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FINANCIAL RISK MANAGEMENT AT GALP:
MODELING CASH FLOW AT RISK

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Abstract

This thesis analyses Galp Energia's financial risk management practices, focusing on quantifying its market exposure to commodities, foreign exchange, and interest rates. Using a proprietary Cash Flow at Risk (CFaR) model, gasoline is identified as an optimal short-term hedging instrument due to its strong representation of overall business-level risk. The proposed Collar Strategy effectively reduces the likelihood of a cash flow problem and adheres to industry hedging standards. By mitigating risks of underinvestment, credit downgrades, and liquidity constraints, the framework strengthens financial stability and investor confidence. These recommendations offer a robust foundation for managing market uncertainties and achieving sustainable growth.

Keywords

Risk Management, Financial Risk Management, Hedging, Simulations, Oil and Gas Industry

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Introduction

In today's global and highly dynamic business environment, effective risk management is essential for ensuring long-term stability and corporate performance.

Organizations face a range of risks that can significantly impact profitability and operational sustainability. Among these, financial - specifically market risks - can be effectively managed using financial instruments, particularly derivatives. Exposure to fluctuations in commodity prices, exchange rates, and interest rate variability can be mitigated through hedging strategies. Hedging involves taking an opposing position in a related asset to offset potential losses from an existing position. The advantages and disadvantages of this strategy are well-documented in both academic literature and empirical research. While corporate hedging is widely practiced, controversy remains over the optimal approach to risk management and its effectiveness in creating additional value for shareholders.

The capital-intensive nature of exploration and development projects, along with ongoing shifts like the energy transition that fundamentally redefine the industry, make stable revenue generation crucial. Long-term competitiveness depends on maintaining sufficient cash flow to support both traditional operations and investments in emerging energy sectors.

This thesis focuses on Galp, the leading Portuguese-origin energy company with global operations. Their integrated business model spans the entire energy value chain, from exploration and production to refining and distribution of oil and gas, exposing the company to market risks at multiple stages and highlighting the potential for effective financial risk management strategies. Given the capital-intensive nature of business operation, and ambitions to support mankind through sustainable energy, Galp requires access to significant funding.

Oil and gas markets have faced substantial price volatility in recent years, driven by geopolitical tensions, supply disruptions, and fluctuations in economic activity, leading to frequent supply and demand imbalances. Global demand for energy plummeted in 2020 due to the Covid-19 pandemic, causing prices to fall to historic lows, but has since rebounded in most regions. Similarly, Russia's invasion of Ukraine disrupted supply chains, causing market prices to surge globally, though particularly in Europe.

The outlook for energy markets remains uncertain, influenced by various economic and political factors that affect global energy demand, consumer preferences, and supply availability. Key themes expected to shape the near- to medium-term future include the impact of political developments such as Trump’s election sweep, the behaviour of OPEC+ countries, the evolution of conflicts in the Middle East, and the growing need to transition towards renewable energy sources, driven by government regulations and technological advancements.

Galp needs to forecast and prepare appropriate responses to the evolving challenges impacting the company, particularly those related to market exposure and cash flow sensitivity. Accordingly, this field lab provides in-depth analysis of Galp´s market risk exposures and its current financial risk management practices. A Cash Flow at Risk model is used to develop a hedging strategy recommendation aligned with firm-level financial policies and corporate strategy, providing a comprehensive managerial perspective.

Four key segments will ensure a suitable structure which facilitates comprehension and chronological delivery. Accordingly, the methodology is introduced first, followed by a review of the literature and relevant empirical studies, before progressing to the diagnostic and prescriptive sections.

Methodology

Firstly, a systematic literature review is conducted, synthesizing existing academic and empirical research on hedging strategies, relevant financial instruments, and common financial risk management practices.

Secondly, the diagnostic phase utilizes both qualitative and quantitative methods to assess Galp's market exposures and their corresponding impacts. To provide contextual depth, two expert interviews were conducted with employees from Galp’s LNG Trading and Risk Management Departments. These interviews offer valuable insights into the company’s risk governance structure and help interpret the findings. The analysis begins with an evaluation of Galp’s exposures, focusing on their severity and potential for hedging, based on the company’s business model. Key market risk factors are identified and defined through relevant proxy indicators. Using simple linear and multiple regression analyses, this section quantifies the sensitivities of Galp’s critical financial metrics -such as Ebitda, capex, and debt - to market variables. Subsequently, natural hedging within Galp's value chain is examined, with a focus on the implications of business model diversification and the offsetting relationships between input and output linkages. Next, market variable volatility is calculated and compared with the extent of exposure to determine the importance of risk factors for cash flow stability and to guide hedging prioritization. Finally, Galp’s financial risk management practices are assessed and compared to expectations based on the industry benchmark and the identified exposures. This includes consolidating insights from Galp’s annual reports, calculating a proxy hedge ratio, and conducting a cash flow impact analysis to evaluate the effectiveness of the company’s current risk management strategies.

Thirdly, the final component of this research adopts a prescriptive approach, focusing on identifying actionable insights to optimize Galp’s financial risk management strategy. A driverbased Cash Flow at Risk (CFaR) model is developed, leveraging previously established relationships between market exposures and Galp's cash flows. Volatility and correlation estimates are used as inputs to simulate commodity prices, oil product spreads, exchange rates, and interest rates over the next eight quarters. By running simulations for each market exposure and quarter, the model provides a quantitative view of tail risk, specifically a desired Two-Year Operating Cash Flow at Risk at the 5th percentile. The objective is to tame cash flow volatility, thereby reducing uncertainty, preventing underinvestment, and ensuring Galp can meet its discretionary financial needs over the next two years. Based on the insights gained from the Cash Flow at Risk analysis, a hedging strategy is proposed, focusing on the most critical exposures to hedge.

Literature Review

The Role of Financial Risk Management in Enhancing Firm Value

Financial risk management, central to corporate strategy and governance, seeks to minimize disruptive events that could hinder investment strategies or performance (Froot, Scharfstein, and Stein 1993; Stulz 1996; Fisher and Kumar 2010). It involves managing market risks - such as fluctuations in foreign exchange rates, interest rates, and commodity prices - using operational adjustments or financial instruments. Corporate hedging, a key component of this strategy, aims to reduce exposure to adverse price movements, typically through derivatives linked to underlying assets like commodities (Kolb and Overdahl 2003). Unlike speculation, which seeks to profit from market movements, hedging manages existing exposure, reducing sensitivity to price changes while limiting potential gains (Guay and Kothari 2003; Fama 1970).

Modigliani and Miller's foundational theories in corporate finance argue that in perfect markets - free from information asymmetry, taxes, or transaction costs - risk management, like capital structure, does not affect firm value, as investors can manage risk through diversification at no cost (Modigliani and Miller 1958; Froot, Scharfstein, and Stein 1993; Haushalter 2005). In such markets, market risk exposures, such as interest rate, currency, and commodity risks, would not influence a diversified portfolio (Stulz 1996). However, real-world market imperfections, such as information asymmetries and transaction costs, justify the need for corporate risk management.

The Agency Problem: Financial risk management aligns shareholder and managerial interests by addressing risk aversion and mitigating the principal-agent problem. Hedging allows risk-averse managers, whose wealth is tied to the firm's stock performance, to reduce exposure to financial volatility (Stulz and Smith 1985; Stulz 1996; Duffie 1995; Tufano 1996). This alignment incentivizes decisions that protect firm value, as managers' financial interests are linked to the company's health. In the oil and gas sector, where commodity price fluctuations cause revenue volatility, effective risk management reduces uncertainty and supports informed long-term decision-making.

The Cost of Financial Distress: Hedging reduces cash flow variability, maintaining liquidity, and decreasing default risk (Stulz 1996; Froot, Scharfstein, and Stein 1993; Stulz and Smith 1985). While hedging minor earnings variability may not benefit shareholders due to portfolio diversification, hedging major risks that increase distress probability benefits both shareholders and creditors. Financial distress, even without bankruptcy, incurs indirect costs, such as reduced sales or reinvestment, eroding firm value (Haushalter 2005). Effective hedging strategies help oil and gas firms reduce cash flow volatility, mitigate liquidity issues, lower default risk, and protect firm value.

The Underinvestment Problem: Stable free cash flow supports corporate investment, reduces reliance on costly external funds, and mitigates the underinvestment problem (Froot, Scharfstein, and Stein 1993). Hedging reduces earnings variability, enabling reinvestment in long-term value-generating projects (Bessembinder 1991). Underinvestment, particularly in high-debt situations, can lead to missed growth opportunities, as equity holders avoid investments benefiting creditors, harming firm value and competitiveness (Hennessy, Levy, and Whited 2007). In the oil and gas sector, where significant capital expenditure is essential, hedging ensures stable cash flows, providing liquidity for long-term projects and strategic investments, such as renewable energy or new exploration, even during market volatility, thus enhancing competitiveness.

The Capital Structure and Cost of Debt: Hedging can reduce external funding costs by minimizing transaction costs and information asymmetries. Firms with valuable growth opportunities, who typically prefer the use of internal funds due to lower capital costs, may access external capital at more attractive rates (Ahn et al. 2003). Additionally, risk management influences capital structure by balancing debt and equity. While debt offers tax advantages, it also introduces fixed obligations, increasing financial risk. Hedging mitigates volatility, bankruptcy risk, and information asymmetries, enabling firms to access cheaper debt and take on more leverage with reduced distress risk (Chen and King 2014). By addressing the trade-off between debt's tax benefits and bankruptcy costs, hedging supports the trade-off theory of capital structure, enhancing firm value (Stulz 1996; Leland 1998; Ross 1997). In the capital-intensive oil and gas industry, effective hedging helps manage debt obligations, stabilize financing costs, and maintain access to capital for new projects, while minimizing financial distress risk.

Empirical Evidence on Hedging and Firm Value

This section examines empirical research, with a particular focus on the Oil & Gas sector. It compares these findings to the expectations outlined earlier, providing a benchmark for understanding the effectiveness, and suitability, of Galp's approach to hedging.

Empirical evidence indicates that an effective hedging program can reduce stock price volatility, with some studies suggesting a positive impact on firm value, although the findings on this relationship remain mixed (Jin and Jorion 2006; Allayannis and Weston 2001; Li, Visaltanachoti, and Luo 2014). The optimal approach to financial risk management is recognized to depend on factors such as company size, industry, and specific risk exposures (Allayannis and Weston 2001; Culp and Miller 1995; Guay and Kothari 2003; The Wharton School 1994). Research generally suggests that hedging against commodity price fluctuations can enhance firm value by reducing sensitivity to risk exposure. In addition to market risk, studies emphasize that a firm's revenues are significantly influenced by the variability in production volumes (Haushalter 2000; Jin and Jorion 2006; Allayannis and Weston 2001). This is particularly relevant as demand in oil-dependent sectors is highly sensitive to oil price fluctuations (Hamilton 2009). Without hedging, rising prices passed on to consumers can reduce demand for oil and refined products, leading to decreased production, lower revenues, and a drop in stock prices (Basher, Haug, and Sadorsky 2018). The anticipated relationship between management compensation and hedging, designed to align principal-agent interests, is not directly supported by evidence from the oil and gas sector (Haushalter D. 2005; Haushalter G. 2000). However, levered oil and gas companies tend to hedge more frequently to mitigate financial distress, which aligns with theoretical expectations that hedging reduces bankruptcy costs (Haushalter 2002; Haushalter 2005). Analysis indicates that firms often adopt a "selective" rather than "full cover" approach to hedging, seeking to leverage informational advantages to determine their hedge ratios (Stulz 1996). High implementation and maintenance costs of derivatives further discourage full hedging, particularly for smaller firms (Brown 2001). While classical theory suggests smaller firms ought to hedge more to mitigate financial distress risk, Rampini and Viswanathan (2010) argue that financial constraints limit hedging activities, as smaller, financially constrained firms lack the capital and collateral necessary for (effective) risk management. The the extent of hedging is positively correlated with firm size, with studies revealing that oil and gas companies, on average, hedge only approximately 33% of next-year production(Jin and Jorion 2006, 903;Haushalter 2005).

<u>Hedging Instrument Choice and Strategic Considerations in the Oil & Gas Industry</u>

In the oil and gas industry, selecting the appropriate hedging instruments and their mix is particularly challenging due to high commodity price volatility, fluctuating revenue streams, and the variety of available contracts. Given the absence of a universally accepted hedging framework, companies must tailor their approach to specific goals and prevailing market conditions (Froot, Scharfstein, and Stein 1993; Adam 2005).

Risk managers typically choose between linear derivatives - such as futures, forwards, and swaps - and non-linear derivatives, like options, often combining both to achieve effective risk management (Schulte, Nicholson, and Lambert 2022). Linear derivatives stabilize cash flows cost-effectively, particularly in volatile markets, but carry the risk of over/under hedging if actual exposures deviate significantly from forecasts (Adam and Fernando 2006). Options, on the other hand, provide flexibility for an upfront premium, enabling firms to manage uncertain exposures while retaining the ability to capitalize on favourable price movements. This flexibility is particularly valuable in the oil and gas sector, where price volatility and production uncertainty are significant concerns. Options allow firms to manage downside risks while preserving upside potential, supporting capital preservation for essential investments in exploration or infrastructure (Froot, Scharfstein, and Stein 1993). Particularly, in cases where production levels and market prices are negatively correlated, options offer a more suitable hedging solution (Gay, Nam, and Turac 2002). However, the significant costs associated with non-linear derivatives mean that larger, financially stable firms are more likely to utilize them, as they can better absorb these expenses (Geczy et al. 1997).

Section 1: Diagnostic Analysis

Introduction to Galp

Galp Energia SA is a leading Portuguese energy company operating across the entire energy value chain, structured into four core segments. Upstream Operations focus on global oil and natural gas exploration and production. The Industrial & Midstream (I&M) division covers oil refining and trading activities. The Commercial segment manages the sale of refined oil products, natural gas, and electricity to end customers. Lastly, the Renewables & New Business segment drives Galp's expansion into renewable energy, aligning with its transition to low-carbon solutions. While Galp's oil exploration operations are global, its refining, retailing, and electricity sales are largely concentrated in Europe, particularly Iberia. This geographic concentration shapes risk assessment and hedging strategies, necessitating careful selection of benchmarks, proxies, and financial instruments (Galp 2023, 34–66).

Overview of Key Risk Factors

Galp faces five primary risk factors: commodity price, foreign exchange, interest rate, liquidity and insurance, and credit risks, each with varying levels of relevance and mitigation potential through risk management (Galp 2023, 286). Commodity price risk is the most significant for Galp, given its reliance on oil and gas operations. The company faces positive exposure from exploration and production and negative exposure from input costs in refining and trading. Effective management of these opposing exposures requires evaluation of natural hedges that offset risks across its business units. Liquidity and insurance risk are closely linked to commodity price fluctuations, which affect operating cash flow and capital availability for strategic investments. As the insurance market for oil and gas assets declines and lending to the sector decreases, mostly in response to the energy transition (Rickman et al., 2024), maintaining stable cash flows through effective hedging becomes crucial for mitigating these risks. Foreign exchange (FX) risk is of moderate significance for Galp, as its operating margin is sensitive to fluctuations in the US Dollar, with transactions largely in USD while financial reporting is in Euros. FX risk is influenced by oil and natural gas price fluctuations, which determine cash flow exposure. However, this risk is secondary to commodity risk, which has a more direct impact on revenue and costs. Interest rate risk is a moderate concern for Galp, primarily due to its debt profile. Preference is given to floating-rate (57%), medium- to long-term (86%) debt in form of bonds issuance and loans (Galp 2024b). Therefore, rising interest rates increase borrowing costs, creating negative exposure for the company. Credit and counterparty risk is moderate, stemming from potential defaults in Galp's financial and commercial transactions, particularly related to trade and receivables. While this risk is less volatile, it tends to rise during economic downturns. However, due to its lower relevance to the core business and the difficulty in quantifying this exposure, it will not be included in the exposure analysis.

Financial Risk Management at Galp

This chapter critically evaluates Galp's financial risk management programme. Insights are obtained through the consolidation of annual reports, the calculation of a proxy hedge ratio, and an evaluation of the hedging impact on Galp’s financial performance and liquidity.

Galp employs a multifaceted strategy to mitigate market sensitivity, aiming to protect cash flows and shareholder value (Galp 2023, 286). The Strategic Hedging Programme is aligned with Galp’s Risk Appetite Statement, which defines the categories and extent of risk the company is prepared to accept to achieve its strategic objectives. Both are reviewed annually. While official documentation is unavailable, employee interviews suggest a conservative, risk-averse approach to financial risk management (Clemente Silva 2024; Franco 2024).

Employed Hedging Instruments

Galp employs an integrated approach, hedging net exposure at company level, to account for the sensitivity offsets which occur due to involvement Upstream and Downstream Operations.

Derivative positions at year-end highlight a strong focus on commodity hedging, as evidenced by Total Notionals (Galp 2022, 304; Galp 2023, 279). While notional values are not disclosed by energy resource, fair value breakdowns confirm hedging activities address oil, gas, and electricity exposures. Refining margins are reported excluding hedging impacts, implying potential use of refined product or spread derivatives, though specific details are not disclosed. Alternatively, refining margin sensitivity may be mitigated by hedging highly correlated market variables (see Figure 1). FX and interest rate sensitivities are also managed, though with lower notional values, reflecting comparatively minor Ebitda exposure and volatility.

Hedging at Galp is focused on short-term contracts, with most positions maturing in under a year, followed by those with one- to two-year maturities (Galp 2022, 304; Galp 2023, 279). The company primarily uses linear derivatives, particularly futures and swaps, with minimal reliance on non-linear derivatives. No positions in forwards or exchange-traded funds (ETFs) are disclosed. This approach benefits from the liquidity and daily mark-to-market advantages of futures and the tailored hedging benefits of swaps. In contrast, the characteristics of forwards and commodity-linked ETFs make them less relevant, due to non-standardization, counterparty risks, lower liquidity, and poor alignment with Galp's concentrated exposure. The limited use of options reflects the absence of significant quantity risk. Key output indicators show minimal sensitivity to market variables, particularly in the Ebitda-dominant upstream segment. Galp holds both long and short positions across all instruments, except for those managing interest rate exposure. In this case, the company focuses on fixed-rate receiver swaps to mitigate interest rate risk by converting floating-rate debt into fixed-rate debt (Galp, 2023, 279).

Hedge Ratio Proxy

In assessing how Galp’s hedging programme aligns with expectations, the firm’s hedge ratio is compared to the established industry benchmark (33% of next-year production). However, Galp’s use of both linear and non-linear derivatives complicates the calculation of the hedged exposure ratio. The option delta, which measures sensitivity to price changes, cannot be determined from public data due to the lack of details such as moneyness, strike price, and maturity. As a result, a proxy approach was employed to estimate Galp’s hedged exposure.

$$Hedge\ Ratio\ Proxy = \frac{Notional\ of\ Short\ Linear\ Commodity\ Derivatives(maturity < 1\ year; (t-1))}{Upstream\ Revenue\ (t)}$$

Equation 1. Hedge Ratio Proxy

The combined notional of futures and swap sales with expirations under one year is used as a proxy for hedged exposure. Since linear derivatives have payoffs directly proportional to changes in the underlying commodity price (delta equal to one), their notional values provide a reliable estimate of hedged positions. The focus is on the notional of instruments sold, as these correspond to obligations to sell at a predetermined price, relevant to production exposure. By considering only derivatives expiring within a year of period t-1 and comparing this to revenue in period t, alignment with the timeframe for recognizing revenue is achieved. Upstream commodity revenue clearly reflects production value. Derivative notionals have been disclosed since 2021, and with the 2024 Annual Report due for release, two ratios for the reference period can be obtained.

Galp's production proxy hedge ratio of 35.15% (32.61% in 2022; 37.69% in 2023) closely aligns with industry standards and suggests one third of production exposure being hedged. The proxy serves as a robust metric, offering a valuable quantification of Galp's hedging of production during the period analysed. Acknowledging that it excludes non-linear products, and the nuances of hedge accounting, these represent the minor share of overall positions.

Cashflow Impact Analysis

While the analysis confirms that Galp's hedging program broadly aligns with the industry, and its exposure profile, there remains room for improvement. The importance of effective financial risk management - and potential shortfalls in Galp's current strategy - becomes evident when examining its cash flow challenges during two energy crises in the study period.

In 2020, the global collapse in oil demand, precipitated by the Covid-19 pandemic, caused unprecedented revenue disruptions. Galp’s Upstream and I&M segments experienced substantial declines in contributions, highlighting reliance on oil price stability. As a result, Galp reported low, to negative quarterly Free Cash Flow, while its Net Debt to Ebitda ratio doubled from 0.7x to 1.5x and dividends were cut in half compared to 2019 (Galp, 2020, 44). Similarly, Russia's invasion of Ukraine in 2022 triggered a surge in natural gas prices, which particularly challenged the I&M segment, as previously demonstrated. Galp's hedging activities resulted in margin calls on derivatives used to hedge trading risks, leading to a EUR 605m working capital outflow and strained cash flow ahead of the war (Galp 2021, 92). This cash draw caused Galp to report negative Free Cash Flow for two consecutive quarters in Q3 and Q4 2021, necessitating increased borrowing to meet liquidity needs (Galp 2022b).

For Galp, stabilizing cash flow is essential for supporting its strategic priorities, including capital expenditures and dividends. Annual capex is guided to remain below EUR 1,000m, while dividends (totalling EUR 591m in 2023, excluding buybacks) are projected to grow by 4% annually (Galp, 2024c; Galp 2024d). Accordingly, combined **discretionary cash flow needs** amount to approximately **EUR 1,500m**, assuming divestments to be EUR 100m per year.

Ensuring these discretionary cash flow needs can be covered with internally generated funds, represents a key objective of effective financial risk management. The inability to do so, hereafter, is described as a cash flow problem understood to result in underinvestment in strategic projects, creating uncertainty for shareholders, undermining confidence and long-term value creation. From a risk management perspective, it is critical for Galp to anticipate adverse market scenarios, evaluating the likelihood of resulting cash flow challenges.

The next section quantifies Galp's 5% worst-state expected cash flows, comparing them to cash flow needs, and identifying the variables, most suitable for hedging. Throughout, the impact of correlations, volatilities, and market dynamics on bottom-line operational cash flow beyond Ebitda, is considered. The analysis specifically targets cash flow challenges that could affect Galp's strategic needs over a short-term horizon (1-2 years), as opposed to quarterly fluctuations.

Section 2: Prescriptive Analysis

Modeling Cash Flow at Risk

The following framework outlines the structure of a value-creating Cash Flow at Risk (CFaR) model, designed for a forward-looking time frame of eight quarters (up to Q3 2026).

First, the concept of the Post Obligation Operating Cash Flow (POOCF) is introduced. This metric represents the operating cash flow after taxes and interest, capturing its inherent volatility and serving as the model's focal point. Next, findings and assumptions regarding the relationships between market variables and cash flow components, which form the foundation of the CFaR model, are presented. These insights are derived from statistical regressions, operational data, and guidance from Galp. Quarterly historical data from Q1 2020 to Q3 2024 ("the period") is leveraged. The third step involves a detailed explanation of the assumptions underpinning the simulation of key market variables, including commodity prices, spreads, exchange rates, and interest rates. These variables are modelled using processes that account for correlations, volatilities, and a random component based on a normal distribution. In the fourth step, the CFaR model is tested against various (including extreme) market scenarios through scenario analysis. This is followed by a quantitative risk assessment using 100,000 simulations. The simulated cash flows are analysed across three-time horizons within the forward-looking period (Q4 2024 to Q3 2026): Year One (Quarters 1–4), Year Two (Quarters 5–8), and the Two Years period (Quarters 1–8). These assessments yield cash flow distributions, and single-variable simulations are used to pinpoint the primary market exposures driving risk.

Finally, the worst-state Post Obligation Operating Cash Flow is compared against Galp's discretionary cash flow requirements, particularly for capital expenditures and dividends. The resulting Two Years Cash Flow at Risk value at the 5th percentile serves as the key metric guiding proposed risk management improvements through a hedging strategy.

i) Cash Flow at Risk - Galp's Post Obligation Operating Cash Flow

Galp's reported cash flow items are analysed to determine the Post Obligation Operating Cash Flow, the Cash Flow From Operations after accounting for tax and debt obligations. This custom measure reflects the internal cash flow available for Galp to allocate towards discretionary capital expenditures and distributions (e.g., dividends or stock buybacks).

The accompanying table summarizes Galp's key cash flow items, exhibiting the standard deviation and average per quarter in the 2020-2024 period, as well as the total for 2023 and the total for the last four quarters (Q4 2023 to Q3 2024). The CFaR model is built on this structure.

€m

Cash Flow Table Galp	*Standard Deviation*	*Average*	*Total 2023*	*Total (4 Quarters)*
Upstream	176	533	2,263	2,240
Industrial & Midstream	123	119	929	758
Commercial	19	76	303	288
Renewables & New Businesses	17	10	131	59
Others	13	(6)	(69)	(17)
Total RCA Ebitda	**251**	**732**	**3,558**	**3,328**
Dividends from associates	16	15	31	12
Taxes paid	111	(226)	(1,320)	(1,107)
Adjusted operating cash flow	**176**	**521**	**2,269**	**2,233**
Special items	22	(1)	(13)	(49)
Inventory effect	161	(11)	(59)	(92)
Changes in working capital	356	(37)	179	(203)
Cash flow from operations	**286**	**471**	**2,376**	**1,889**
Interest, Leases and Principal	16	(67)	(301)	(334)
Post obligation operating cash flow	**285**	**405**	**2,075**	**1,556**

Figure 1. Cash Flow Table Galp, selected Statistics. 2020 - 2024 period

The concise breakdown up to "Cash Flow From Operations" and all numerical data deployed follows Galp's reporting (Galp 2020; Galp 2022b; Galp 2024a). Further deducting aggregated Interest, Leases, and Principal cash flows yields the Post Obligation Operating Cash Flow (POOCF). This volatile cash flow, with a historical quarterly average of EUR 405m and a standard deviation of EUR 285m, is well-suited for the scope of this model. By linking it to market exposures, it can subsequently be used to quantify how adverse market conditions can lead to an organic financing problem for Galp's capital expenditures and shareholder distributions.

ii) Cash Flow at Risk - Relationship to Market Exposures:

RCA Ebitda

Total RCA Ebitda (standard deviation of EUR 251m) already explains a significant portion of volatility in cash flows in the 2020-2024 period. As extensively analysed before, volatile market exposures largely determine the price and the margins at which Galp's products are sold.

Thus, the Upstream- (standard deviation of EUR 176m) and Industrial & Midstream- (standard deviation of EUR 123m) RCA Ebitda is best described by linking it to the market exposures as per the table below. The relationship in the CFaR model is taken from the regression in Figure 14Figure 14; Upstream is linked to Brent and Industrial & Midstream is linked to Natural Gas, Gasoline vs. Brent spread and the Euro/Dollar Exchange Rate in the CFaR model.

The stable yet seasonal Commercial Ebitda (standard deviation of EUR 19m) shows no statistically significant exposure to disclosed market data (Figure 14Figure 14). It is modelled based on its three-year seasonal quarterly average, with a year-on-year growth rate linked to the Portuguese 10-year interest rate, which is closely related to the previously used European benchmark variable.

For the Renewables segment (standard deviation of EUR 17m), Ebitda can be best related to operational data over the last nine quarters, namely renewable power generation and the realised solar sale price. In the CFaR model, Galp's realized solar price is linked to Iberian electricity prices (market exposure). A regression over the whole period shows that the realized solar price correlates with approximately 95% of Iberian electricity prices (R-squared = 98%). Due to the newness of the Renewables business, market exposures alone do not yet capture the segments variation well (small R-squared). Assumption: Renewable power generation capacity is projected to increase from 1.5 GW to 1.6 GW in the following quarters (Galp 2024e, 6). The resulting growth rate of 6.67% is applied year-on-year to account for seasonality, as solar power generation varies by quarter. However, this is not linked to market exposures.

Others Ebitda (standard deviation of EUR 13m) is uncorrelated with market exposures and contributes a low, negative impact to the CFaR model. It is therefore set to its average since Q1 2022, which is a negative EUR 4m.

The table below summarizes the relationships between RCA Ebitda and market exposures in the CFaR model for each business segment. It highlights the significant variables and their corresponding coefficients, along with key regression statistics such as R-squared and significance figures. Fields labelled as "Linked" highlight non-regressed market exposures that are linked to the respective cash flow item in the CFaR model (in the above-described relationship).

	Upstream Ebitda	*I&M Ebitda*	*Commercial Ebitda*	*Renewables Ebitda*
Intercept	(30.0)	628.2	-	(33.37)
Dated Brent price (USD/bbl)	7.5	-	-	-
Dutch TTF natural gas price (EUR/MWh)	-	(1.4)	-	-
Gasoline vs Brent spread (USD/bbl)	-	11.2	-	-
Diesel vs Brent spread (USD/bbl)	-	-	-	-
Iberian baseload pool price (EUR/MWh)	-	-	-	Linked
Exchange rate EUR:USD	-	(556.6)	-	-
Long Term Interest Rates (10y Portugal)	-	-	Linked	-
Renewable power generation (GWh)	-	-	-	0.05
Galp realised sale price (EUR/MWh)	-	-	-	0.4
Diesel Price Change (Brent + Spread)	-	-	-	-
R Square	0.89	0.92	NA	0.83
Significance F	5.61E-09	7.85E-08	NA	5.30E-03
N (Quarters)	18	18	NA	9

Figure 2. Overview RCA Ebitda Relationship to Market Variables in CFaR Model

Note: Omitting output variables in three of the Ebitda relationships assumes constant or stable output, production, and supply levels for future periods. Given the historical stability of production levels and no differing guidance from Galp, this assumption is reasonable.

Adjusted Operating Cash Flow

To bridge to Galp's Adjusted Operating Cash Flow (standard deviation of EUR 177m), the CFaR model incorporates assumptions regarding Dividends from Associates and Taxes Paid.

Dividends from Associates (standard deviation of EUR 16m) do not exhibit meaningful market exposure and are therefore set to the average figure since Q1 2022 (average of EUR 6m).

Taxes Paid (standard deviation of EUR 111m) require careful consideration, as Galp's tax rate is influenced by multiple factors, including its exposure to various jurisdictions, specific upstream-related oil and natural gas taxes, additions/deductions from taxes and windfall taxes imposed between 2022 and 2023. In 2023, Galp's effective tax rate stood at 38.5%, significantly down from 44.5% in 2022 (Galp 2023, 67), highlighting the variability of tax rates over time. Taxes Paid per quarter cannot be directly matched to any income statement item for the same period due to timing discrepancies. However, segment-level reporting for both RCA Ebitda and Adjusted Operating Cash Flows provides valuable insights. Notably, 93% of Total Taxes paid in the 2020–2024 period is attributed to the upstream segment. The Upstream segment faces by far the highest tax burden due to Brazil's Special Participation Tax (SPT). The lower rate for the other segments reflects the historically lower exhibited tax rates, as well as partial offsets from tax shields, deductibles, and loss carryforwards.

CFaR Tax Rate Assumption: To reasonably incorporate taxes into the CFaR model, Galp's Taxes Paid is obtained for Upstream, at 40% of RCA Upstream Ebitda, and for the other segments, at 17% of RCA Ebitda. This ratio is quite stable over different sub-periods. The chosen approach implies that Taxes Paid is exposed to all market exposures that affect Ebitda.

Note: Adjusted Operating Cash Flow exhibits reduced fluctuation in absolute standard deviation terms compared to Ebitda, due to the consistent negative cash flow impact of Taxes Paid.

<u>Cash Flow from Operations</u>

Galp's cash flow items bridging to Cash Flow From Operations (standard deviation of EUR 286m) contribute significant volatility to bottom-line cash flows, making them one of the most critical and intriguing components to analyse. These items consist of the Inventory Effect, Changes in Working Capital, and Special Items.

The Inventory Effect (standard deviation of EUR 160m) is the adjustment item Galp uses to transition from its preferred replacement cost adjustment (RCA) measure to IFRS reporting. It captures the part of the Ebitda cash flows that are related to changes in inventory (and do not reflect operational performance). It is driven by movement in market prices and associated with the Industrial & Midstream segment. According to Galp's reporting, inventories mainly consist of raw materials, finished and semi-finished products, and other goods (Galp, 2023, p. 255). The market exposure found to have the strongest relationship to the Inventory Effect (R-squared of 74%) is the change in diesel prices. This relationship is incorporated into the CFaR model as the change in Brent + the Diesel vs Brent spread. Given that diesel is the largest product of Galp's refinery operations, linking the Inventory Effect to this benchmark is logical. Notably, gasoline and other price changes do not exhibit statistical significance for this period. In the CFaR model, the Inventory Effect is expressed as the percentage change from the previous inventory level. The model assumes that inventory changes align with the Inventory Effect, providing a reasonable approximation while presuming stable inventory volumes (excluding price effects) across future periods.

Changes in Working Capital (standard deviation of EUR 356m) exhibits strong exposure to Brent. Analysis indicates that oil prices significantly influence Galp's Working Capital, explaining 87% of its variation (excluding gas margin account holdings). This linkage is logical, as oil prices impact inventory valuation and the value of Trade Payables and Receivables in a similar manner. The established relationship adjusts for the Working Capital fluctuations associated with margin account holdings between 2021 and 2022 due to extremely high Dutch TTF natural gas volatility (please refer to Section 1: Cashflow Impact Analysis). The Changes in Working Capital due to gas derivative hedges (standard deviation of EUR 272m) accounted for a significant portion of cash flow volatility during this time. Both the Inventory Effect and Changes in Working Capital contribute significantly to cash flow fluctuations, with Working

Capital having a larger impact. However, their combined effect on bottom-line cash flow volatility is somewhat mitigated by their negative correlation. Intuitively, rising oil and oil product prices lead to a Working Capital build, but this effect is partially offset by a positive contribution from the Inventory Effect, and vice versa.

Note: Special Items (with a standard deviation of EUR 22m during the 2020-2024 period), as reported in Galp's Cash Flow Statement, are not incorporated into the CFaR model. Due to their nature, they do not exhibit significant forward-looking market exposures. During the period, their average quarterly cash flow was a negative EUR 1m.

Post Obligation Operating Cash Flow

To complete the assessment of market exposures and get to the Post Obligation Operating Cash Flow (standard deviation of EUR 285m), the CFaR model deducts Galp's relatively stable payments for Interest, Leases, and Principal (standard deviation of EUR 16m).

To establish an intuitive relationship for Interest, Leases, and Principal, quarterly net Interest Payments are calculated as a percentage of debt, while lease payments are calculated as a percentage of lease liabilities. The CFaR model assumes that debt and lease payments are linked to the previous interest rate and changes in the simulated Portuguese 10-year interest rate (linked but not regressed to market exposure). For simplicity, it is further assumed that bonds, loans, and leases on the balance sheet remain constant throughout the forward-looking period.

	Upstream Ebitda	*I&M Ebitda*	*Commercial Ebitda*	*Renewables Ebitda*	*Taxes Paid*	*Inventory Effect*	*Working Capital*	*Interest, Leases & Principal*
Intercept	(30.0)	628.2	-	(33.37)	-	0.38%	(327.8)	-
Dated Brent price (USD/bbl)	7.5	-	-	-	Exposure	Linked	22.0	-
Dutch TTF natural gas price (EUR/MWh)	-	(1.4)	-	-	Exposure	-	-	-
Gasoline vs Brent spread (USD/bbl)	-	11.2	-	-	Exposure	-	-	-
Diesel vs Brent spread (USD/bbl)	-	-	-	-	-	Linked	-	-
Iberian baseload pool price (EUR/MWh)	-	-	-	Linked	Exposure	-	-	-
Exchange rate EUR:USD	-	(556.6)	-	-	Exposure	-	-	-
Long Term Interest Rates (10y Portugal)	-	-	Linked	-	Exposure	-	-	Linked
Renewable power generation (GWh)	-	-	-	0.05	-	-	-	-
Galp realised sale price (EUR/MWh)	-	-	-	0.4	-	-	-	-
Diesel Price Change (Brent + Spread)	-	-	-	-	-	*0.5*	-	-
R Square	0.89	0.92	NA	0.83	NA	0.74	0.87	NA
Significance F	5.61E-09	7.85E-08	NA	5.30E-03	NA	4.28E-06	4.43E-09	NA
N (Quarters)	18	18	NA	9	NA	18	18	NA

Figure 3. Overview Cash Flow Item Relationships to Market Exposures in CFaR Model

In summary, the cash flow items outlined collectively form the volatile Post Obligation Operating Cash Flow. Within the CFaR model, all fluctuations are driven entirely by the simulated trajectory of the introduced market exposure variables. Operational exposures are excluded from simulation and remain static within the model. Figure 3 provides a comprehensive overview of all regressed and assumed relationships between cash flow items and market exposures. Cash flow items with relationships labelled as "Exposure" are indirectly influenced by market variables, whereas those labelled "Linked" are directly tied to market exposures through the predefined relationships, rather than being solely derived from a (multi) linear regression model. This distinction ensures clarity in how different cash flow components interact with market variables within the CFaR framework.

iii) Cash Flow at Risk - Assumptions Market Variables

The presented market variables have been found to be the best in explaining volatility in Galp's cash flows and are simulated according to assumed processes in the CFaR model. These processes share several common characteristics: all future values of the variables depend on their values in the preceding period, introducing path dependency. Starting from an observed value, the subsequent value is influenced by a shock with a random component (draw from an assumed normal distribution). For each variable a constant volatility is assumed, which determines the magnitude of this shock. To account for interdependencies, correlations between variables are incorporated into the shocks using the Cholesky decomposition (Hull 2015, 473). As a result, the variable movements in the CFaR model are interdependent, providing a more realistic representation than assuming independency.

An overview of the market variable assumptions used for simulating is presented in Figure 4 below. A different methodology for the volatility (standard deviation) is applied for the spreads and interest rates as these are not assets (but derived from them). For those variables, the standard deviation is calculated based on the quarterly differences in spreads and rates instead of returns. Also, for those variables, the Drift column contains a value for the mean-reverting level. The simulation processes and formulas used account for these methodologies and are described hereafter. For all variables, forward-looking volatilities are estimated using either historical volatility observed during the 2020–2024 period or implied volatilities. WTI and Henry Hub 3-month option-implied volatilities are used as proxies for forward-looking volatilities of European oil and gas benchmarks. This approach is preferred because US benchmark implied volatilities are lower and assumed to provide a more realistic estimate for a constant volatility figure over the next eight quarters (Bloomberg 2024b; Bloomberg 2024c). For Iberian Electricity, implied volatility is assumed to match that of Dutch TTF natural gas due to their strong correlation and similar historic volatility (Appendix: *Figure* 17).

Exposure	*Volatility (Annual SD)*	*Assumption*	*Drift*	*Theta*	*Process*
Dated Brent price (USD/bbl)	32%	Implied Vol	2.00%	NA	GBM
Dutch TTF natural gas price (EUR/MWh)	59%	Implied Vol	2.00%	NA	GBM
Gasoline vs Brent spread (USD/bbl)	18.72	Historic SD	15.99	1	Ornstein-Uhlenbeck
Diesel vs Brent spread (USD/bbl)	20.40	Historic SD	22.02	1	Ornstein-Uhlenbeck
Iberian baseload pool price (EUR/MWh)	59%	Implied Vol	2.00%	NA	GBM
Exchange rate EUR:USD	6%	Historic Vol	-	NA	GBM
Long Term Interest Rates (10y Portugal)	0.73%	Historic SD	2.00%	0.5	Vasicek

Figure 4. Overview CFaR Assumptions about Market Variable Volatilities and Processes

Process Assumptions

Geometric Brownian Motion (GBM): The simulation of Dated Brent price (32% assumed volatility), Dutch TTF natural gas (59% assumed volatility), Iberian baseload pool electricity price (59% assumed volatility), and the EUR:USD exchange rate (6% assumed volatility) is conducted based on a Geometric Brownian Motion process. For commodities, a drift of 2% is assumed, aligning with the inflation target by Western Central Banks. In contrast, no drift is applied to the exchange rate. The variables are assumed to move free in the short to medium term, no mean-reversion behaviour expected.

The simulated values are generated using the following formula, where *s* represents the variable modelled by the GBM, *r* is the drift, *sigma* is the volatility, *delta t* is the time step (one quarter), and *Z* is the scalar product of the random draws (normal distribution) and the Cholesky matrix.

$$s_{t+1} = s_t \cdot \exp\left[\left(r - \frac{\sigma^2}{2}\right)\Delta t + \sigma\sqrt{\Delta t} \cdot Z\right]$$

Equation 2. Discrete-Time Timestep GBM (Hull 2015, 309–310)

The Cholesky matrix (Figure 18), is derived from market variable correlations in the 2020-2024 period and ensures that the simulated shocks account for dependencies across all variables.

<u>Ornstein-Uhlenbeck Process:</u> The Gasoline vs Brent spread (assumed SD of USD 18.72) and Diesel vs Brent spread (assumed SD of USD 20.40) are key variables in this analysis due to their tradability and relevance as indicators of refining profitability. Oil product spreads are modelled with a different process than commodity asset prices, assuming they exhibit mean-reverting behaviour. To account for this, the process incorporates a mean-reverting property (average of 2020-2024 period), assuming the variable realization is influenced by this value (gravitation). For the gasoline and diesel spreads, the mean-reversion levels (*mu*) are set to USD 15.99 and USD 22.02, respectively, while the mean-reversion speed (*theta*) is set to one. Additionally, a lower bound of zero is imposed on the spreads in the CFaR model to reflect the assumption that refining spreads cannot be negative, as it would be uneconomical to refine under such conditions. The formula below represents the discrete timestep used for this simulation. Here, *x* is the spread value, *mu* is the mean-reversion level, *theta* is the mean-reversion speed, *sigma* is the annual SD, *delta t* is the time step, and *Z* is the simulated shock.

$$x_{t+1} = x_t + \theta(\mu - x_t)\Delta t + \sigma\sqrt{\Delta t} \cdot Z$$

Equation 3. Discrete-Time Timestep Ornstein-Uhlenbeck process (Patrick 2016, 15)

Vasicek Process: The Portuguese 10-year interest rate (assumed SD of 0.73%), representing a long-term interest rate, is simulated based on a Vasicek process. Like spreads, the interest rate is assumed to exhibit mean-reverting behaviour, reflecting a tendency to be influenced by an equilibrium. The mean-reversion level (*mu*) is assumed to be 2%, aligning with the interest rate that cancels out the inflation target set by central banks. The mean-reversion speed (*theta*) is set to 0.5, ensuring a moderate gravitational force influencing the interest rate realization.

The Vasicek process is effectively an application of the Ornstein-Uhlenbeck, specifically for interest rates. The formula below illustrates the discrete timestep applied in this simulation.

$$r_{t+1} = r_t + \theta(\mu - r_t)\Delta t + \sigma\sqrt{\Delta t} \cdot Z$$

Equation 4. Discrete-Time Timestep Vasicek process (Hull 2015, 708-709)

In Appendix, Figure 20 can be found an illustration of how the path of market variables can look like in the CFaR model simulation. Notice how the exhibited simulated shocks (measured in SD) lead to different realizations of the variable in the forward-looking quarters. Recall that realizations are dependent on the previous variable realization and the random draw from the normal distribution in conjunction with volatilities and the Cholesky matrix that incorporates correlations.

iv) Cash Flow at Risk - Scenario Analysis

Before proceeding with simulation results, a scenario analysis is conducted to illustrate how the CFaR model output responds to different realizations of single market variables. For simplicity, the analysis assumes a constant change in a single market variable across all eight quarters. Scenario values for each market variable are calculated within a range of +/- 2 standard deviations relative to the base case Q3 2024 values, based on the previously assumed volatilities in *Figure* 4. These values are summarized in the table below.

Market Variables	- 2 SD	- 1 SD	Q3/24	+ 1 SD	+ 2 SD
Dated Brent price (USD/bbl)	46.04	60.82	80.34	106.13	140.20
Dutch TTF natural gas price (EUR/MWh)	13.92	22.18	35.33	56.29	89.68
Gasoline vs Brent spread (USD/bbl)	5.44	10.12	14.80	19.48	24.16
Diesel vs Brent spread (USD/bbl)	7.20	12.30	17.40	22.50	27.60
Iberian baseload pool price (EUR/MWh)	31.14	49.52	78.73	125.18	199.04
Exchange rate EUR:USD	0.98	1.04	1.10	1.16	1.23
Long Term Interest Rates (10y Portugal)	1.42%	2.14%	2.87%	3.59%	4.32%

Figure 5. Overview Market Variable Values used for Scenario Analysis

Yearly standard deviations (SDs) are applied to all market exposures except spreads. For spreads, quarterly SDs are used to account for their strong mean-reverting behaviour, capped at zero to avoid unrealistically high or negative values. Interest rates are modelled with slower mean-reversion dynamics, therefore yearly SDs are applied for scenario analysis. For all variables, realizations beyond the specified bandwidths remain possible. This is particularly true for variables modelled without mean-reverting behaviour, where deviations are increasingly likely in the later quarters of the simulation.

Base Case: Figure 6 provides the moderate base case cash flow outcomes for Year One, Year Two, and the Two Years period, assuming market variables remain constant at Q3 2024 levels.

€m

Cash Flow Table Galp	Standard Deviation	Average	Total 2023	Total (4 Quarters)	Total Year One	Total Year Two	Total Two Years
Upstream	176	533	2,263	2,240	2,288	2,288	4,575
Industrial & Midstream	123	119	929	758	528	528	1,055
Commercial	19	76	303	288	301	301	602
Renewables & New Businesses	17	10	131	59	101	109	210
Others	13	(6)	(69)	(17)	(14)	(14)	(28)
Total RCA Ebitda	**251**	**732**	**3,558**	**3,328**	**3,202**	**3,211**	**6,414**
Dividends from associates	16	15	31	12	25	25	49
Taxes paid	111	(226)	(1,320)	(1,107)	(1,057)	(1,059)	(2,116)
Adjusted operating cash flow	**176**	**521**	**2,269**	**2,233**	**2,170**	**2,177**	**4,347**
Special items	22	(1)	(13)	(49)	-	-	-
Inventory effect	161	(11)	(59)	(92)	16	17	33
Changes in working capital	356	(37)	179	(203)	-	-	-
Cash flow from operations	**286**	**471**	**2,376**	**1,889**	**2,186**	**2,194**	**4,380**
Interest, Leases and Principal	16	(67)	(301)	(334)	(304)	(304)	(609)
Post obligation operating cash flow	**285**	**405**	**2,075**	**1,556**	**1,882**	**1,889**	**3,771**

Figure 6. Cash Flow Table - Base Case (Market Variables constant as in Q3 2024)

Notably, with oil product spreads declining in recent quarters, the I&M Ebitda in Year One and Year Two (EUR 528m) would remain below previous years if spreads persist at this level. In the base case, the Inventory Effect and Changes in Working Capital are null, as market variables remain constant. The other cash flow items for Year One and Year Two align closely with "Total

2023" and the "Last Four Quarters." Consequently, the bottom-line Post Obligation Operating Cash Flow in the base case totals EUR 1,882m in Year One, EUR 1,889m in Year Two and EUR 3,771m in Two Years. In the base case, Galp is sufficiently capable of paying discretionary cash flow needs defined in Section 1 - Cashflow Impact Analysis from its operational capabilities.

Scenario Results: The scenario analysis results (Figure 7) illustrate the ceteris paribus figure of the Post Obligation Operating Cash Flow for a change in the specified market variable in Year One and in Year Two. As exhibited, adverse implications occur when key market exposures deviate significantly (in relative terms) from the Q3 2024 base case.

€m Post obligation operating cash flow

Market Variables	- 2 SD	- 1 SD	Q3/24	+ 1 SD	+ 2 SD
Year One					
Dated Brent price (USD/bbl)	1832	1853	1882	1919	1969
Dutch TTF natural gas price (EUR/MWh)	1983	1944	1882	1783	1625
Gasoline vs Brent spread (USD/bbl)	1533	1707	1882	2056	2230
Diesel vs Brent spread (USD/bbl)	1827	1855	1882	1909	1936
Iberian baseload pool price (EUR/MWh)	1823	1846	1882	1939	2030
Exchange rate EUR:USD	2106	1997	1882	1759	1629
Long Term Interest Rates (10y Portugal)	1950	1916	1882	1848	1813
Year Two					
Dated Brent price (USD/bbl)	1266	1534	1889	2358	2977
Dutch TTF natural gas price (EUR/MWh)	1990	1951	1889	1790	1633
Gasoline vs Brent spread (USD/bbl)	1541	1715	1889	2064	2238
Diesel vs Brent spread (USD/bbl)	1888	1889	1889	1890	1890
Iberian baseload pool price (EUR/MWh)	1831	1853	1889	1946	2037
Exchange rate EUR:USD	2114	2005	1889	1767	1637
Long Term Interest Rates (10y Portugal)	1957	1923	1889	1855	1821

Figure 7. Scenario Analysis POOCF – Constant Change in Single Market Exposure

For instance, if the Brent price declines by 2 SDs to USD 46.04/bbl (refer to Figure 5), the CFaR model predicts that Galp's Post Obligation Operating Cash Flow would, ceteris paribus, drop to EUR 1,832m in Year One and further decline to EUR 1,266m in Year Two. The relatively smaller impact in Year One results from an expected one-time release of Working Capital, as existing Receivables continue to flow in despite the drop in Brent prices. By Year Two, however, the CFaR model projects a sharper decline in cash flow, aligning with expectations. Similarly, a 2 SD decrease in the Gasoline vs. Brent spread to USD 5.44/bbl would significantly impact the profitability of the I&M segment. In this scenario, the CFaR model predicts Galp's Post Obligation Operating Cash Flow would fall to EUR 1,533m in Year One and EUR 1,541m in Year Two. Notably, the Diesel vs. Brent spread impacts the model only through changes in the Inventory Effect, which means it exhibits no deviation under the constant scenario analysis.

In the scenario case of a one-time change in a single specified market variable by two standard deviations, Galp is close to experiencing a Cash Flow Challenge particularly for a Dated Brent, and a Gasoline vs Brent Spread decline.

v) Cash Flow at Risk - Simulation

To quantitatively assess how Galp's modelled cash flows behave across a wide range of market conditions with different likelihoods, a simulation approach is employed. This method incorporates the dynamics of all variables, using the most robust processes and relationships identified. A total of 100,000 simulations are conducted, producing different realizations of quarterly market variables over the forward-looking horizon. These simulated paths determine cash flow realizations for eight quarters, enabling an evaluation of the magnitude and likelihood of potential cash flow challenges while identifying exposures that are most effective to hedge.

Simulation Results: In the first four quarters (Year One), the POOCF averages EUR 1,962m, with a standard deviation of EUR 351m, reflecting moderate uncertainty over the relatively short horizon. In the subsequent four quarters (Year Two), the average amounts to EUR 2,054m, accompanied by a significantly higher standard deviation of EUR 731m, indicating greater uncertainty further out, due to greater likelihood of market variable dispersion. Notably, the simulated Year One and Year Two averages are higher than the base case figures (EUR 1,882m and EUR 1,889m*,* Figure 6). These elevated averages result from assumed drifts in key variables, such as a positive 2% drift in commodity prices, which influence the modelled market variables in the forward-looking period.

Single Market Variable Risk Simulation:

In contrast to the scenario analysis, which focused on constant single-variable changes, simulating single market variables allows to evaluate the variables impact on uncertainty and likelihood of adverse states of the POOCF. Keeping other variables constant at Q3 2024 values, the SDs and 5th percentile outcomes (worst cash flow states) are exhibited below. Hereafter, a particular emphasis is put on the Two Years timeframe.

€m Post obligation operating cash flow	Standard Deviation			5th Percentile		
	Year One	*Year Two*	*Two Years*	*Year One*	*Year Two*	*Two Years*
Dated Brent	205	535	425	1,506	1,200	3,185
Dutch TTF natural gas	72	142	200	1,743	1,621	3,390
Gasoline vs Brent	318	373	583	1,464	1,455	3,074
Diesel vs Brent	70	88	74	1,791	1,761	3,686
Iberian Electricity	42	82	115	1,832	1,816	3,654
EUR:USD	84	148	218	1,741	1,638	3,402
Long Term Interest Rate	20	29	44	1,860	1,865	3,733
Diversification Effects	(460)	(665)	(730)	(274)	(606)	(822)
Total Cash Flow	**351**	**731**	**930**	**1,431**	**1,016**	**2,624**

Figure 8. POOCF Simulation Results – Single Market Variable and Total

Notably, the Gasoline vs Brent spread (Two Years SD of EUR 583m) has the largest single-variable impact on cash flow variation. Similarly, Dated Brent contributes significant cash flow uncertainty, with a Two Years standard deviation of EUR 425m. The associated 5% worst-case cash flows for these variables are EUR 3,074m and EUR 3,185m, respectively, over the Two Years period which would not be considered a cash flow problem for Galp as previously defined. However, when considering the combined impact of all variable movements, the **Total 5th percentile Post Obligation Operating Cash Flow amounts to EUR 2,624m**. This underscores the amplifying effect of market exposure correlations, where adverse movements in key variables are likely to occur simultaneously, heightening the total downside risk. The negative Diversification Effects, calculated as the difference between single variable standard deviation and total standard deviation, as well as the difference between the single variable average 5th percentile and the Total 5th Percentile is exhibited in *Figure* 8.

Distribution:

Galp's Post Obligation Operating Cash Flow distribution in Year One and Year Two is illustrated below, clearly demonstrating the increased uncertainty in the second year. Note that the uncertainty or dispersion of cash flows is particularly sensitive to the assumed volatility levels and diversification effects among market variables. Higher correlations between key drivers contribute to less diversification, amplifying the overall risk exposure.

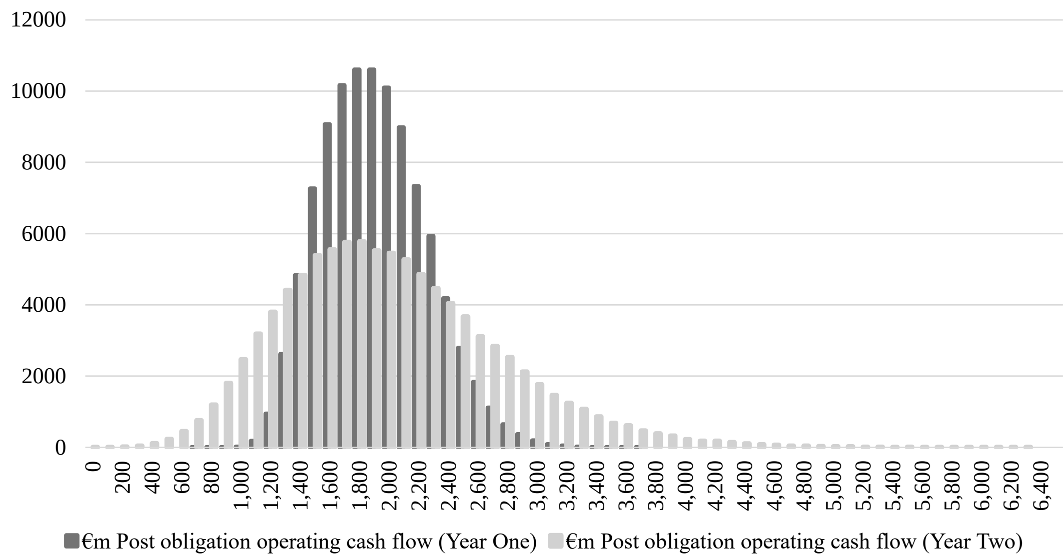

Figure 9. POOCF distribution Year One and Year Two (N=100,000)

vi) Cash Flow at Risk - 5th percentile

Galp's discretionary cash flow needs for capex and dividends have been assumed to total at least EUR 3,000m over two years, with EUR 1,800m for net capex and EUR 1,200m for dividends (refer to Section 1: Cashflow Impact Analysis). The CFaR at the 5th percentile is calculated as Galp's POOCF at the 5th percentile minus cash flow needs in the corresponding timeframe: Thus, Galp's current **Two Years Cash Flow at Risk at the 5th percentile** equals **EUR 376m** (EUR 2,624m – 3,000m). This is the operational cash flow contribution Galp is missing with a 5% probability at the end of the Two Years period and shall be the targeted metric to hedge.

Hedging Strategy

To reduce Galp's quantified Two Years Cash Flow at Risk and lower the missing operational cash flow contributions in the 5% most unfavourable market paths according to the CFaR model, a risk mitigating and value-adding Hedging Strategy is presented. The following measure is to be implemented at the company level, in addition to the financial risk management measures currently in place. Accordingly, the aim of the proposed strategy is to tame the forward-looking dispersion of the Post Obligation Operating Cash Flow.

As quantified and exhibited, Galp has significant exposure to oil and refining spreads. Both exposures are positively correlated (no natural hedge) and have been quantified as impacting Galp's cash flow items with highest significance. The created macro view (managerial perspective) of the company is leveraged and thus, instead of hedging exposures independently as is often the case, the hereafter proposed risk management strategy is focused on the single market exposure (commodity) that incorporates both exposures, namely Gasoline (Brent + Gasoline vs Brent Spread).

A non-linear hedging approach has been strategically selected to balance risk management with the opportunity for profit maximization. To protect against the downside risk of selling oil and oil products at unfavourable (low) market prices, put options provide the ability to set the exact level at which compensation is useful and needed to prevent a Cash Flow Challenge, ensuring critical cash flow protection during adverse market environments. Flexibility in setting hedge levels (strike prices) is a major advantage compared to Futures - but it comes with a premium cost. To enhance cost efficiency, a collar hedging strategy - combining long put options with short call options – is implemented for Year One and Year Two. This strategy not only mitigates downside risks but also minimizes hedging costs, ensuring the company avoids additional cash flow strain while retaining a degree of exposure to potential price upside.

In line with the literature and Hedge Ratio findings, the Option Notional is linked to 30% of the output in the Upstream segment (112.5 kboepd, close to the average).

Options contracts are incorporated in the CFaR model and are initiated at the end of Q3 2024, with both collars designed to be self-financing. To hedge downside risk, a gasoline put option with a strike price of USD 75.0/bbl is utilized, which is close to the scenario analysis assumption of a one-standard-deviation decline in the combined Brent and Gasoline spread variables from Q3 2024 levels. Using the Black-Scholes option pricing model and assuming an implied gasoline volatility of 44% (*Figure* 22), call strike prices are determined such that the call premium offsets the cost of the put option (Black and Scholes 1973). This results in a call strike price of USD 135.8/bbl for Year One and USD 149.5/bbl for Year Two.

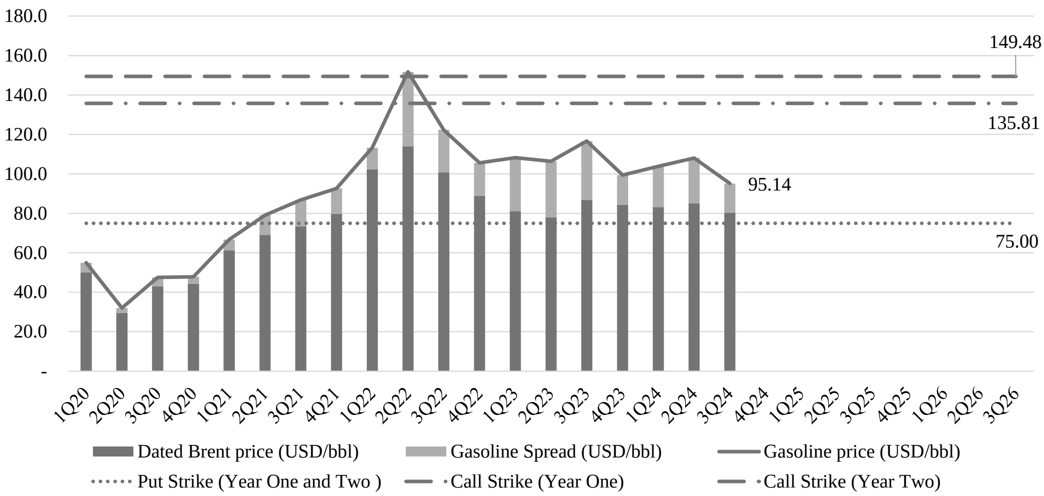

Figure 10. Gasoline Price and Collar Strike Prices (USD/bbl) used in Hedging Strategy

In Figure 10, the historical gasoline price and components (Brent + Spread) are illustrated, alongside the proposed collar strike prices. The proposed structure hedges part of Galp's production over two years. The Year One options mature at the end of four quarters, while the Year Two options mature at the end of eight quarters. This setup provides essential risk protection while allowing for the possibility of minor maturity mismatches, as price fluctuations may occur between option expiries.

€m	Post obligation operating cash flow			Post obligation operating cash flow (hedged)		
	Year One	*Year Two*	*Two Years*	*Year One*	*Year Two*	*Two Years*
Standard Deviation	351	731	930	346	619	712
Mean	1,962	2,054	4,016	1,966	2,060	4,026
Percentiles						
0.01	1,290	720	2,212	1,088	974	2,667
0.05	1,431	1,016	2,624	1,453	1,230	2,999
0.5	1,940	1,975	3,945	1,955	1,979	3,958
0.95	2,572	3,366	5,652	2,535	3,180	5,286
0.99	2,853	4,134	6,448	2,788	3,847	5,798
Skew	0.38	0.74	0.45	(0.30)	0.68	0.28
Kurtosis	(0.07)	1.13	0.22	2.74	1.60	0.50

Figure 11. Summary Statistic - Simulated POOCF (before and after hedging) N=100,000

The Collar Option Hedging Strategy is dynamically incorporated into the CFaR model and simulation of market variables determine the payoff at maturity. As demonstrated in the simulation results (Figure 11), the hedged Two Years Post Obligation Operating Cash Flow at the 5th percentile improves significantly to EUR 2,999 m, compared to EUR 2,624 m in the unhedged scenario. While the Hedging Strategy is shown to reduce downside exposure, it also limits upside potential by the same magnitude. Nevertheless, the strategy effectively mitigates Galp's tail risks and reduces cash flow dispersion, with particularly notable benefits in the second year. The simulation process, conducted with 100,000 iterations, extracted the Post Obligation Operating Cash Flows after implementing the gasoline collar hedging strategy. The resulting distribution is illustrated below (Figure 12).

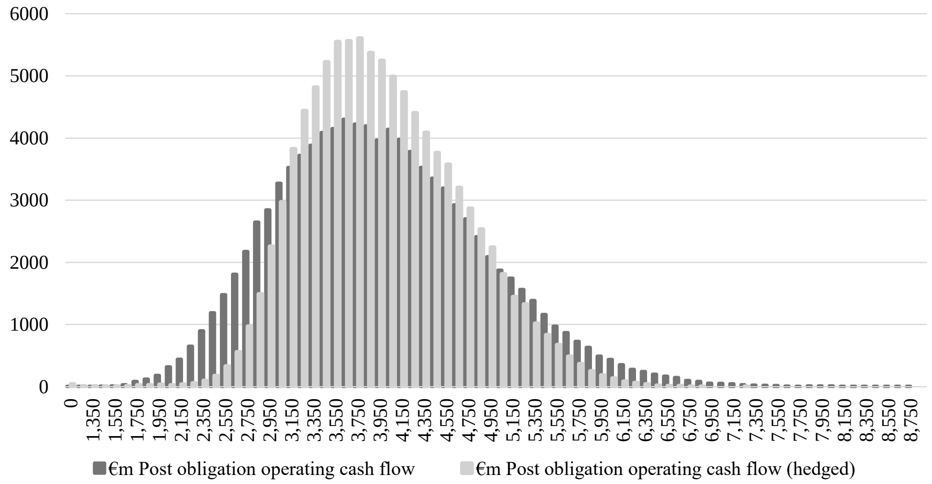

Figure 12. Two Year POOCF distribution, Before and after hedging (N=100,000)

The collar strategy results in a significantly less skewed cash flow distribution and exhibits higher kurtosis. The quantitative analysis demonstrates that the Hedging Strategy effectively mitigates forward-looking uncertainty related to cash flow generation and liquidity over the Two Years horizon. With this strategy in place, Galp achieves over 95% confidence in meeting its cash flow requirements, compared to 85% in the unhedged scenario, at no additional cost. The **Two-Year Cash Flow at Risk (hedged) at the 5th percentile** improves to **EUR 1m**, indicating a substantial reduction in downside risk and probability of a cash flow problem.

Note: The cash flow table used to extract the simulated POOCF after hedging (Year One, Year Two and Two Years) can be found in the Appendix (Figure 19). The initial option pricing table at T=0 (Q3 2024) is exhibited in the Appendix (Figure 22). The Option Payoff x Notional at maturity (Year One and Year Two) determines the cash flows from the collar hedging strategy.

Conclusion

This thesis presents a thorough analysis of Galp's market exposures, offering a detailed quantification of the key risks influencing its cash flow volatility. It demonstrates the critical role of hedging in mitigating these risks, with a focus on maximizing financial resilience. Gasoline has been identified as an effective hedging instrument at the company level, due to its strong positive price correlation with both Brent crude and refined oil product spreads. This makes gasoline an optimal proxy for addressing Galp's exposure to market fluctuations, enabling a targeted reduction in cash flow volatility and supporting the company's overall financial stability.

The developed methodology - integrating Exposure Assessment, Cash Flow at Risk (CFaR) Modelling, and a Gasoline-Based Hedging Strategy - provides a comprehensive and adaptable framework for Galp's risk management. By quantifying hedge levels and ratios while improving transparency around market exposures, this approach delivers significant value for both managerial decision-making and investor confidence. For management, the proposed strategy ensures the safeguarding of dividend-paying capacity, minimizes the likelihood of underinvestment, and mitigates risks of credit rating downgrades or excessive debt burdens. For investors, it reinforces confidence in Galp's capacity to deliver consistent, stable growing, and predictable dividends that are justified by Galp's cash flow performance, positioning the company for sustainable growth in a volatile energy market.

The model effectively captures historical price dynamics while incorporating forward-looking scenarios, offering Galp a valuable tool to manage future uncertainties. Crucially, the proposed strategy ensures that Galp can mitigate risks without tapping into its cash reserves or resorting to additional debt - an increasingly important consideration given Galp's recognition of liquidity risk as a top priority. The developed framework enhances Galp's capacity to navigate these challenges, supporting data-driven, informed financial risk management for key exposures and ensuring greater stability in its operations and financial performance.

Findings of this thesis provide valuable insights for Galp's risk management strategy. Future studies could explore various aspects to build upon the existing framework. For instance, testing different market variable correlations and volatility assumptions, along with their impacts on cash flows and hedged cash flows, can provide deeper insights. Exploring alternative distributions for commodities, exchange rates, and interest rates, particularly those emphasizing heavier tails, could also refine the risk assessment.

Likewise, specific transitory supply and demand shocks related to Geopolitical Events, Unexpected Recessions or even Pandemics could be tested. Finally, several hedging intensities and instruments (although the theoretical implications are well known) could be compared. In all cases, the financial risk management approach would stay the same.

Bibliography

Adam, Tim R., and Chitru S. Fernando. 2006. "Hedging, Speculation, and Shareholder Value." *Journal of Financial Economics* 81 (2): 283–309.

Adam, Tim. 2005. "Capital Expenditures, Financial Constraints, and the Use of Options." *Journal of Financial Economics* 92(2): 238–251.

Adam, Tim, Sudipto Dasgupta, and Sheridan Titman. 2007. "Financial Constraints, Competition, and Hedging in Industry Equilibrium." *The Journal of Finance* 62 (5): 2445-2473.

Ahn, Dong-Hyun, Jacob Boudoukh, Matthew Richardson, and Robert F. Whitelaw. 2003. "Optimal Risk Management Using Options." *The Journal of Finance* 54 (1): 359–375.

Allayannis, George, and James Weston. 2001. "The Use of Foreign Currency Derivatives and Firm Market Value." *Review of Financial Studies* 14: 243–276.

Allayannis, George, Jane Ihrig, and James P. Weston. 2001. "Exchange-Rate Hedging: Financial vs. Operational Strategies." *American Economic Review* 91 (2): 391–395.

Basher, Syed Abul, Alfred A. Haug, and Perry Sadorsky. 2018. "The Impact of Oil-Market Shocks on Stock Returns in Major Oil-Exporting Countries." *Journal of International Money and Finance* 86: 264–280.

Bessembinder, Hendrik. 1991. "Forward Contracts and Firm Value: Investment Incentive and Contracting Effects." *The Journal of Financial and Quantitative Analysis* 26 (4): 519–532.

Black, Fischer, and Myron Scholes. 1973. "The Pricing of Options and Corporate Liabilities." Journal of Political Economy 81 (3): 637-654.

Bloomberg. 2024a. Financial Model for Galp Corporation, *Bloomberg Terminal*, accessed October 1, 2024.

Bloomberg. 2024b. WTI: Crude Oil 3m Implied Volatility, *Bloomberg Terminal*, accessed October 25, 2024.

Bloomberg. 2024c. Henry Hub: Natural Gas 3m implied volatility, *Bloomberg Terminal*, accessed October 25, 2024.

Brown, Gregory. 2001. "Managing Foreign Exchange Risk with Derivatives." *Journal of Financial Economics* 60: 401–448.

Chen, Jun, and Tao-Hsien Dolly King. 2014. "Corporate Hedging and the Cost of Debt." *Journal of Corporate Finance* 29: 221–245.

Culp, Christopher, and Merton Miller. 1995. "Hedging in the Theory of Corporate Finance: A Reply to Our Critics." *Journal of Applied Corporate Finance*.

Dolde, Walter. 1993. "The Trajectory of Corporate Financial Risk Management." *Journal of Applied Corporate Finance* 6: 33–41.

Duffie, Darrell. 1995. "Corporate Incentives for Hedging and Hedge Accounting." *Review of Financial Studies* 743–771.

European Central Bank. 2024. *Euribor 3-Month: Historical Close, Average of Observations Through Period, Euro Area (Changing Composition), Monthly*. ECB Data Portal. Accessed October 10, 2024. https://data.ecb.europa.eu/data/datasets/FM/FM.M.U2.EUR.RT.MM.EURIBOR3MD_.HSTA.

Fama, Eugene. 1970. "Efficient Capital Markets: A Review of Theory and Empirical Work." *Journal of Finance* 25 (2): 383–417.

Fisher, Bryan, and Ankush Kumar. 2010. "The Right Way to Hedge." *McKinsey on Finance* 36.

Federal Reserve Bank of St. Louis. 2024. *Interest Rates: Long-Term Government Bond Yields: 10-Year: Main (Including Benchmark) for Euro Area (19 Countries)*. Federal Reserve Economic Data (FRED). Accessed October 10, 2024. https://fred.stlouisfed.org.

Franco, Diogo Melo. 2024. Interview by Luisa Kloth and David Stilkenböhmer. LNG Trader, Galp, October 29, 2024.

Froot, Kenneth A., David S. Scharfstein, and Jeremy C. Stein. 1993. "Risk Management: Coordinating Corporate Investment and Financing Policies." *The Journal of Finance* 48: 1629–1658.

Galp. 2020. *Reports and Accounts, Q4 2020: Additional Information*. Excel file. Accessed October 10, 2024. https://www.galp.com/corp/en/investors/reports-and-presentations/reports-and-results.

Galp. 2021. *Annual Integrated Report 2021*. Lisbon: Galp. Accessed September 11, 2024. https://www.galp.com/corp/Portals/0/Recursos/Investidores/SharedResources/Relatorios/en/2021/AIRGalp2021EN2book1IMRFull.pdf.

Galp. 2022a. *Annual Integrated Report 2022*. Lisbon: Galp. Accessed September 11, 2024. https://www.galp.com/corp/Portals/0/Recursos/Investidores/2023_IR/1Q_RESULTS_2023/GALP_RC22_EN_ESEF.pdf.

Galp. 2022b. *Reports and Accounts, Q4 2022: Additional Information*. Excel file. Accessed October 10, 2024. https://www.galp.com/corp/en/investors/reports-and-presentations/reports-and-results.

Galp. 2023. *Annual Integrated Report 2023*. Lisbon: Galp. Accessed September 11, 2024. https://www.galp.com/corp/en/investors/publications-and-announcements/investor-announcements/investor-announcement/id/1526/annual-integrated-report-2023.

Galp. 2024a. *Reports and Accounts, Q3 2024: Additional Information*. Excel file. Accessed October 10, 2024. https://www.galp.com/corp/en/investors/reports-and-presentations/reports-and-results.

Galp. 2024b. "Debt Indicators and Debt Structure." Galp. Accessed November 1, 2024. https://www.galp.com/corp/en/investors/information-to-bondholders/debt-indicators.

Galp. 2024c. "Dividends." Galp. Accessed November 1, 2024. https://www.galp.com/corp/en/investors/information-to-shareholders/dividends#:~:text=The%20base%20dividend%20related%20to,after%20approval%20at%20the%20AGM.

Galp. 2024d. " Dividends and share repurchases." Galp. Accessed November 2, 2024. https://www.galp.com/corp/en/investors/information-to-shareholders/dividends-and-share-repurchases.

Galp. 2024. "3Q 2024 Results." Galp. Accessed November 12, 2024. https://www.galp.com/corp/Portals/0/Recursos/Inv_3Q24/Galp_3Q24_Presentation.pdf.

Gay, Gerald, Jouahn Nam, and Marian Turac. 2002. "How Firms Manage Risk: The Optimal Mix of Linear and Non-Linear Derivatives." *Journal of Applied Corporate Finance* 14 (4): 82–93.

Geczy, Christopher, Bernadette Minton, and Catherine M. Schrand. 1997. "Why Firms Use Currency Derivatives." *Journal of Finance* 52: 1323–1351.

Gerken, Arno, Olivier Plantefève, and Xavier Veillard. 2019. "Managing Industrials' Commodity-Price Risk." *McKinsey&Company*.

Guay, Wayne, and S. P. Kothari. 2003. "How Much Do Firms Hedge with Derivatives?" *Journal of Financial Economics* 423–461.

Hamilton, James D. 2009. "Causes and Consequences of the Oil Shock of 2007–08." *Brookings Papers on Economic Activity*.

Haushalter, David. 2005. "Why Hedge? Some Evidence from Oil and Gas Producers." *Journal of Applied Corporate Finance* 87–92.

Haushalter, G. David. 2000. "Financing Policy, Basis Risk, and Corporate Hedging: Evidence from Oil and Gas Producers." *Journal of Finance* 55 (1): 107–152.

Hennessy, Christopher A., Amnon Levy, and Toni M. Whited. 2007. "Testing Q Theory with Financing Frictions." *Journal of Financial Economics* 83 (3): 691–717.

Hull, John C. 2015. *Options, Futures, and Other Derivatives*. 9th ed. Pearson.

Jin, Yanbo, and Philippe Jorion. 2006. "Firm Value and Hedging: Evidence from US Oil and Gas Producers." *The Journal of Finance* 61 (2).

Kolb, Robert, and James Overdahl. 2003. *Financial Derivatives*. New Jersey: John Wiley & Sons, Inc.

Leland, Hayne E. 1998. "Agency Costs, Risk Management and Capital Structure." *Journal of Finance* 53: 1213–1243.

Li, Hao, Nuttawat Visaltanachoti, and Robin H. Luo. 2014. "Foreign Currency Derivatives and Firm Value: Evidence from New Zealand." *Journal of Financial Risk Management* 3.

McKinsey. 2013. "Strategic Commodity and Cash-Flow At-Risk Modeling for Corporates." *McKinsey*.

Patrick, M. U. M. U. 2016. "A Comparison of Prices Generated by the Derivative Commodity Model (Ornstein-Uhlenbeck Process) with Those Obtained by the Conventional Arbitrage-Free Method of Pricing Forward Derivatives with Respect to Tea in Nduti Tea Factory Kenya." *Journal of Statistics and Actuarial Research* 1 (1): 12–23.

Press, William H., Saul A. Teukolsky, William T. Vetterling, and Brian P. Flannery. 2007. *Numerical Recipes: The Art of Scientific Computing.* 3rd ed. Cambridge: Cambridge University Press.

Rampini, Adriano, and S. Viswanathan. 2010. "Collateral, Risk Management, and the Distribution of Debt Capacity." *The Journal of Finance* 65 (6): 2293–2322.

Repsol. 2020. "Financial and Operating Data Tables, Q3 2020." Excel file. Accessed November 12, 2024. https://www.repsol.com/en/shareholders-and-investors/financial-information/quarterly-results/archive/index.cshtml.

Repsol. 2021a. "Financial and Operating Data Tables, Q1 2021." Excel file. Accessed November 12, 2024. https://www.repsol.com/en/shareholders-and-investors/financial-information/quarterly-results/archive/index.cshtml.

Repsol. 2021b. "Financial and Operating Data Tables, Q3 2021." Excel file. Accessed November 12, 2024. https://www.repsol.com/en/shareholders-and-investors/financial-information/quarterly-results/archive/index.cshtml.

Repsol. 2022a. "Financial and Operating Data Tables, Q1 2022." Excel file. Accessed November 12, 2024. https://www.repsol.com/en/shareholders-and-investors/financial-information/quarterly-results/archive/index.cshtml.

Repsol. 2022b. "Financial and Operating Data Tables, Q3 2022." Excel file. Accessed November 12, 2024. https://www.repsol.com/en/shareholders-and-investors/financial-information/quarterly-results/archive/index.cshtml.

Repsol. 2023a. "Financial and Operating Data Tables, Q1 2023." Excel file. Accessed November 12, 2024. https://www.repsol.com/en/shareholders-and-investors/financial-information/quarterly-results/archive/index.cshtml.

Repsol. 2023b. "Financial and Operating Data Tables, Q3 2023." Excel file. Accessed November 12, 2024. https://www.repsol.com/en/shareholders-and-investors/financial-information/quarterly-results/archive/index.cshtml.

Repsol. 2024a. "Financial and Operating Data Tables, Q1 2024." Excel file. Accessed November 12, 2024. https://www.repsol.com/en/shareholders-and-investors/financial-information/quarterly-results/archive/index.cshtml.

Repsol. 2024b. "Financial and Operating Data Tables, Q3 2024." Excel file. Accessed November 12, 2024. https://www.repsol.com/en/shareholders-and-investors/financial-information/quarterly-results/archive/index.cshtml.

Rickman, J., M. Falkenberg, S. Kothari, F. Larosa, M. Grubb, and N. Ameli. 2024. "The Challenge of Phasing-Out Fossil Fuel Finance in the Banking Sector." *Nature Communications* 15.

Ross, Michael P. 1997. "Corporate Hedging: What, Why, and How?" *Working Paper*, Berkeley: University of California.

Schulte, Josh, Jeff Nicholson, and Reece Lambert. 2022. "Perspectives: Oil and Gas Companies Continue to Hedge." *Hart Energy*, July 15. Accessed October 30, 2024. https://www.hartenergy.com/exclusives/perspectives-oil-and-gas-companies-continue-hedge-201172.

Silva Clemente, Ana Sofia. 2024. Interview by Luisa Kloth and David Stilkenböhmer. Head of Corporate Enterprise Risk Management and Business Continuity, Galp, October 25, 2024.

Spanò, Marcello. 2004. "Determinants of Hedging and Its Effects on Investment and Debt." *Journal of Corporate Finance* 10 (1): 175–197.

Stulz, René M. 1996. "Rethinking Risk Management." *Journal of Applied Corporate Finance* 9 (3): 8-25.

Stulz, René. 1984. "Optimal Hedging Policies." *Journal of Financial and Quantitative Analysis* 19: 127–140.

Stulz, René, and Clifford Smith. 1985. "The Determinants of a Firm's Hedging Policies." *Journal of Financial and Quantitative Analysis* 391–405.

The Wharton School. 1994. "Survey of Derivative Usage Among U.S. Non-Financial Firms."

Tufano, Peter. 1996. "Who Manages Risk? An Empirical Examination of Risk Management Practices in the Gold Mining Industry." *Journal of Finance* 51 (4): 1097–1137.

Uhlenbeck, G. E., and L. S. Ornstein. 1930. "On the Theory of the Brownian Motion." Physical Review 36 (5): 823–841.

Vasicek, O. 1977. "An Equilibrium Characterization of the Term Structure." *Journal of Financial Economics* 5 (2): 177–188.

Appendix

Key Output Indicators

	Indicator	*Unit*	*Source*
Upstream	Working Interest Production	(kboepd)	Galp
	Oil Production	(kbpd)	Galp
Industrial & Midstream	Raw Materials Processed	(mboe)	Galp
	NG/LNG Trading Volume	(TWh)	Galp
Commercial	Oil Product Sales	(mton)	Galp
	Natural Gas Sales	(TWh)	Galp
	Electricity Sales	(TWh)	Galp
Renewables & New Business	Power Generation	(GWh)	Galp

Figure 13. Key Output Indicators

(€m) Ebitda

Regression Results	*Total*	*Upstream*	*I&M*	*Commercial*	*Renewables*
Intercept	0.4	(30.0)	628.2	68.6	11.0
Dated Brent price (USD/bbl)	8.0	7.5	-	-	-
Dutch TTF natural gas price (EUR/MWh)	(1.2)	-	(1.4)	-	-
Gasoline vs Brent spread (USD/bbl)	11.9	-	11.2	*1.16	-
Diesel vs Brent spread (USD/bbl)	-	-	-	*(0.43)	-
Iberian baseload pool price (EUR/MWh)	-	-	-	*(0.03)	*0.007
Exchange rate EUR:USD	-	-	(556.6)	-	-
Short Term Interest Rates (3m Euribor)	-	-	-	-	-
Long Term Interest Rates (10y Europe)	-	-	-	-	-
R Square	0.94	0.89	0.92	0.17	0.00055
Significance F	9.92E-09	5.61E-09	7.85E-08	4.50E-01	9.26E-01
N (Quarters)	18	18	18	18	18

* Not Significant at any Conventional Level

Figure 14. Ebitda Regression Results, best-fit models highlighted in grey

```
Function CholeskyDecomposition(matrixRange As Range) As Variant
    Dim n As Integer
    n = matrixRange.Rows.Count
    Dim L() As Double
    ReDim L(1 To n, 1 To n)

    Dim i As Integer, j As Integer, k As Integer
    Dim sum As Double

    ' Perform Cholesky decomposition
    On Error GoTo NotPositiveDefinite
    For i = 1 To n
        For j = 1 To i
            sum = matrixRange.Cells(i, j).Value
            For k = 1 To j - 1
                sum = sum - L(i, k) * L(j, k)
            Next k
            If i = j Then
                If sum <= 0 Then GoTo NotPositiveDefinite
                L(i, j) = Sqr(sum)
            Else
                L(i, j) = sum / L(j, j)
            End If
        Next j
    Next i

    ' Output the result in the lower triangular matrix
    Dim result As Variant
    ReDim result(1 To n, 1 To n)
    For i = 1 To n
        For j = 1 To n
            result(i, j) = L(i, j)
        Next j
    Next i

    CholeskyDecomposition = result
    Exit Function

NotPositiveDefinite:
    CholeskyDecomposition = CVErr(xlErrNum)
End Function
```

Figure 15. Code for Cholesky Transformation, Adapted from Press et al. (2007, 100)

```
Sub SaveMultiplePeriodFCFValues()
    Dim sourceSheet As Worksheet
    Dim storageSheet As Worksheet
    Dim resultsArray() As Variant
    Dim numIterations As Long
    Dim numPeriods As Long
    Dim i As Long, j As Long
    Dim FCFRange As Range

    ' Set the source and storage sheets
    Set sourceSheet = ThisWorkbook.Sheets("GALP Model")
    Set storageSheet = ThisWorkbook.Sheets("Simulation")

    ' Define the number of iterations
    numIterations = 100000 ' Adjust as needed

    ' Define the range of FCF values (e.g., AW145:BB145)
    Set FCFRange = sourceSheet.Range("BK105:BL105")
    numPeriods = FCFRange.Columns.Count ' Count the number of FCF periods

    ' Resize the results array: numIterations rows and numPeriods columns
    ReDim resultsArray(1 To numIterations, 1 To numPeriods)

    ' Turn off screen updates and events for performance
    Application.ScreenUpdating = False
    Application.EnableEvents = False
    Application.Calculation = xlCalculationManual

    ' Loop through iterations
    For i = 1 To numIterations
        ' Recalculate the GALP Model sheet
        sourceSheet.Calculate

        ' Save the FCF values for all periods
        For j = 1 To numPeriods
            resultsArray(i, j) = FCFRange.Cells(1, j).Value
        Next j
    Next i

    ' Write the entire array to the Simulation sheet in one go
    storageSheet.Range("G3").Resize(numIterations, numPeriods).Value = resultsArray

    ' Restore Excel settings
    Application.Calculation = xlCalculationAutomatic
    Application.ScreenUpdating = True
    Application.EnableEvents = True

    ' Notify the user
    MsgBox numIterations & " simulations saved to the Simulation sheet!", vbInformation
End Sub
```

Figure 16. VBA Code for Automating Simulations, Own implementation.

Exposure	*Dated Brent*	*Dutch TTF natural gas*	*Gasoline vs Brent*	*Diesel vs Brent*	*Iberian Electricity*	*EUR:USD*	*Interest Rate*
Dated Brent price (USD/bbl)	1.00000						
Dutch TTF natural gas price (EUR/MWh)	0.70972	1.00000					
Gasoline vs Brent spread (USD/bbl)	0.77121	0.39884	1.00000				
Diesel vs Brent spread (USD/bbl)	0.76022	0.67370	0.73918	1.00000			
Iberian baseload pool price (EUR/MWh)	0.70815	0.74436	0.35660	0.40989	1.00000		
Exchange rate EUR:USD	-0.55204	-0.55939	-0.59717	-0.86517	-0.20700	1.00000	
Long Term Interest Rates (10y Portugal)	0.63984	0.28809	0.77824	0.74045	0.07536	-0.78910	1.00000

Figure 17. Correlation Table Market Exposures (Q1 2020- Q3 2024)

Exposure	*Dated Brent*	*Dutch TTF natural gas*	*Gasoline vs Brent*	*Diesel vs Brent*	*Iberian Electricity*	*EUR:USD*	*Long Term Interest Rate*
Dated Brent price (USD/bbl)	1.00000	0	0	0	0	0	0
Dutch TTF natural gas price (EUR/MWh)	0.70972	0.70448	0	0	0	0	0
Gasoline vs Brent spread (USD/bbl)	0.77121	-0.21079	0.60067	0	0	0	0
Diesel vs Brent spread (USD/bbl)	0.76022	0.19043	0.32136	0.53154	0	0	0
Iberian baseload pool price (EUR/MWh)	0.70815	0.34319	-0.19509	-0.24669	0.53087	0	0
Exchange rate EUR:USD	-0.55204	-0.23789	-0.36889	-0.52988	0.11847	0.45582	0
Long Term Interest Rates (10y Portugal)	0.63984	-0.23566	0.39142	0.32570	-0.26403	-0.31524	0.32663

Figure 18. Cholesky Transformation of above Correlation Table, Code in Figure 15

€m

Cash Flow Table Galp	*Standard Deviation*	*Average*	*Total 2023*	*Total (4 Quarters)*	*Total Year One*	*Total Year Two*	*Total Two Years*
Upstream	176	533	2,263	2,240	2,117	2,773	4,891
Industrial & Midstream	123	119	929	758	519	536	1,054
Commercial	19	76	303	288	300	300	601
Renewables & New Businesses	17	10	131	59	68	91	159
Others	13	(6)	(69)	(17)	(14)	(14)	(28)
Total RCA Ebitda	**251**	**732**	**3,558**	**3,328**	**2,991**	**3,687**	**6,677**
Dividends from associates	16	15	31	12	25	25	49
Taxes paid	111	(226)	(1,320)	(1,107)	(983)	(1,250)	(2,233)
Adjusted operating cash flow	**176**	**521**	**2,269**	**2,233**	**2,032**	**2,462**	**4,494**
Special items	22	(1)	(13)	(49)	-	-	-
Inventory effect	161	(11)	(59)	(92)	83	117	200
Changes in working capital	356	(37)	179	(203)	5	(510)	(505)
Cash flow from operations	**286**	**471**	**2,376**	**1,889**	**2,120**	**2,068**	**4,188**
Interest, Leases and Principal	16	(67)	(301)	(334)	(284)	(272)	(556)
obligation operating cash flow	**285**	**405**	**2,075**	**1,556**	**1,836**	**1,796**	**3,632**

Figure 19. Cash Flow Table for a Simulated Path of Market Variables

		Year One				**Year Two**			
Market Exposures	3Q24	*4Q24*	*1Q25*	*2Q25*	*3Q25*	*4Q25*	*1Q26*	*2Q26*	*3Q26*
Dated Brent price (USD/bbl)	80.3	67.08	65.88	69.49	76.60	75.45	99.01	93.34	99.75
Dutch TTF natural gas price (EUR/MWh)	35.3	24.41	25.29	28.68	25.07	32.97	47.82	57.51	46.73
Gasoline vs Brent spread (USD/bbl)	14.8	1.70	12.72	16.46	27.48	23.44	27.81	24.68	23.48
Diesel vs Brent spread (USD/bbl)	17.4	10.51	18.75	26.19	37.60	42.15	54.37	50.34	48.90
Iberian baseload pool price (EUR/MWh)	78.7	60.18	48.57	42.64	47.18	44.43	49.26	55.61	49.16
Exchange rate EUR:USD	1.10	1.13	1.09	1.08	1.06	1.01	0.98	0.96	0.96
Long Term Interest Rates (10y Portugal)	2.87%	2.10%	2.20%	2.49%	2.68%	2.83%	3.00%	2.62%	2.87%
Random Draw from Distribution:									
Dated Brent price (USD/bbl)	Normal	-1.0750	-0.0625	0.3812	0.6562	-0.0456	1.7425	-0.3187	0.4632
Dutch TTF natural gas price (EUR/MWh)	Normal	-0.5007	0.4198	0.4054	-1.1198	1.5441	0.2104	1.3907	-1.2730
Gasoline vs Brent spread (USD/bbl)	Normal	-1.1791	1.5520	0.1740	0.7449	0.3930	-1.0553	0.8659	-0.8689
Diesel vs Brent spread (USD/bbl)	Normal	0.9468	-0.0110	0.4261	1.3100	0.8317	1.2520	0.1829	1.3592
Iberian baseload pool price (EUR/MWh)	Normal	0.2950	-0.7456	-1.0942	1.6234	-0.5448	-1.3611	0.9493	-0.0240
Exchange rate EUR:USD	Normal	0.6858	-0.8296	0.6193	0.6329	-1.5284	0.9030	0.0546	0.4973
Long Term Interest Rates (10y Portugal)	Normal	-2.4496	-1.8493	1.2471	-0.2174	-0.0710	-1.1684	-0.9150	1.0496

Figure 20. One Simulated Path of Market Variable Realizations in the CFaR Model

€m

Cash Flow Table Galp	*Standard Deviation*	*Average*	*Total 2023*	*Total (4 Quarters)*	*Total Year One*	*Total Year Two*	*Total Two Years*
Upstream	176	533	2,263	2,240	1,679	1,238	2,917
Industrial & Midstream	123	119	929	758	26	(61)	(35)
Commercial	19	76	303	288	300	300	600
Renewables & New Businesses	17	10	131	59	58	35	93
Others	13	(6)	(69)	(17)	(14)	(14)	(28)
Total RCA Ebitda	**251**	**732**	**3,558**	**3,328**	**2,049**	**1,498**	**3,547**
Dividends from associates	16	15	31	12	25	25	49
Taxes paid	111	(226)	(1,320)	(1,107)	(726)	(534)	(1,260)
Adjusted operating cash flow	**176**	**521**	**2,269**	**2,233**	**1,347**	**989**	**2,336**
Special items	22	(1)	(13)	(49)	-	-	-
Inventory effect	161	(11)	(59)	(92)	(218)	42	(175)
Changes in working capital	356	(37)	179	(203)	582	198	780
Cash flow from operations	**286**	**471**	**2,376**	**1,889**	**1,712**	**1,229**	**2,941**
Interest, Leases and Principal	16	(67)	(301)	(334)	(273)	(250)	(523)
ost obligation operating cash flow	**285**	**405**	**2,075**	**1,556**	**1,439**	**979**	**2,418**
Hedging Gasoline (Collars)	-	-	-	-	193	366	560
ash flow after hedging	**-**	**-**	**-**	**-**	**1,632**	**1,345**	**2,978**

Figure 21. Cash Flow Table incl. Hedging for a Simulated Path of Market Variables

Black Scholes Option Price	*Year One*	*Year One*	*Year Two*	*Year Two*
S	95.14	95.14	95.14	95.14
K	**75.00**	**135.8**	**75.00**	**149.5**
sigma	44%	44%	44%	44%
r	2.00%	2.00%	2.00%	2.00%
T	1.0	1.0	2.0	2.0
S-PV(D)	95.14	95.14	95.14	95.14
PV(K)	73.51	133.12	72.06	143.62
sigma*sqrt(T)	0.44	0.44	0.62	0.62
d1	0.80	-0.54	0.76	-0.35
d2	0.36	-0.98	0.13	-0.97
N(d1)	0.79	0.29	0.78	0.36
N(d2)	0.64	0.16	0.55	0.17
Call	27.94	**6.32**	33.96	**10.88**
Put	**6.32**	44.30	**10.88**	59.37

Figure 22. Black Scholes Option Pricing used for Hedging in CFaR Model in Q3 2024