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Financing the Future: How Electrification Shapes Capital Structure Decisions in the Automotive Industry

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Abstract

This study examines the impact of electrification on the capital structure decisions of car manufacturers, addressing a gap in the literature on financial strategies during technological transitions. While traditional capital structure theories have explored firm-specific and macroeconomic determinants of leverage, little research has been conducted on how major industry shifts—particularly the transition to electric vehicles (EVs)—affect firms' financing choices. Using a dataset covering 30 global automakers from 2014 to 2023, this study employs regression analysis to assess the relationship between electrification and leverage. The results indicate that electrification does not reduce leverage but instead influences debt structure. Firms shifting toward electrified vehicle production decrease their long-term debt while increasing their use of short-term debt. This finding aligns with prior research on technological change, which suggests that declining asset tangibility and increased financial uncertainty lead firms to adopt more flexible financing strategies. These findings contribute to the literature by providing empirical evidence that technological disruption influences not overall total leverage levels but rather debt maturity structures. The study also provides practical insights for industry leaders, investors, and policymakers. By bridging the gap between capital structure theory and technological change, this research offers a foundation for future studies on financial strategies in rapidly evolving industries. Understanding the financial implications of electrification is essential for ensuring the long-term sustainability and competitiveness of automotive manufacturers in the global market.

Keywords: Capital Structure, Electrification, Automotive Industry, ESG, Corporate Finance

Resumo

Este estudo analisa o impacto da eletrificação nas decisões de estrutura de capital dos fabricantes de automóveis, abordando uma *gap* existente na literatura sobre estratégias financeiras durante transições tecnológicas. Enquanto as teorias tradicionais de estrutura de capital exploram determinantes específicos da empresa e fatores macroeconómicos, pouca investigação tem sido feita sobre como grandes mudanças na indústria — em particular a transição para veículos elétricos (EVs) — afetam as escolhas de financiamento das empresas. Utilizando dados que abrange 30 fabricantes automóveis globais entre 2014 e 2023, este estudo recorre a uma análise de regressão para avaliar a relação entre eletrificação e dívida. Os resultados indicam que a eletrificação não reduz a dívida total, mas influencia a estrutura desta. As empresas que orientam a sua produção para veículos eletrificados tendem a reduzir o recurso a dívida de longo prazo, aumentando o uso de dívida de curto prazo. Este resultado alinha com investigações anteriores sobre mudança tecnológica, que sugerem que a diminuição da tangibilidade dos ativos e o aumento da incerteza financeira levam as empresas a adotar estratégias de financiamento mais flexíveis. Estes resultados contribuem para a literatura ao fornecer evidência empírica de que a disrupção tecnológica influencia a maturidade da dívida. Ao fazer a ponte entre a teoria da estrutura de capital e a mudança tecnológica, esta investigação fornece uma base para futuros estudos sobre estratégias financeiras em indústrias em rápida transformação. Compreender as implicações financeiras da eletrificação é essencial para garantir a sustentabilidade e competitividade a longo prazo dos fabricantes automóveis no mercado global.

Palavras-Chave: Estrutura de Capital, Eletrificação, Indústria Automóvel, ESG, Finanças Corporativas

Contents

Table of Tables

Abbreviations

BEV- Battery Electric Vehicle

CSR- Corporate Social Responsibility

ESG- Environmental Social and Governance

EV- Electrified Vehicle

FCEV- Fuel Cell Electric Vehicle

ICE- Internal Combustion Engines

OLS- Ordinary Least Squares

PHEV- Plugin Hybrid Electric Vehicle

R&D- Research and Development

RV- Recreational Vehicle

U.S.- United States

USD- United States Dollar

VIF- Variance Inflation Factor

1. Introduction

The global automotive industry is undergoing a profound transformation driven by the shift towards electrification of the manufactured vehicles. Electrified vehicles (EVs) such as battery electric vehicles (BEVs), plugin hybrid electric vehicles (PHEVs) and fuel cell electric vehicles (FCEVs) have experienced remarkable growth, increasing from just 0.4% of global car sales in 2014 to around 16% in 2023 (Statista, 2024). This shift is fueled by technological advancements, environmental concerns and government policies that are incentivizing the transition away from internal combustion engines (ICE). However, the financial implications of this shift, particularly how electrification is reshaping manufacturers´ capital structure decisions, still remain unexplored in current literature.

Theoretical foundations on the topic of capital structure have long tried to explain firms´ financing decisions. Modigliani and Miller (1958, 1963) were pioneers in studying this topic, suggesting that, under perfect market conditions, capital structure is irrelevant to firm value. However, when incorporating tax benefits and bankruptcy costs, the trade-off theory emerged, proposing that firms balance debt and equity to optimize the benefits from tax shields while avoiding financial distress costs (Kraus & Litzenberger, 1973; Scott, 1976). Later, the pecking order theory introduced by Myers (1984) argued that firms prioritize internal financing before next resorting to debt and only using equity as a last resort. Meanwhile, Baker and Wurgler (2002) market timing theory suggests that firms issue equity when their stock price is overvalued and repurchase it when undervalued, implying that financing decisions are also driven by market conditions.

While these theories provide a general framework for understanding capital structure decisions, they do not fully account for more specific scenarios such as the impact of technological transformations on leverage. Lang et al. (1996) argue that during technological shifts, firms decrease their asset tangibility which in turn reduces their borrowing capacity. Similarly, Miao (2005) suggests that firms going through such changes tend to reduce leverage to maintain financial flexibility and avoid underinvestment risks. In the automotive industry, technological advancements have already been shown to reshape financial strategies (Llopis-Albert et al., 2021). However, research has yet to analyze the specific impact of electrification on debt levels of firms.

One of the most significant factors influencing capital structure in the automotive industry is the shift towards sustainability. The transition to EV production is not merely a technological update but a structural shift of firms´ financial strategies. Electrification demands substantial capital investments in R&D (Llopis-Albert et al., 2021). Such investments are motivated by the need to meet environmental, social and governance (ESG) factors and studies suggest that firms with stronger ESG commitments tend to adopt more conservative financial strategies, reducing debt to mitigate financial risk (Huang & Ye, 2021; Apergis et al., 2022).

Moreover, governments have increasingly been incentivizing consumers and manufacturers with tax benefits, such as exemptions, to stimulate the adoption rates of EVs (Lévay et al., 2017; Gerlagh et al., 2018) and also giving away subsidies to manufacturers, which have shown to be more effective than tax policies (Bian & Zhao, 2020). Furthermore, Shu et al. (2023) found that companies who are more subjected to these policies tend to lower their debt levels, especially in regions where governments intervene more. Given that electrification is, in big part, driven by sustainability goals, it is reasonable to hypothesize that automakers pursuing EV production show similar behaviors.

Despite these insights, no existing study directly examines how electrification influences capital structure decisions in the automotive sector. While previous literature has analyzed how technological changes (Lang et al., 1996; Miao, 2005) and ESG commitments (Apergis et al., 2022) impact leverage, these studies do not specifically address the unique financial challenges brought by the transition from ICE vehicles to EVs.

This gap in literature underscores the need for an examination of how electrification affects car manufacturers´ capital structure decisions.

Building on these theoretical and empirical foundations, our study aims to investigate whether electrification has an impact on car manufacturers´ use of leverage. Given that technological shifts often reduce firms´ borrowing capacity (Lang et al., 1996; Miao, 2005) and that companies with stronger ESG commitments tend to reduce their debt levels (Apergis et al., 2022), we hypothesize that transitioning to EV production leads to a decrease in leverage. This hypothesis is particularly relevant in the current state of this industry, where firms are facing increasing capital expenditures and R&D costs related to electrification, along with mounting regulatory pressures related to sustainable business practices.

By addressing this research gap, this study contributes to the broader topic of how major industrial transformations affect firms´ corporate finance decisions. Understanding the financial consequences of electrification is crucial for multiple stakeholders. Investors interested in the automotive industry will find a thorough financial analysis of the main players in the industry by seeing how their different financial determinants affect each other. They can also apply this knowledge to firms in other changing industries as some key financial decisions show similar patterns across shifting industries. All these insights can be helpful for their own portfolios´ decisions. Policymakers can use these insights to design more effective incentives for EV production and managers can develop financing strategies to ensure long-term growth and competitiveness.

2. Hypothesis development

2.1. Literature Review

In this section, we will start by reviewing the main theories explaining how firms make financing decisions, including the trade-off theory, pecking order theory, and market timing theory. Following this, we look at the few existing studies on capital structure determinants in the automotive industry. Next, we will examine how technological shifts affect capital structure decisions, followed by showing how these shifts are happening in the automotive industry. Following this, we will delve into studies that link how sustainability commitments are affecting firms financing choices, followed by how different policies are pushing towards these sustainability efforts. Lastly, combining all this knowledge acquired in literature leads us to hypothesize how electrification impacts debt level choices in automakers.

Foundational Capital Structure Theories

The first academic study on capital structure dates to 1958, when Modigliani and Miller (1958) laid the foundation for modern capital structure theory. In their paper, they introduced the proposition that, in perfect capital markets (with no taxes, transaction costs, or bankruptcy costs), a firm´s value is entirely independent of its capital structure. This implies that it is irrelevant to a firm´s value whether it finances itself with debt or equity. Later, Modigliani and Miller (1963) incorporated tax shields, asserting that corporate taxes incentivize the use of debt as a financing source since interest payments on debt are tax-deductible. This work formed the basis of the trade-off theory.

Subsequent studies further developed this theory. Kraus and Litzenberger (1973) examined the trade-off theory between the tax benefits of debt and the expected costs of bankruptcy. Scott (1976) introduced the concept of an optimal target debt ratio, suggesting that firms adjust their debt levels to maintain a balance between tax shields and the financial distress costs associated with debt. Scott (1976) also proposed that while firms may deviate from their target ratio, they eventually return to it. In addition to tax and bankruptcy costs, agency costs- arising from conflicts of interest between shareholders and debt holders- also influence firms′ capital structure decisions (Jensen & Meckling, 1976; Kim, 1978; Harris & Raviv, 1991).

In contrast, Myers (1984) criticized the trade-off theory and proposed the pecking order theory, which posits that firms prefer internal funds as their primary source of financing. This preference arises because internal funds are assumed to be the cheapest and least restrictive option. When internal funds are insufficient, firms turn to debt financing until they reach their debt capacity, using equity financing only as a last resort. This is because debt is cheaper, as debt holders require a smaller risk premium compared to equity holder.

Further studies, such as Shyam-Sunder and Myers (1999), tested traditional capital structure theories against the pecking order model, concluding that firms often deviate from the trade-off theory, supporting the idea of hierarchical financing preferences. Frank et al. (2003) found that the pecking order theory aligns with large, profitable firms but observed that smaller firms do not consistently exhibit behavior in line with this theory.

Later, Baker and Wurgler (2002) introduced the market timing theory, which argues that firms issue equity when their stock prices are overvalued and repurchase equity when prices fall, attempting to “time the market”. Their study also found that firms issuing equity during periods of high valuation tend to maintain lower debt levels in the long term.

Technological Shifts and Capital Structure

Lang et al. (1996) studied the relationship between shifts in asset structure, often associated with changes in business models, and leverage. They argued that asset tangibility decreases during technological transitions. This, consequently, reduces a firms´ borrowing capacity.

Companies shifting their corporate strategy, either by diversification or by adopting new business models, often reassess their capital structure decisions. They are believed to adjust leverage levels to meet increased capital requirements to go through with the change. Kochhar (1997) found that firms going through substantial changes in strategic approaches, may reduce debt levels to preserve financial flexibility or, in contrast, increase it to finance new growth opportunities.

Miao (2005) also concludes that leverage decreases with technology growth in a firm. He argues that the benefits of employing debt decrease as firms prioritize equity to hold stable financial flexibility and avoid underinvestment risks. Furthermore, during these periods, firms require higher technological efficiency to be successful. This incentivizes them to lower debt levels to avoid financial distress during fast changes.

Technological shift in the Automotive industry

The automotive industry is undergoing a deep technological transformation, driven by digitalization, automation and electrification. This shift is altering companies´ business models, supply chains and investment strategies.

Llopis-Albert et al. (2021) highlight how digital transformation is reshaping the industry through the integration of autonomous driving and big data analytics. They argue that these investments require significant investments in R&D and infrastructure which increase capital expenditures and financial uncertainty. In their sample composed of Spanish companies, they found that this uncertainty related to investment risk, makes companies reluctant to devote capital to such efforts.

Similarly, Yun et al. (2025) study the impact of digital transformation across different automotive markets, namely Japan, South Korea and Germany. Their paper suggests that manufacturers are restructuring their processes to remain competitive in an era of change in the industry. Their analysis highlights how firms are increasingly looking for collaborative partnerships to acquire technological knowledge to implement in their research and development efforts.

ESG and Capital Structure

Llopis-Albert et al (2021) also state that the technological shift in the automotive industry is changing the way car manufacturers are delivering goods to the market. They argue that this change is, in part, the result of governmental legislation regarding environmental concerns. This suggests two things: that the industry is going through transformation and that firms are increasing their ESG commitments. As we have seen, Lang et al. (1996) found that firms going through technological shifts reduce their borrowing capacity due to changes in asset structure. Parallelly, Miao (2005) concluded that firms going through technological growth reduce their debt levels.

Huang and Ye (2021) argued that firms with stronger CSR commitments usually opt for more conservative financial strategies. They tend to lower debt levels to keep resilience during periods of higher uncertainty. On the other hand, overleveraged firms with poor CSR performance are more vulnerable in times of economic uncertainty.

Apergis et al. (2022) studied the relationship between firms´ ESG scores and their debt levels, finding that they are inversely correlated as shown in bond yields. Firms with higher ESG scores tend to have lower bond yields as they´re considered to be less risky by investors. While it may seem that lower borrowing costs would incentivize more use of debt as a financing source, in this context, firms with higher ESG scores prioritize long-term stability and maintain financial flexibility for future investments, which can be achieved by reduced debt levels.

Similarly, firms also tend to decrease leverage when faced with carbon policy risk (Shu et al., 2023). Following the previous rationale regarding ESG and debt levels, the behavior with carbon policy also reflects a strategy to maintain financial flexibility and reduce the risk of financial stress caused by strict carbon regulations. Furthermore, it was also found that companies in regions where the governments have greater influence on the economy respond more strongly to carbon policy by reducing the use of debt.

Electrification and Legislation

Besides environmental policies, there are also other policies that incentivize the adoption of electrified vehicles among manufacturers, namely financial incentives. Previous studies have explored the impact of incentives such as exemption from registration and annual taxes (Lévay et al., 2017) and also sales tax exemption (Gerlagh et al., 2018).

In fact, financial incentives are found to have a positive impact on EV adoption. Jenn et al. (2018) evaluated this impact in the US and found that for every 1000 USD offered as tax credit, the average sale of EVs increased by 2.6%. However, instead of incentives, penalties were also found to be very effective. In his paper, Deuten et al. (2020) found that in Norway, only penalties on manufacturers for not adhering to emission targets resulted in increased share of EV production.

Another crucial incentive for the adoption of this technology are government subsidies. Research conducted by Bian and Zhao (2020) compared subsidy policies versus tax policies and found that subsidy policies were more effective at making manufacturers reduce their emissions.

Electrification and Capital Structure

To the best of our knowledge, no prior studies have directly examined the impact of electrification on leverage, as this topic has been specifically investigated for the purposes of this paper. However, existing research offers valuable insights that enable us to infer its potential relationship with capital structure decisions. As previously researched, the automotive industry is increasing its digitalization, tied to electrification efforts (Llopis-Albert et al., 2021;Yun et al., 2025). Furthermore, we know by studying the papers of Lang et al. (1996) and Miao (2005) that companies going through technological advancements decrease their leverage and that such changes are happening with electrification. Moreover, Llopis-Albert et al. (2021) said that those changes are boosted, in part, by environmental concerns which incentivize car manufacturers to become more sustainable.

Finally, some studies relating ESG with capital structure argue that firms tend to decrease debt levels when subjected to carbon policy risks. Firms in regions where governments intervene more on the economy decrease their leverage more than firms in less strict legislated regions (Shu et al 2023). In line with this, we argue that car manufacturers advancing toward electrification are likely to exhibit higher ESG scores, as shown by the correlation between these variables in Table 7 (See Appendices).

All these ideas combined led us to the hypothesis that, since the automotive industry is facing technological transformation and becoming more sustainable, we expect their debt levels to have decreased due to advancements in electrification during the period analyzed for our sample. In summary, our hypothesis is the following:

H1: Electrification has a negative impact on car manufacturers' use of leverage.

2.2. Data and Variables

2.2.1. Data Source and Description

Moving on to the study, research was conducted on a set of companies to assess how their transition to electrification is impacting their capital structures.

This study employs a panel dataset collected from the Refinitiv Eikon database. Panel data is a collection of observations obtained across multiple individuals, in this case firms, that are assembled over even intervals in time and in chronological order. Panel data combines features of time series and cross-section. It provides information on several statistical units for a number of years. It has several advantages for economic research as it provides the researcher with a large number of data points, while increasing the degrees of freedom and reducing co-linearity among explanatory variables. This improves the efficiency of econometric estimates (Baltagi, n.d.)

In our study, this data covers 10 years of financial information from 2014 to 2023. Additionally, data on vehicle sales, including electrified models, was manually gathered from firms' annual reports. Since this information is non-financial, it could not be extracted from Refinitiv Eikon, requiring direct consultation of each company's official documents.

The selected companies belong to the General Industry Classification Standard (GICS) "Automobiles" industry, which includes 175 publicly listed firms. However, due to data availability constraints, the final analysis focuses on 30 companies, resulting in 300 observations.

To make sure that our results are not driven by extreme values and possible data entry errors, we winsorize all the variables at the 1st and 99th percentile of their distributions (Dittmar & Mahrt-Smith, 2007).

Inside this industry there are car, motorcycle, recreational vehicle (RV) and auto parts manufacturers. However, this study will exclude companies that solely produce motorcycles, RVs, or auto parts. This is because the electrification of the motorcycle industry is still in its early stages (Gupta et al., 2023) and the same is true for the RV industry (RVIA, 2022).

Companies in the sample belong to 11 different countries: France, Germany, Sweden, Italy, The Netherlands, United Kingdom, United States, China, India, South Korea and Japan. This allows for the comparison of capital structure changes derived from electrification between the traditional car manufacturers of the west (US and Europe) and the fast-growing producers of Asia, namely in China.

2.2.2. Variables Description

Dependent Variables

The selection of appropriate dependent and independent (explanatory) variables is made through previous research on studies regarding capital structure of firms. To capture changes in the variable "Capital Structure", leverage ratios are pivotal in assessing such changes.

The seminal paper by Rajan and Zingales, (1995) defines leverage as the ratio of total liabilities to total assets. Frank and Goyal (2009) argue that there can be several definitions of leverage such as: total debt to market value of assets; total debt to book value of assets; long-term debt to market value of assets and long-term debt to book value of assets.

Since the data collected from the Refinitiv Eikon platform regarding debt and assets comes from the firms´ financial statements, we will only employ book value ratios. Furthermore, we will also include the short-term debt to book value of assets ratio, as short-term debt represents a significant proportion of the total debt used for financing in our sample´s firms.

Hence, this paper uses three approaches to measuring leverage:

- **Total Debt to Assets ratio (TD/A**)
- **Long-Term Debt to Assets ratio (LTD/A)**
- **Short-Term Debt to Assets ratio (STD/A)**

These ratios let us know what is the proportion of assets that are financed using debt (TD/A), long-term debt (LTD/A) and short-term debt (STD/A). The way they are computed is seen in Table 1.

Independent Variables

Based on existing literature and through research, it was considered relevant to include ten variables and study their impact on leverage. Nine of them were already presented by previous scholars. Where this dissertation is innovative, is through its developed variable: electrification.

This paper aims at assessing whether the shift towards increased production of BEVs, PHEVs and FCEVs is influencing manufacturers' capital structure decisions, and if so, in what way.

Size: The influence of size on the use of debt is pretty agreed upon by scholars. It is believed that bigger firms benefit from economies of scale in accessing debt markets, which reduces their borrowing costs. This is because these firms are perceived as less risky by creditors. Larger companies tend to have more diversified revenue streams and operations, which reduces their likelihood of financial distress or bankruptcy. They are also seen as more financially stable and more capable of meeting their financial obligations (Titman & Wessels, 1988; Rajan & Zingales, 1995).

Booth et al. (2001) expanded his study to developing countries, achieving the same findings. Bigger firms in developing countries are less likely to default and, therefore, more trusted by lenders which facilitate access to debt by these companies.

Assets Tangibility: Jensen and Meckling (1976) introduced the concept of agency costs which arise from conflicts between lenders and shareholders. Tangible assets emerge as a mitigant to these conflicts as they provide lenders security against loans. This is because tangible assets can serve as collateral for loans if a firm fails to meet its obligation. This incentivizes firms with higher asset tangibility to take on more debt as they are secured by such assets as collateral.

Empirical studies such as the one from Titman and Wessels (1988) reinforce the same positive relationship for the same previously mentioned reasons. It expands by proving that firms with lower tangibility, such as R&D intensive firms, have lower leverage levels. This was also later confirmed by MacKay and Phillips, (2005). Lang et al., (1996) expanded by finding that technological growth was related to changes in asset structure, particularly in the decrease of tangibility. He found that firms decrease their leverage levels when becoming more technologically advanced, further proving the positive relationship between asset tangibility and leverage.

Profitability: The trade-off theory suggests profitability has a positive relationship with debt. Kraus and Litzenberger, (1973) posited that more profitable firms use more debt to benefit from tax-shields. On the other hand, the pecking order theory predicts a negative correlation between profitability and use of debt. This is because firms prefer to finance themselves with an order of preference that prioritizes internal funds first, before resorting to debt and finally equity. Since more profitable firms have higher funds at their disposal, they are less likely to resort to debt financing, hence this negative relationship that was confirmed by several scholars (Myers, 1984; Titman & Wessels, 1988; Rajan & Zingales, 1995).

Growth: Previous literature suggests a negative relationship between debt and growth opportunities. Jensen and Meckling (1976) argue that growing firms take on riskier positive net present value (NPV) projects which generate resistance among debt holders and limits debt financing. In contrast, Titman and Wessels (1988) found a positive relationship between these two. However, this doesn't necessarily indicate inconsistency of results but rather shows that since growth opportunities add value to a firm, it increases their debt capacity and, therefore, the debt to book value ratio. There doesn't seem to be much consensus among scholars regarding the relationship between debt levels and growth opportunities. Barclay and Smith (1995) like Jensen and Meckling (1976), share the same view by stating that with more growth options, the higher the conflict between equity and debt holders. The latter imposes more restrictive covenants for borrowing which desensitizes debt financing.

Earnings volatility: Bradley et al. (1984) explored earnings volatility as a determinant of leverage. They found that these had a negative correlation due to firms with more stable earnings facing low probabilities of financial distress. Because of this, they are able to sustain higher levels of debt. Titman and Wessels (1988) later confirmed this by concluding that firms with higher earnings volatility tend to use less debt since it increases their risk of default, making debt a less attractive financing source because of bankruptcy costs.

Similarly, Fama and French (2002) stated that firms with volatile earnings face higher uncertainty in meeting their financial obligations, which leads to lower leverage. This was also found to be true for Chinese companies, making it consistent with western studies (Huang & Song, 2006).

Liquidity: The pecking order theory suggests firms have a preference for the use of internal funds. These internal funds are not only captured by profitability but also liquidity (Mazur, 2007). Following this rationale, if the pecking order theory holds, then firms with more liquidity would use less debt. On the other hand, Jensen (1986) suggests that high cash-abundant firms buy debt to prevent managers from spending free cash flow on bad investments. By this logic, it implies a positive relationship with leverage.

Uniqueness: Titman and Wessels (1988) argue that firms that offer unique products have increased bankruptcy costs. This is because when a firm has unique products, their customers, workers and suppliers suffer relatively high costs in case of liquidation. For these reasons, they predicted uniqueness to have a negative relationship with debt.

Dividends: Myers (1984) concluded that the pecking order theory does not explain why firms choose to pay dividends. However, when a firm decides to do so, it reduces retained earnings, which increases the need for external financing sources, such as debt. Firms were also found to be very reluctant about changing dividend policies due to the signaling effect [1] to investors (Lintner, 1956). Jensen (1986) argued that higher dividends reduce free cash flow available to managers, leading companies to take on higher levels of debt, suggesting a positive relationship between dividend payments and leverage.

Non-debt tax shields: Modigliani and Miller (1963) originally suggested that there are tax advantages to debt. These benefits were related to the fact that interest payments are deductible, which reflected on a higher income after tax for some companies. However, DeAngelo and Masulis, (1980) argue that

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[1] The dividend signaling theory suggests that when firms decide to increase their payout ratio, investors read that as a sign of positive financial outlook. Inversely, decreasing dividend payments might be interpreted as a sign of financial distress from the firm. (https://corporatefinanceinstitute.com/resources/career-map/sell-side/capital-markets/signaling/)

non-debt tax shields are substitutes for the tax benefits of debt financing and that firms with higher levels of non-debt tax shields are expected to have less debt in their capital structure. Both Chaplinsky and Niehaus (1993), Wald (1999) and Huang and Song, (2006) support this negative correlation. Following the latter, we use employment measures of non-debt tax shields as the ratio of depreciation and amortization to total assets. Since there was not completely available information regarding depreciation and amortization for all the companies in our sample, we had to use the proxy earnings before interest, taxes, depreciation and amortization minus earnings before interest and taxes (EBITDA)-(EBIT) to obtain an estimated value.

Electrification: Since this variable was developed for this study, there are no previous studies focusing on its impact on leverage levels. However, we could estimate its impact through previous literature. For instance, it is believed that firms with higher ESG scores have lower debt levels because their bond yields were found to be lower as they're considered to be less risky to investors Apergis et al. (2022). We believe that car manufacturers that are striving towards electrification are showing higher ESG scores, as proven by studying its correlation (see Table 7). For this reason, we estimate that electrification will have a negative correlation with leverage.

In order to understand how well a company is transitioning to the production of electrified vehicles, this determinant was developed. This variable shows the proportion of electrified vehicles sold relative to the total number of vehicles sold by each company in a given year.

By employing this variable in the study, we aim to evaluate how it affects manufacturers´ capital structure decisions. This variable can be obtained by dividing the number of electrified cars sold over the total number of sales for a given year.

Table 1 summarizes the chosen determinants, their respective formulas and their source:

Table 1: Independent Variables and Expected Effects on Leverage

Variable (Symbol)	**Measure**	**Source**
Size (SZ)	$Log\ of\ Total\ Assets$	Refinitiv Eikon
Tangibility (TAN)	$\frac{Tangible\ Assets}{Total\ Assets}$	Refinitiv Eikon
Profitability (PROF)	$\frac{EBIT}{Total\ Assets}$	Refinitiv Eikon
Growth (GRW)	$\Delta\ Total\ Assets$	Refinitiv Eikon
Earnings Volatility (VOL)	$\Delta\ Revenues$	Refinitiv Eikon
Liquidity (LQD)	$\frac{Current\ Assets}{Current\ Liabilities}$	Refinitiv Eikon
Uniqueness (UNQ)	$\frac{R\&D}{Revenues}$	Refinitiv Eikon
Dividends (DIV)	$Payout\ Ratio$	Refinitiv Eikon
Non-Debt Tax Shields (NDTS)	$\frac{D\&A}{Total\ Assets}$	Refinitiv Eikon
Electrification (ELT)	$\frac{Electrified\ Vehicles\ Sold}{Total\ Vehicles\ Sold}$	Annual Reports

Note: Table 1 presents the variables addressed in this study, their formulas and expected effect leverage. Note that "$\Delta\ Total\ Assets\ and\ \Delta\ Revenues$" is given by dividing the difference between Assets/Revenues of year t and year t-1 by Assets/Revenues of year t-1. "R&D" means Research and Development costs and "D&A" means Depreciation and Amortization costs

2.2.3. Regression Model

The main objective of this study is to analyze the impact of electrification on the capital structure of car manufacturers. To achieve this, we employ an Ordinary Least Squares (OLS) regression model.

This model is commonly applied in the field of corporate finance to investigate how different firm-specific factors affect leverage decisions (Rajan & Zingales, 1995). Furthermore, prior empirical studies on capital structure such as those that delved on the Trade-off theory (Kraus & Litzenberger, 1973) and the Pecking order theory (Myers & Majluf, 1984), have successfully used OLS to test the determinants of leverage.

With this in mind, Equations 1, 2 and 3 were developed:

Equation (1): $TD/A_{it} = \beta_0 + \beta_1 ELT_{it} + \beta_2 SZ_{it} + \beta_3 TAN_{it} + \beta_4 PROF_{it} + \beta_5 GRW_{it} + \beta_6 VOL_{it} + \beta_7 LQD_{it} + \beta_8 UNQ_{it} + \beta_9 NDTS_{it} + \beta_{10} DIV_{it} + \epsilon_{it}$

Equation (2): $LTD/A_{it} = \beta_0 + \beta_1 ELT_{it} + \beta_2 SZ_{it} + \beta_3 TAN_{it} + \beta_4 PROF_{it} + \beta_5 GRW_{it} + \beta_6 VOL_{it} + \beta_7 LQD_{it} + \beta_8 UNQ_{it} + \beta_9 NDTS_{it} + \beta_{10} DIV_{it} + \epsilon_{it}$

Equation (3): $STD/A_{it} = \beta_0 + \beta_1 ELT_{it} + \beta_2 SZ_{it} + \beta_3 TAN_{it} + \beta_4 PROF_{it} + \beta_5 GRW_{it} + \beta_6 VOL_{it} + \beta_7 LQD_{it} + \beta_8 UNQ_{it} + \beta_9 NDTS_{it} + \beta_{10} DIV_{it} + \epsilon_{it}$

Where:

- **TD/A, LTD/A and STD/A** represent the firms´ capital structure decisions, composed of three dependent variables.
- **ELT** (electrification) is the main independent variable of interest.
- **SZ, TAN, PROF, GRW, VOL, LQT, UNQ, NDTS** are firm-specific control variables previously and often studied in capital structure research.
- **DIV** is a dummy variable for dividend-paying firms, as dividends can influence leverage decisions (Fama & French, 2002).
- $\boldsymbol{\epsilon}$ represents the error term.

For OLS estimates to be reliable, some assumptions must hold:

Firstly, there should not be perfect multicollinearity. To assess this, we conduct variance inflation factor (VIF) tests to ensure that independent variables are not highly correlated (Gujarati & Porter, 2009). This assumption is violated if any VIF for any variable is above 10. As we can see in the correlation matrix in Table 7, our variables respect this assumption as no variable exceeds this cap value.

Furthermore, there should not be any endogeneity issues. We acknowledge concerns regarding reverse causality in the sense that firms with lower leverage may have more flexibility to invest in electrification.

3. Results

3.1. Descriptive statistics

By looking at Table 3 (See Appendices) we see the different leverage measures of car manufacturers discriminated by two regions, as well as the full sample. We separate the regions into two groups: Europe and the United States (western companies) and Asia.

What we observe is that, between the period under analysis (2014-2023), western companies are on average more levered than Asian ones- total debt to assets ratio for western firms is higher (38.8% vs 26.2%) with a standard deviation of 14.7% and 26.2% for Europe and the US and Asia, respectively. To see if these results were statistically significant, we performed a mean comparison test and concluded that these values were, indeed, significant to make this statement: western firms have significantly higher leverage than Asian firms at the 5% level ($\rho = 0.047$)- see Table 4 (See Appendices). This suggests more homogeneity between western firms' employment of debt on their capital structure. For the whole sample, the average is 30.8% with a standard deviation of 23.5%, meaning that around 31% of their assets are financed using debt.

Regarding the maturity structure of employed debt, manufacturers in the western market rely more on long-term debt than short-term debt while the opposite happens for Asian firms: short-term debt accounts for 13.8% of total debt for western firms and 18.9% for Asian firms. while long-term debt represents 25% and 7.3%, respectively. Asian firms show greater consistency on the employment of long-term debt over western firms, with a standard deviation of 7.9% vs 12.5%. On the other hand, Asian companies differ more between each other in regards to the employment of short-term debt, having a standard deviation of 22.9% vs 11.8% for western firms

Across all firms analyzed, the average debt structure consists of 13.8% long-term debt and 17% short-term debt. The standard deviations of 13% for long-term debt and 19.7% for short-term debt suggests that firms, overall, maintain a fairly consistent approach to debt structuring.

By analyzing the descriptive statistics in Table 5 (See Appendices), we can draw some conclusions about the chosen independent variables.

European and North American firms are, on average, larger (11.38) and show slightly higher growth (3.8%). They also exhibit greater earnings volatility (4.7%), and benefit more from non-debt tax shields (5.1%). Additionally, they are further ahead in electrification, with 13.5% of all cars sold already being electrified.

In contrast, Asian firms have, on average, higher tangibility levels, with 93.8% of their assets being tangible. They also show slightly higher profitability (4.9%), higher liquidity (1.29) and are more unique (12.2%).

However, liquidity levels vary more among them, with a standard deviation of 35.8% compared to 18.9% for western firms. This implies that while more western firms can comfortably cover their current liabilities with current assets, the fewer Asian firms that manage to do so have even stronger liquidity positions, reflected in higher current ratios.

Another thing worth mentioning is that, although western firms showed a higher degree of electrification during the sample period, this does not paint the full picture of what is happening. To get a grasp of the progress in this shift, we need to look at data per year. When looking at Table 6 (See Appendices), we can see that Asian firms started selling electrified cars at a significant proportion far later than western manufacturers- for instance, in 2018 only 5.1% of all cars sold by Asian firms were electrified, compared to 10.6% for western manufacturers. At the end of the period analyzed these ratios became evened out (23.5% vs 23.4%).

Although we also separated our descriptive statistics by region, this was done to have a more in-depth view of the market. However, we will not be able to use this discrimination for the regression analysis. This is due to the sample being already small and dividing it into two subgroups would decrease its size even further. This would lead to the results not being significant, compromising the reliability of the results.

A correlation matrix of dependent and independent variables is shown in Table 7.

Firm size positively correlates with TD/A (0.18) and LTD/A (0.15), suggesting larger manufacturers rely more on long-term debt. This aligns with Titman and Wessels (1988) and Rajan and Zingales (1995). Furthermore, short-term debt also correlates positively with size, contradicting the argument that smaller firms prefer short-term debt due to its lower costs and accessibility (Barclay & Smith, 1995; Titman & Wessels, 1988).

Tangibility negatively correlates with TD/A (-0.10) and LTD/A (-0.39), contradicting Jensen and Meckling (1976) and Titman and Wessels (1988), who argue that firms use tangible assets as collateral.

Profitability positively correlates with TD/A (0.24) and LTD/A (0.15), supporting the trade-off theory (Kraus & Litzenberger, 1973) but contradicting the pecking order theory (Myers, 1984) and findings from Titman and Wessels (1988) and Rajan and Zingales (1995). Additionally, profitability positively correlates with STD/A (0.20), contrasting with previous research (Titman & Wessels, 1988).

Non-debt tax shields strongly correlate with leverage, but contrary to prior studies, they show a positive relationship with TD/A (0.35) and LTD/A (0.54) (DeAngelo & Masulis, 1980; Chaplinsky & Niehaus, 1993; Wald, 1999; Huang & Song, 2006).

Electrification negatively correlates with TD/A (-0.02) and LTD/A (-0.05), supporting our hypothesis that it reduces leverage due to its ESG association (0.08). However, ESG scores unexpectedly correlate positively with TD/A (0.24) and LTD/A (0.39), contradicting prior research (Apergis et al., 2022).

The problem with looking at just correlation is that it is not a sufficient method to analyze relationships between variables. This is because it only compares the linear relationship between two variables at each time, without considering other factors that may be factoring in on their relationship. This is why a more thorough analysis is required to get valuable insights into how electrification is affecting firms' choice of capital structure.

3.2. Regression Results

Table 2 contains the pooled OLS estimates of the regression described by Equation 1. Our hypothesis predicts the coefficients β_1 of each equation to be negative, suggesting a negative relationship between leverage levels and electrification.

Table 2: OLS estimates of Equations (1), (2) and (3) (Source: Author´s calculations)

	TD/A	LTD/A	STD/A
Variables	**Coefficient**	**Coefficient**	**Coefficient**
SZ_{it}	-0.026**	-0.014	0.049***
	(0.013)	(0.009)	(0.007)
TAN_{it}	-0.289	-0.230*	0.255
	(0.178)	(0.125)	(0.173)
$PROF_{it}$	-0.63***	-0.228**	0.959***
	(0.124)	(0.09)	(0.176)
GRW_{it}	0.019	0.028*	-0.059
	(0.023)	(0.017)	(0.059)
VOL_{it}	0.037*	0.031*	-0.055
	(0.019)	(0.014)	(0.052)
LQT_{it}	0.048**	0.053***	0.309***
	(0.024)	(0.017)	(0.035)
UNQ_{it}	0.092	0.147	1.141***
	(0.151)	(0.109)	(0.187)
$NDTS_{it}$	0.627	0.874***	-0.503
	(0.443)	(0.324)	(0.767)
ELT_{it}	0.003	-0.049*	0.092*
	(0.037)	(0.027)	(0.053)
DIV_{it}	-0.016	-0.004	-0.001
	(0.014)	(0.01)	(0.009)
Adjusted R^2	0.265	0.193	0.376
p value	0.000	0.000	0.000
Industry effe	No	No	No
Year effects	Yes	Yes	Yes
Observations	300	300	300

Note: Table 2 reports the pooled OLS estimates of Equations 1,2 and 3 for the period between 2014-2023 for 30 companies. DIV is the dummy variable that equals one if the company pays dividends and zero if it does not. SZ (Size) is given by Log of Total Assets; TAN is obtained by dividing Tangible Assets over Total Assets; PROF (Profitability) is given by EBIT over Total Assets; GRW (Growth) is the change in Total Assets year-on-year; VOL (Volatility) is the change in Revenues year-on-year; LQT (Liquidity) is calculated as Current Assets over Current Liabilities; UNQ (Uniqueness) is given by Research and Development costs over Revenues; NDTS (Non-Debt Tax Shields) is given by dividing Depreciation and Amortization costs over Total Assets; ELT (Electrification) is given by dividing the total number of electrified cars sold over the total number of vehicles sold by each company.

*Significance level at 10%

**Significance level at 5%

***Significance level at 1%

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The regression analysis was conducted with the main goal of examining the impact of electrification (ELT) on the capital structure of car manufacturers. However, we also studied the impact of several control variables on firms' leverage decisions:

The coefficient for firm size (SZ) is negative and significant for TD/A (-0.026**), positive and significant for STD/A (0.049***) but not significant for LTD/A. This suggests that larger car manufacturers tend to have lower total leverage. This is consistent with the pecking order theory which argues that larger firms have better access to retained earnings and, therefore, do not need to rely heavily on debt (Frank & Goyal, 2009). However, the bigger a firm is in our sample, the more it relies on short-term debt. This might seem contrary to previous findings in the literature. We attribute this being due to the fact that, since the firms in our sample are all multinational companies- with all having operations in foreign countries- this increases their need for foreign debt to manage their currency exposure. However, many foreign debt markets are less liquid than U.S. and even European debt markets, especially for longer maturities. Therefore, multinational companies are more likely to issue more short-term debt (Barclay & Smith, 1995).

Tangibility (TAN) has a negative and significant relationship with LTD/A (-0.230*). However, no significant relationship with TD/A and STD/A is observed. This contradicts traditional capital structure theories, which suggest that firms that have higher asset tangibility in their balance sheet use more long-term debt because of the collateral that these assets can represent (Rajan & Zingales, 1995). We attribute this negative relationship with LTD/A to being a consequence of technological obsolescence. The transition from ICE vehicles to electrified ones means that existing manufacturing plants, machinery and equipment are becoming decreasingly used. For instance, in its 87 years of history, Volkswagen plans to close three domestic plants for the first time in its existence (Financial Times, 2024). We believe this may be contributing to a decrease in the asset tangibility that reduces the availability of collateral assets that make long-term financing more attractive.

Profitability (PROF) is highly significant and negatively related to TD/A (-0.63*) and LTD/A (-0.228**) but positively related to STD/A (0.959***). This goes in line with the pecking order theory, suggesting that profitable car manufacturers also prefer to use internal funds over debt (Myers, 1984). On the other hand, the positive relationship with STD/A indicates that while profitable firms incur less on the issuance of long-term debt, they still employ short-term debt for working capital requirements and liquidity management.

Growth (GRW) is positively and significantly related to LTD/A (0.028*), while having no significant effect on TD/A and STD/A. From this, we can conclude that firms with higher growth opportunities tend to increase their long-term debt use, aligning with the trade-off theory. Growing firms often need stable and long-term financing to support expansion, as argued by Titman and Wessels (1988).

Volatility (VOL) has a significant positive relation to TD/A (0.037*) and to LTD/A (0.031*) but has no significant relationship with STD/A. This indicates that automakers with more volatile earnings increase their total and long-term debt issuance. Hower, this goes against what previous literature has found, as volatility is believed by scholars to have a negative relationship with total and long-term debt.

Liquidity (LQT) is observed to have a positive and significant relationship with TD/A (0.048**), LTD/A (0.053***) and with STD/A (0.309***). These results are consistent with the view that liquid firms have better access to credit markets, making it easier for them to negotiate more favorable long-term debt conditions as they are seen as more financially healthy to lenders.

The Uniqueness (UNQ) variable is not statistically significant for either TD/A or LTD/A. On the other hand, it is the variable on our study with the highest significant relationship with STD/A (1.141***). This indicates that, as firms are investing more in R&D to become more differentiated and innovative, they are increasing their reliance on shorter maturity debt. This can be explained by the fact that banks and debtholders are reluctant to lend when projects demand considerable R&D investment because of the uncertainty underlying the projects (Hall & Lerner, 2009). As we know, uncertainty tied to R&D leads to firms preferring the issuance of shorter-term debt over longer-term debt (Rejeb et al., 2013).

Non-debt tax shields (NDTS) are positively and significantly related to LTD/A (0.874***). However, no significant relationship is observed with total (TD/A) and short-term leverage (STD/A) levels. We interpret this having to do with the fact that firms with higher non-debt tax shields incur more depreciation expenses tied to the higher tangibility character of their assets. As we have seen before, this incentivizes manufacturers to choose long-term financing over short-term one because of the possibility to use these assets as collateral.

The dummy variable for dividends (DIV) is not significant for any leverage measure, suggesting that dividend policies do not have an impact on capital structure choices in the automotive industry.

The negative relationship between ELT and LTD/A suggests that firms increasing their focus on electrified vehicle production tend to reduce their reliance on long-term debt financing. This finding aligns with prior research on technological transitions and capital structure adjustments. Lang et al. (1996) argue that firms undergoing technological shifts experience a decline in asset tangibility, which reduces their borrowing capacity. This occurs because lenders prefer tangible assets as collateral to secure loans, and when firms transition toward new technologies, their asset base increasingly consists of intangible investments, such as R&D and intellectual property. In line with this, Jensen and Meckling (1976) emphasized that lower asset tangibility limits firms' ability to issue secured debt.

Furthermore, Miao (2005) found that leverage tends to decrease as firms grow technologically, as companies prioritize financial flexibility to avoid financial distress. Firms in industries experiencing rapid technological change must continuously invest in innovation while managing uncertainty. Excessive long-term debt could constrain their ability to adapt to these evolving market conditions. Given that the automotive industry is currently undergoing one of the most significant technological transformations in its history—driven by digitalization, automation, and electrification (Llopis-Albert et al., 2021)—our findings are consistent with the expectation that firms reduce their long-term debt levels to maintain strategic flexibility.

Another crucial factor influencing this trend is the growing emphasis on ESG considerations in corporate decision-making. Llopis-Albert et al (2021) highlight that regulatory and environmental concerns are pushing automotive firms toward sustainability-focused investments, including electrification. This shift is reinforced by Shu et al (2023), who found that firms with higher ESG commitments tend to have lower debt levels, as they adopt more conservative financial strategies to mitigate regulatory and reputational risks.

Our study confirms this link, as we observe a negative correlation between ELT and ESG scores, suggesting that firms increasing their electrification efforts also tend to prioritize ESG objectives. Given that higher ESG scores are associated with reduced leverage, this further explains the decline in long-term debt among electrifying firms.

On the other hand, the positive coefficient between ELT and STD/A indicates that automakers are increasing their use of short-term debt to finance their electrification efforts. This can be attributed to the substantial capital expenditure and R&D investments required to remain competitive in this evolving industry. From 2019 to 2024, the automotive sector led R&D spending in Europe and Japan and consistently ranked fourth in the United States, behind Healthcare, ICT services, and ICT producers (Source: European Commission, 2024). Additionally, Damodaran (2025) ranks the automotive industry ninth out of 94 US industries in total capital expenditure, with an annual spend of approximately $33 billion.

Agency theory provides additional insights into this pattern. Myers (1977) describes the underinvestment problem, where managers may hesitate to take on long-term debt for financing growth opportunities if the benefits accrue more to debtholders than shareholders. To avoid this, firms often finance R&D-intensive projects with shorter-maturity debt, as these investments carry greater uncertainty and are harder to collateralize (Bah & Dumontier, 2001). Rejeb et al (2013) further support this view, finding that firms with high R&D intensity prefer short-term over long-term debt. Our results align with these findings, suggesting that car manufacturers are managing the risks associated with electrification by adjusting their debt maturity structure rather than increasing overall leverage.

Finally, the lack of a significant relationship between ELT and TD/A indicates that electrification is not fundamentally altering total leverage levels in the industry. Instead, firms are restructuring their capital structure by reducing long-term debt reliance while increasing short-term debt usage. This suggests a cautious approach, where firms recognize the high uncertainty associated with electrification and seek to maintain financial flexibility without significantly increasing overall debt burdens.

Our findings contribute to the literature on capital structure adjustments in answer to technological changes. Prior studies suggest that firms going through these transitions decrease leverage (Lang et al., 1996; Miao, 2005). However, our results provide a more in-depth analysis by this happens because of shifts in debt maturity rather than total debt reduction. Moreover, by linking electrification to ESG-related financial strategies, our paper adds to the growing literature in sustainable finance and corporate decision making.

Our results are also useful from a managerial perspective as it highlights the importance of adjusting financial strategies during times of technological disruptions. Firms striving for electrification may need to reassess their debt structures, favoring shorter maturity debt financing to remain adaptable through uncertainty and to more easily move their investment efforts to R&D spending (Miao, 2005; Rejeb et al 2013). Investors and creditors must recognize that credit risk assessment based solely on asset tangibility may not be enough to capture the financial needs of firms transitioning to new technologies.

Finally, our study also has implications for policymakers and regulators that could be shaping the future of automotive electrification. Governments worldwide are implementing regulations and incentives to accelerate the adoption of electrified vehicles (Bian & Zhao, 2020; Deuten et al., 2020; Gerlagh et al., 2018; Jenn et al., 2018; Lévay et al., 2017)

Thus, while our initial hypothesis predicted a uniform negative relationship between electrification and leverage across all measures, our findings indicate a more nuanced effect. Electrification leads to a reduction in long-term debt, an increase in short-term debt, and no significant change in total leverage. This suggests that firms are responding to technological shifts by adjusting their debt composition rather than outright reducing their overall debt levels.

4. Conclusion

This study investigates the impact of electrification on the capital structure decisions of car manufacturers, addressing a significant gap in the literature. While extensive research exists on capital structure determinants, few studies have examined the implications of technological transitions, particularly electrification, on firms' leverage choices. By analyzing financial data from 30 global automakers over the period 2014-2023, this research provides empirical insights into how firms adjust their financing strategies in response to industry-wide transformation.

Our findings reveal a nuanced relationship between electrification and leverage. Contrary to our initial hypothesis, electrification does not uniformly decrease leverage but instead alters the debt maturity structure. Firms increasing their focus on electrification reduce their reliance on long-term debt while simultaneously increasing their use of short-term debt. This suggests that companies prioritize financial flexibility to navigate the uncertainties associated with technological change. These findings align with Lang et al. (1996) and Miao (2005), who argue that firms undergoing technological transitions reduce leverage due to declining asset tangibility and the need to maintain strategic flexibility. Furthermore, the shift toward short-term debt is consistent with agency theory, particularly Myers (1977) underinvestment problem, which suggests that firms prefer shorter maturities when financing uncertain investments such as R&D.

This study makes several contributions to literature. First, it extends capital structure research by demonstrating that technological shifts influence not only the overall level of leverage but also its composition. Unlike previous studies that focus on traditional determinants of leverage, our research highlights electrification as a significant factor shaping financing decisions in the automotive industry. Second, our findings contribute to the growing body of work on ESG and corporate finance. We provide empirical evidence that firms advancing toward electrification tend to exhibit higher ESG commitments, reinforcing prior studies that link sustainability efforts with more conservative financial policies (Apergis et al., 2022; Shu et al 2023).

From a practical perspective, our results offer valuable insights for industry practitioners, investors, and policymakers. Managers should recognize that electrification requires adaptable financing strategies, favoring short-term debt to accommodate high R&D expenditure and capital investments. Investors and financial institutions must account for these structural shifts when assessing the creditworthiness of automakers. Additionally, policymakers aiming to accelerate electrification should consider how financial regulations and incentive structures influence firms' debt maturity choices. The fact that firms rely more on short-term debt suggests a potential need for government-backed financing mechanisms, such as green bonds or subsidized long-term loans, to support sustainable industry transitions.

Despite these contributions, the study is subject to certain limitations that should be acknowledged. A primary constraint was the lack of ESG scoring data for all firms in the sample, which prevented its inclusion as a control variable in the regression analysis. As a result, interpreting the correlation between ESG scores and electrification as a means to explain electrification and its impact on capital structure is not the most reliable approach. In addition, the analysis was constrained by the relatively small sample size. This limitation did not allow for the implementation of robustness checks, such as examining whether the results hold across different geographical regions—for instance, comparing firms operating in Western versus Asian markets, as was originally intended. Dividing the sample in this manner would yield subsamples too small to produce statistically meaningful results. Similarly, any other robustness test requiring the segmentation of the dataset would further reduce statistical power and compromise the reliability of the findings

Overall, this research enhances our understanding of how major industrial shifts influence capital structure decisions. As electrification continues to reshape the automotive sector, future studies could explore its long-term effects on firm profitability, risk exposure, and access to alternative financing sources. By bridging the gap between capital structure theory and technological change, this study provides a foundation for further research on financial strategies in rapidly evolving industries.

Declaração de IA generativa e tecnologias assistidas por IA no processo de redação

Durante a elaboração do meu trabalho escrito/dissertação, "Financing the Future: How Electrification Shapes Capital Structure Decisions in the Automotive Industry", foi(ram) utilizada(s) a(s) Chat GPT para as tarefas de melhoria de redação, pedido de sugestão de papers relevantes para a minha pesquisa inicial da *Literature Review* tendo sido utilizadas as *prompts* listadas no final do documento na secção Lista de *Prompts*. Após a utilização desta(s) ferramenta(s)/serviço(s), revi e editei o conteúdo conforme necessário e assumo total responsabilidade pelo conteúdo do trabalho apresentado.

Declaro ainda conhecer e respeitar o Código de Conduta de Inteligência Artificial da Católica Porto Business School.

Appendices

Table 3: Leverage Measures´ Summary Statistics by region and whole sample (2014-2023

	EU and US			**Asia**			**Whole Sample**		
Leverage Measure	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Total Debt/Assets	0.3877	0.4213	0.1469	0.2621	0.1969	0.2623	0.3082	0.2643	0.2346
Long-Term Debt/Assets	0.2500	0.2672	0.1250	0.0731	0.0458	0.0785	0.1379	0.0868	0.1299
Short-Term Debt/Assets	0.1378	0.1390	0.1176	0.1891	0.1269	0.2289	0.1702	0.1325	0.1971

Note: Table 3 analyzes our three leverage determinants` mean, median and standard deviation across all years (2014-2023) for both Europe and the United States in the first column, the Asian market in the second column and lastly for the whole 30 companies englobed in our sample.

Table 4: Mean t-Test: Two-Sample Assuming Unequal Variances by region (2014-2023)

	EU and US	Asia
	TD/A	TD/A
Mean	0.3877	0.2621
Variance	0.0180	0.0691
Observations	11	19
Hypothesized Mean Difference	0	
df	28	
t Stat	1.7286	
P(T<=t) one-tail	0.0474	
t Critical one-tail	1.7011	
P(T<=t) two-tail	0.0948	
t Critical two-tail	2.0484	

Note: Table 4 represents a mean test. This was performed to test the statistical significance of the results regarding the mean of the Total Debt between the two regions that we name the western market (composed of Europe and the US) and the Asian market. The results are significant as $p<0.05$.

Table 5: Independent Variables´ Summary Statistics by region and whole sample (2014-2023)

	EU and US			Asia			Whole Sample		
Independent Variables	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
SZ	11.3836	11.9945	1.6722	10.1680	10.0991	1.3108	10.6137	10.3499	1.5652
TAN	0.8911	0.9436	0.1309	0.9379	0.9551	0.0545	0.9207	0.9507	0.0929
PROF	0.0472	0.0415	0.0511	0.0486	0.0367	0.0606	0.0481	0.0388	0.0572
GRW	0.0381	0.0117	0.1854	0.0337	0.0111	0.1885	0.0353	0.0111	0.1870
VOL	0.0473	0.0033	0.2211	0.0280	0.0334	0.2169	0.0350	0.0212	0.2183
LQD	1.1250	1.1265	0.1889	1.2944	1.2382	0.3584	1.2323	1.1643	0.3176
UNQ	0.1204	0.0966	0.0890	0.1218	0.1038	0.0566	0.1213	0.0999	0.0701
Dummy (DIV)	0.5909	1.0000	0.4939	0.8632	1.0000	0.3446	0.7633	1.0000	0.4257
NDTS	0.0506	0.0506	0.0166	0.0380	0.0344	0.0160	0.0426	0.0387	0.0173
ELT	0.1351	0.0176	0.2850	0.0898	0.0307	0.1684	0.1064	0.0231	0.2191

Note: Table 5 shows all our independent variables´ mean, median and standard deviation across all years (2014-2023) for both Europe and the United States in the first column, Asia in the second column and for the whole 30 companies in the sample in the last column.

Table 6: Electrification by region per year (%) (2014-2023)

Electrification %	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014
EU and US	23.56%	19.74%	17.69%	13.19%	10.95%	10.62%	10.36%	9.84%	9.57%	9.54%
Asia	23.44%	17.41%	14.97%	10.02%	6.10%	5.12%	3.53%	2.60%	1.71%	1.91%

Note: Table 6 shows the adoption of electrified vehicles across our observed period discriminated in two regions: The western market (composed of Europe and the US) and the Asian market. This serves as a visual representation of the later but yet faster adoption of this technology in Asia

Table 7: Pearson Correlation Matrix for all determinants of all 30 companies in the sample (2014-2023)

VARIABLES	TD/A	LTD/A	STD/A	SZ	TAN	PROF	GRW	VOL	LQT	UNQ	NDTS	ELT	(DIV)	ESG	VIF
TD/A	1.0000														2.47
LTD/A		1.0000													2.33
STD/A			1.0000												1.60
SZ	0.1768	0.1459	0.1230	1.0000											2.18
TAN	-0.1022	-0.3874	0.1450	0.3705	1.0000										3.30
PROF	0.2412	0.1452	0.1950	0.0015	0.0331	1.0000									1.43
GRW	-0.0625	0.0018	-0.0740	0.0484	-0.0173	0.0012	1.0000								1.55
VOL	-0.0935	0.0080	-0.1170	0.0017	-0.0010	0.0696	0.3862	1.0000							1.63
LQT	0.1895	-0.1991	0.3690	-0.3703	0.2101	-0.0516	-0.0906	-0.1255	1.0000						1.96
UNQ	0.3182	0.3906	0.1200	-0.3321	-0.6820	-0.0997	0.0032	-0.0753	-0.0505	1.0000					2.54
NDTS	0.3475	0.5399	0.0510	-0.1411	-0.5927	0.1710	-0.1531	-0.0576	-0.1163	0.5053	1.0000				2.48
ELT	-0.0223	-0.0541	0.0110	0.0049	0.1201	-0.1338	0.2280	0.3776	0.0293	-0.0937	0.0979	1.0000			1.71
DUMMY (DIV)	0.0168	-0.1919	0.1919	0.1992	0.4325	0.2926	0.0052	0.0415	0.0841	-0.3589	-0.4063	-0.2569	1.0000		1.09
ESG SCORE	0.2359	0.3929	0.3929	0.5219	0.2509	0.0515	0.0415	0.0582	-0.2314	-0.1265	0.0069	0.0813	0.0892	1.0000	N/A

Note: Table 7 reports the correlation matrix of the variables used in this research. VIF stands for variance inflation factor which tests multicollinearity. For an OLS estimate to be reliable, there cannot be multicollinearity. If VIF>10, then the variables are highly correlated, and this principle is violated. ESG score is included in this table to see how it is correlated to ELT. It is not an independent variable we employ in our regression model. Note also that the variable "Dividends (DIV)" is between "()" as it is the dummy variable.

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Prompts List

ChatGPT

"Can you make these paragraphs better written changing as less letters as you can"

"Can you make the list of abbreviations be in alphabetical order?"

"Can you suggest me the most relevant papers regarding capital structure literature?"

"Can you suggest which regression model I should use for my analysis?"

"Can you give me references of papers regarding the automotive industry?"