearer picture of how the industry navigates a constantly evolving economic landscape.

5.5 CONCLUDING REMARKS

Overall, this study demonstrates that inflation has a significant impact on the U.S. automotive market, primarily by reducing the affordability of cars and dampening consumer confidence. When prices rise across the board, households tend to postpone large expenditures, such as buying new cars; however, if the overall economic environment is relatively sound, some of the negative effects may be offset. The results show that maintaining low inflation, moderate interest rates, and stable energy prices are key to ensuring the sound development of the automotive industry. For policymakers, this means taking measures to control inflation and ensure a loose credit environment; automakers should focus on improving production efficiency and increasing technological innovation to meet the challenges of rising costs. Overall, this study provides useful, practical guidance for government and industry leaders to help

maintain the competitiveness and stability of the automotive market in a changing economic environment.



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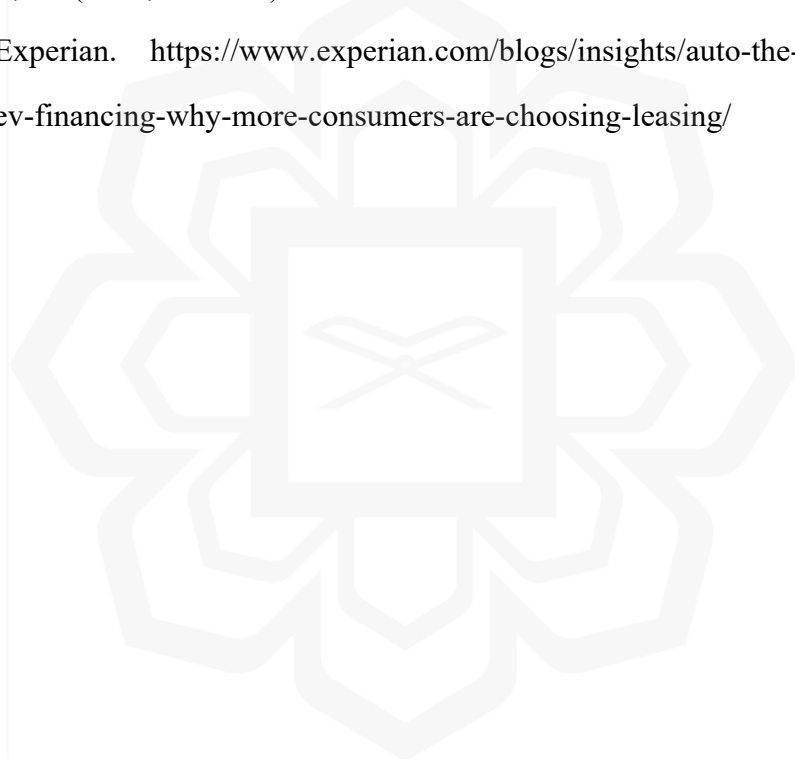
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APPENDIX A: DIAGNOSTIC-TEST RESULTS

Test	Statistic	p-value
Breusch–Pagan–Godfrey heteroskedasticity test	F = 0.337392	0.9905
Breusch–Godfrey serial-correlation LM test (lags = 4)	F = 1.492101	0.2169
Ramsey RESET specification test	F = 1.933009	0.1697
Jarque–Bera normality test	JB = 3.602924	0.165057