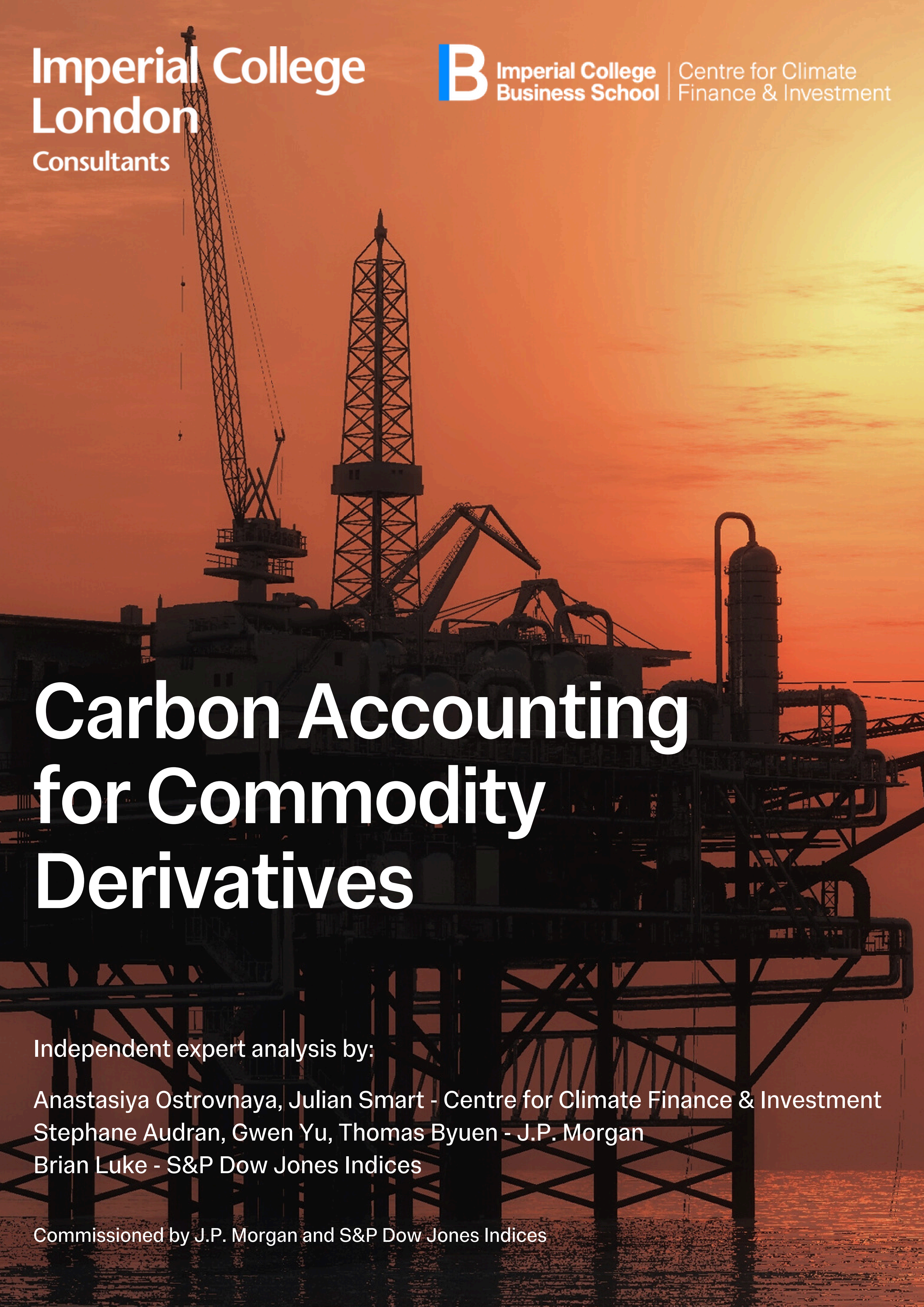

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Carbon Accounting for Commodity Derivatives

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Executive Summary

To date, there is **no common approach to carbon accounting on any financial derivative instruments**. Moreover, some may argue that emissions should be attributed to asset owners rather than to parties of derivative contracts.

In this paper, we present **a basis for carbon accounting for commodity derivatives**. The derivative market facilitates activities related to the extraction, production or consumption of commodities, which are directly linked to greenhouse gas emissions creation. We demonstrate that a) **commodity producers materially use derivative markets to hedge** their production, in order to reduce uncertainty about future revenues and 2) this results in a **substantially lower cost of capital**, and thus the ability of such companies to raise financing and continue their operations.

Parties to commodity derivative contracts facilitate the hedging of producers, regardless of delivery type (physical or cash) and whether they are held to maturity or not. This includes long term investors (directly or via indices) as well as market makers and short-term investors. As a result, commodity derivatives facilitate the emissions.

Numerous open **questions** require further investigation. There are derivative-specific and commodity-specific aspects of how carbon accounting methodologies should evolve. As there is no standard for any derivatives carbon accounting, there needs to be a debate on how or whether to incorporate (a) contract tenor and holding period duration into the calculation, (b) whether short positions in derivatives merit negative emissions accounting, and (c) how to address double (or triple) counting of the associated emissions. For commodities specifically, contract maturity matters since the quantum of market risk transfer increases with “time to expiry”.

Introduction

The concentration of atmospheric greenhouse gases has increased by 50% since the Industrial Revolution (NASA, 2023), the highest measured amount since records began as well as in paleoclimatic records dating back as far as 800,000 years (NOAA, 2023). Such concentrations threaten not only the economic prosperity but also multiple forms of life on Earth. There is an undeniable urgency to mitigate the impacts of climate change and slow down (and ultimately stop and reverse) global heating.

To align with Paris climate targets, coordinated action is required from all ends of society. Climate change mitigation represents an investment challenge. Substantial amounts of capital are required to deliver on the global need for secure, reliable and affordable energy, whilst meeting governments' and companies' net-zero emissions goals by 2050. Financial institutions and investors play an important role in helping facilitate this transition to a lower-carbon global economy. Transition to a lower carbon global economy relies on interconnected efforts from a multitude of players, including governments which set the enabling policy framework to allow investment capital to flow into transition activities and solutions.

Investment in commodities is a critical area for this transition. The extraction, processing and use of materials, fuels and food make up about half of total global greenhouse gas emissions and more than 90 per cent of biodiversity loss and water stress (UNEP, 2019). While there are recognised methods of counting emissions associated with mining activities or burning fossil fuels, there is still ambiguity with regard to the allocation of emissions across commodities markets in general.

Companies worldwide have been making pledges to reduce their emissions. They represent a promise to reduce emissions to net zero level by the stated year, often 2050 (if there were any emissions which cannot be reduced, they would have to be removed). Over 1000 companies globally have pledged carbon neutrality or included it as a part of corporate strategy, among them many banks, insurance and asset management companies. The main challenge for the latter is the decarbonisation of investment portfolios. The methodologies to measure financed emissions are being developed by the firms in-house as well as by industry bodies, consulting firms and various data providers. While there isn't a consensus on one single correct methodology for even the simplest asset classes (like debt or equity), the financial derivatives largely stayed out of sight.

The purpose of this paper is to articulate an approach for commodity derivatives carbon accounting. A simplistic case is occasionally made that commodity futures have no footprint, owing to the fact that an insignificant proportion of traded contracts actually go to physical delivery. We argue instead that commodity derivatives constitute an important link in the financing chain, by helping to reduce producers' cost of capital. The same framework can be applied to commodity indices, where earlier publications made the case for tilting portfolios based on the components' sustainability attributes (Audran, Boal, Bullock et al, 2023). However, the exact amount of emissions that should be attributed to derivatives positions remains an open question, along with the potential impact on the calculation of contract tenor, holding period, how long/short exposures be treated and how to address double counting.

This paper is structured in the following way. First, we establish that on a net basis, corporates are short oil futures as a result of substantial producer hedging via derivatives. Secondly, we build a model to demonstrate that hedges matter for the producers' cost of capital, thus impacting their ability to raise debt and finance operations, particularly for entities with lower capital bases / riskier credit profiles. Thirdly, we discuss how to translate this into emissions accounting for derivatives – regardless of the fact that those instruments typically do not result in physical delivery/consumption of the commodity, by the hedge provider. We offer concluding remarks in the last section.

Background

With the primary focus on their scope 3 emissions, financial institutions face a particularly challenging task of emissions measurement and attribution. The complexity of investment portfolios and financing structures with an added variety of financial instruments makes this task far from trivial. The choice of methodology can lead to either inflated or underestimated results, e.g. some financial institutions reported in 2023 the financed emissions dropped by up to 30% year on year while their financing for fossil fuel firms remained unchanged (Marsh, 2023). Out of all asset classes, derivatives present a special challenge: they do not constitute direct ownership of the underlying asset or security. Thus, their contribution to the "carbon" balance sheet is questioned.

Sustainable finance regulations and external experts state that financial instruments' contribution to sustainability can be considered through different lenses, including the provision of cash through lending or direct investment, stewardship, engagement and derisking/ impact on the cost of capital. Derivatives have a role to play in sustainable finance as they contribute to liquidity, help mitigate risk, and impact the cost of capital.

However, the actual treatment of derivatives within existing sustainable finance regulations is unclear. For example, the EU Taxonomy (EU 2020/852) definition of the banking ratio (green asset ratio) includes accounting for derivatives in the denominator but not in the numerator. Not all types of commodity manufacturing are included in the EU Taxonomy. EU SFDR (EU 2019/2088) disclosures for Articles 8 and 9 funds ask for qualitative explanations as to whether and how derivatives are used towards achieving stated sustainability objectives. The European Supervisory Authorities (ESA) have recently suggested leveraging the conversion methodology presented in EU 231/2013 Annex II as a way to account for derivative instruments.

But before we can address the methodological issues, it is critical to demonstrate that derivatives, although not constituting direct asset ownership, play a role in emission creation. We invoke a risk transfer approach, which builds on existing academic and industry literature.

The theory of risk/return trade-off goes back at least to the 1950s, with seminal work by Harry Markowitz on "Portfolio Selection" which raises the hypothesis that "the investor does (or should) consider expected return a desirable thing and variance of return an undesirable thing" (Markowitz, 1952). Finding the right balance between risk and returns is important to maintain a corporation's ability to exceed its cost of capital and continue generating value (Fama and French, 2002).

Other academics expand on these relationships showing that the "extra earnings from 'trading on equity' are often regarded by investors as more than sufficient to serve as a 'premium for risk''' (Guthmann and Dougall, 1955). There is also research suggesting that the rate of return on common stock must compensate for the financial risk of the entity (Modigliani and Miller, 1958). As minimizing risk can provide adequate controls to reduce the cost of capital, it becomes apparent that hedging production and stabilizing revenues can be a tool to reduce the cost of capital.

There exists a body of academic research looking at the relationship between production hedging and cost of capital, specifically analysing the link between derivative trading and cost of capital. There is evidence showing that the cost of equity for users of derivatives is between 24-78 basis points (bps) lower than for non-users (Gay et al., 2010). These findings support the notion that hedged firms can increase debt capacity and reduce underinvestment problems as they reduce risk by smoothing earnings (Stulz, 1996; Leland, 1998; Graham and Rogers, 2002; Froot et al., 1993). Similarly, strong evidence has been shown in the literature supporting the idea that hedging is associated with a lower cost of debt across a large population of US firms. This effect is brought on by reducing financial risk and is more pronounced in firms with higher leverage. They found that the cost of debt for hedged firms is 49.2bps lower than for un-hedged firms in their full sample. This is broken down to 19.2bps lower for investment-grade issuers and 45.2bps lower for speculative-grade issuers (Chen and King, 2014). There exists another piece of research that shows the same conclusions surrounding the importance of derivatives for reducing business risk; a 31.2bps difference in loan spread between hedgers and non-hedgers (Campello et al., 2011). The proposed explanation for this phenomenon was that hedging reduces bankruptcy risk thus reducing the negative effect of rising rates on returns.

There is a growing body of literature examining the relationship between capital markets and carbon emissions. It was found that firms with higher total emissions yield higher returns to investors, and concluded that investors demand a higher risk premium from polluting firms (Bolton and Kacperczyk, 2020). It has also been argued that "brown" firms (measured by carbon intensity per unit of output) exhibit large negative impact elasticities, namely they become substantially less brown in response to easier access to capital and more brown if pushed toward financial distress (Hartzmark and Shue, 2023). This suggests that since green investments are capital intensive, if the capital is expensive or scarce and if the short-term financial stability of a firm is at risk, the firm would increase the high-yielding brown activities to extract cash needed for financial survival. The scope of this paper does not include an analysis of the decarbonisation of polluting firms but establishes instead a potential relationship between market risk hedges and the specific cost of capital of polluting activities (as opposed to the aggregate firm's).

Role of derivatives: producers hedge

Derivatives play a significant role in the financial ecosystem. According to the Bank for International Settlements (BIS), the notional value of outstanding over-the-counter derivatives (OTC) reached $715 trillion in June 2023, of which $2.24 trillion represented commodities (BIS, 2023). However, commodity derivatives are also very significantly traded on exchanges across the world.

Commodities resonate with a greenhouse gas emissions theme more than any other asset class. After all, traditional energy commodities (primarily oil and gas) have a direct link to emissions, and the impact of burning any of them is well understood (UN Climate Action, 2023; Gaffney and Marley, 2009). But extraction, growth and/or production of any type of commodity often comes at high environmental costs as well (Audran, Boal, Bullock et al., 2023), such as agricultural or mineral categories. The expansion of unconventional O&G development in the US has significant impacts on land-use and ecosystem services (Moran et al., 2017). Data providers help assess these issues, most notably, the S&P Global Sustainable1 Commodity Environment Data Set assesses the GHG emissions, water consumption and land use impacts associated with the cradle-to-gate value chain of 24 commodities produced around the world.

Carbon accounting for commodity derivatives is not a well-researched or well-discussed topic. A prevalent perspective suggests that the entities or individuals directly accountable for the generation of GHG emissions should exclusively assume responsibility for these emissions. The majority of commodity traders neither produce nor consume said commodities and thus do not have to recognise the associated emissions in relation to their trading or investment portfolios.

We however suggest a different viewpoint: we demonstrate that participation in the commodities market through either market-making or long-term positioning in single-name commodities or indices has a measurable impact on producers' ability to raise capital and therefore produce the commodity. This chapter presents the data about commodity producers and derivative users and establishes the fact that commodity producers hedge in derivative markets.

Our financial data, historical production and data on commodity open interest are collected from Capital IQ, Bloomberg, individual company SEC filings including 10K's and 10Q's, and Commitment of Traders reports (CoT) from derivative exchanges including LME, NYMEX, CME, ICE and more broadly, the Commodity Futures Trading Commission (CFTC) legacy reports. Our company selection process was based on their listing jurisdiction, sorted by industry classification, and data availability. As a result, we analyse a universe of 43 US oil and gas companies (primarily shale), and 18 companies in the metals industry from either the United States, Canada or Australia. Exceptions lie with Rio Tinto PLC and Grupo Mexico SAB de CV who have a large amount of their assets in the jurisdictions of interest. It is important to note that most of the companies have business lines beyond the headline industry classification (only three of the companies in the sample are pure plays in oil production and exploration). This business line diversification may reduce the impact of revenue volatility and/or hedging in any single commodity on total corporate performance and cost of borrowing.

Data: the derivative market is used by producers to hedge

Producers report hedge positions in their corporate filings. They can hedge either through a direct position on an exchange or through a bilateral trade facing a market maker (primarily banks). Banks, on the other hand, not only provide liquidity to producers and consumers but also run commodity index positions, providing exposure to index investors and hedging in the market. Therefore, it is important to disaggregate banks' positions facing the exchange index-related and non-index-related trades. As they are not publicly disclosed, we estimate the banks' index-related positions in individual commodities.

Our methodology of calculating the total positions of producers within the overall derivative market leverages the publicly available reports by the CFTC and a calculation for the outstanding index positions. For each commodity, we calculate (1) the net long or short exchange position by producers and consumers; and (2) the outstanding positions per single commodity associated with the commodity index universe. These two combined positions produce the best estimate of the share of the overall derivatives market attributed to activities by producers.

Step 1: Calculating the net position in each trade category

We use Commitment of Traders Reports (CoT) from the Commodity Futures Trading Commission (CFTC) to collect weekly data on the breakdown of open interest by trader category. The disaggregated reports list four trader categories:

(1) Producer/Merchant/Processor/User
(2) Swap Dealers
(3) Managed Money
(4) Other Reportable and are based on the predominant business purpose self-reported by the traders.

In the case of industrial metals, we use the Commitment of Traders Reports from the London Metals Exchange (LME). The LME classifications follow a different naming convention. The classifications are as follows:

(1) Investment Firms or Credit Institutions
(2) Investment Funds
(3) Other Financial Institutions
(4) Commercial Undertakings.

While different, these categories broadly cover the same groups of traders. These reports reflect direct positions held via exchanges by market makers and non-financial firms in relevant commodities.

The CFTC and LME commitment of trader's reports provide the long and short positions within each of their corresponding trader categories. For this analysis, we are interested in the net positions (long minus short) of 'producer/processor/merchant/user' and 'swap dealers' in the CFTC, and 'investment firms or credit institutions' and 'commercial undertakings' in the LME data.

Step 2: Calculating the outstanding index positions

Bloomberg's BCOM and the S&P GSCI have historically been the most popular vehicles for getting exposure to a diversified commodity basket estimated to attract a total index tracking length of $194 billion as of mid-2023, split with a 2:1 ratio between BCOM and the S&P GSCI respectively. BCOM provides a broad-based exposure to commodities with no sector dominating the index. Publicly available data on the index reveals that the index is composed of energy, grains, industrial metals, precious metals, softs, and livestock (Bloomberg, 2023). Bloomberg also releases information on the weights of each commodity within the index. Similarly, the S&P GSCI is composed of commodities in five sectors: energy, industrial metals, precious metals, agricultural, and livestock, and the weights are publicly announced on an annual basis (S&P GSCI, 2023). For the purposes of this report, we ignore any sector-specific or other alternative commodity indices and assume that assets tracking BCOM and the S&P GSCI indices are representative of the entire index population.

The tracking length of each index and the corresponding weights of each commodity within the index can be used to calculate the magnitude of index positions within the total open interest disclosed by the CFTC. By finding the dollar value of each commodity within the broader index and dividing it by the respective contract value, we can determine the number of index positions in the open interest. The formula used is shown in the Equation below:

$$IndexPosition_{j,i,t} = \frac{AUM_{j,t} * Weight_{j,i,t}}{ContractValue_{j,i,t}}$$

Where *j* represents the index, *i* corresponds to the commodity, and *t* is the date of observation.

Calculating the producers' net positions

To derive the exact positions of the producers in commodity derivatives, we need to take their positions on the exchange, and those where they face banks. Banks naturally hedge and their positions facing the exchange would be the reflection of such position after the index exposure can be stripped out. Scaled by total open interest we can compare the producers' activity in the derivatives market across different commodities.

$$\frac{NetProducersAndMerchants_{i,t} + NetSwapDealers_{i,t} - Index_{i,t}}{OpenInterest_{i,t}}$$

The results are presented in Table 1 as market snapshots on various dates as well as the average over the available time period. Consistently, on a net basis, corporates put more short positions than long (to hedge naturally long exposure from commodity production), and up to 50% of the derivatives market is servicing producer's needs. One notable exception in the data analysed is coffee contracts. Although on a long-term basis, there's still more producers' hedging activity, in the most recent observation there was significantly lower hedging activity.

Summary	11Jul23	2May23	6Dec22	Average	Observations
Energy -					
WTI (CFTC)	-31.39%	-29.61%	-38.18%	-34.47%	75
Natural Gas (ICE)	-12.74%	-10.06%	-13.63%	-19.29%	542
Base Metals -					
Copper (CFTC)	-15.22%	-7.82%	-19.67%	-31.82%	706
Aluminium (LME)	-17.57%	-29.53%	-25.56%	-25.79%	4
Nickel (LME)	-23.56%	-26.99%	-29.46%	-25.29%	4
Precious Metals -					
Gold (CFTC)	-30.95%	-43.96%	-39.20%	-38.72%	706
Agriculture -					
Sugar (CFTC)	-19.36%	-37.20%	-40.54%	-34.79%	706
Coffee (CFTC)	3.17%	-34.01%	-7.50%	-24.89%	706

Table 1 Producers' net position, various commodities

Notes:

A. *The **most recent** date refers to 11-July-2023. This is the last reported date with a reported index position at the time of the analysis. The **average** range refers to the period ending on 11-July-2023 and different beginning dates based on data availability: Copper, Gold, Sugar and Coffee begin on the 05-January-2010; Aluminium and Nickel start on the 7-December-2021; WTI on the 8-February-2022; and Natural Gas on the 12-March-2013.*
B. *Aluminium and Nickel have a smaller sample size due to the relative limitation in data availability. While ICE and the CFTC provide legacy reports disclosing all historical open interest position, LME does not have an historical compilation of the open interest.*

Corporate reporting

Corporations often report their hedges in a corporate filing with regulators or annual statements for investors. Investor reporting varies in detail, but the filings with regulators are standardised. We look in detail at the oil & gas sector.

To understand the environment of the oil and gas sectors, we analysed the public reports of the companies within our sample. The main sources of information were 10K filings, Bloomberg, Capital IQ, and JPM reports on the quarterly hedging activity in the O&G sector.

OIL Hedges as a % of production volume
average over period 4Q2013 – 4Q2022

Company size	0-12mo	12-24mo	24-36mo
LARGE	41%	14%	1%
MEDIUM	59%	28%	4%
SMALL	64%	29%	6%

GAS Hedges as a % of production volume
average over period 4Q2013 – 4Q2022

Company size	0-12mo	12-24mo	24-36mo
LARGE	37%	15%	2%
MEDIUM	50%	27%	9%
SMALL	51%	23%	6%

Data Source: J.P. Morgan

The company size is determined by the consolidated production volume (of oil, natural gas, and natural gas liquids), to split the sample based on size (in barrels of oil-equivalent per day).

- LARGE for production above 500,000 BOE/day
- MEDIUM for production between 500,000 – 200,000 BOE/day
- SMALL for production below 200,000 BOE/day.

The hedges are consolidated across companies of each size. The list and number of companies within each group may change from one quarter to another, but this approach would most accurately reflect the behaviour of various-sized companies.

The data shows that companies typically hedge up to 3 years, with a majority of the hedges concentrated in the following 12 months. Smaller companies tend to hedge the most, securing stable revenues for nearly 2/3rd of their oil production in the next year, but only 6% of the production three years forward. At the same time, the largest companies hedge around 40% of their production in year one, with the hedges dropping to nearly zero by year three. The numbers follow the same pattern but are slightly lower for the production of natural gas.

We also analyse other financial metrics among the sample companies. We find that Small companies tend to borrow for shorter amounts of time at a higher price than Large companies (Table 2).

Table 2 Consolidated Financial Data by production volume for sample oil & gas companies

	Company Statistics, average value by company size		
	Large	**Medium**	**Small**
	>500,000	200,000-500,000	<200,000
Production (barrels/day)	896,829	336,751	96,630
% Oil	*34.19%*	*38.44%*	*58.45%*
% Gas	*52.35%*	*49.15%*	*28.52%*
% Other	*13.46%*	*12.41%*	*13.03%*
Proven Reserves:			
Oil Reserves (MMbls)	1,823	649	215
Gas reserves (bcf)	11,329	5,511	861
NGL Reserves (MMbls)	504	252	57
Duration	5.01	4.75	2.71
Debt/Equity	49.4%	60.2%	46.9%
Average Bond Yield (bps)	649	657	824
Property, Plant & Equipment: ($m)			
Gross	*71,024,390*	*26,802,178*	*6,817,529*
Net	*30,952,109*	*15,412,327*	*3,850,994*
Total Assets ($m)	45,115,776	20,872,923	4,498,917

Note: cost of debt is calculated using various metrics due to the data limitations. The first metric is 5-year and 10-year credit default swap spreads. In many cases these are unavailable, therefore, all outstanding debt contracts are mapped against their duration and the respective spread-to-worst. The average is taken for the sample for durations between 1.5 and 4.5. The group average is added to the U.S. bond rate taken from the term structure to derive a Cost of Debt used in the cost of capital model.

The analysed company sample does not include the oil & gas majors, which have larger balance sheets and openly offer their investors exposure to oil pricing, and thus do not tend to hedge extensively. But for smaller companies, hedging may play a crucial role. Overall, the smaller the company, the more difficult it is to raise financing, and the more critical it is to hedge and guarantee stable revenues. The role of hedging has been reported widely in the news as well on the back of large commodity price movements, e.g. Reuters reporting the expected rise in production on the back of increased hedging in 2018 (Ngai, 2017), or Rystad reporting the hedging losses when the companies could not capitalise on the high oil prices in 2022 (Lukash and Busby, 2022).

None of the companies appear to hedge all of their production, which would deprive equity holders of the possibility of extra high returns driven by commodity prices spikes. Also, the hedges are not always as straightforward as futures or forwards and may include complex options strategies. However, all options would be hedged by sellers in the futures market, and therefore one way or another reflected in the above figures.

Although not all producers use derivative markets to manage their exposure to commodity price volatility, those that rely on borrowing from the debt markets especially are enabled to continue their operations by access to this market. The lenders, usually, care more about limiting the downside and having a stable stream of revenues, while there is no upside from the windfall profits to them. Therefore, derivatives are even more important to the producers that use them. The derivative market does not enable all emissions associated with global commodity production, but it does the production by hedging firms.

Case for lower cost of capital

The reason why derivative hedges matter for carbon accounting is that they have a material and measurable impact on the cost of capital for the producers. Due to the high volatility of commodity prices, the provision of debt, as well as the cost, depends greatly on the ability to demonstrate stable revenues. In this section, we build a model for the cost of commodity price volatility. We adopt a discounted cash flow (DCF) model with simulated oil price paths for different hedge ratios, starting prices and production adjustment responses, based on the framework used by Ostrovnaya et al 2020. We quantitatively estimate it on the example of a pure-play oil company.

DCF is widely used in financial modelling. It has also been used in academic literature to model the cash flow of an oil company, e.g. the valuation of Exxon under various climate mitigation scenarios (Riedl, 2021). It is important to note that there are many factors, other than hedging strategy, that would influence the cost of borrowing of various firms (Shil, 2019; Wald, 1999), including capital structure, specifically leverage, macroeconomic environment and business cycle, and firm-specific factors, e.g. specific fields and land rights, as well as the track record of successful exploration and safety records. It is nearly impossible to control for all these factors and compare only hedging strategies on a small sample. However, modelling a typical firm and allowing for a change in one parameter only allows us to explore the impact of such a parameter on the cost of capital. To build such a model, we make a few assumptions.

Model of Commodity Prices

The major determinant of the financial risk faced by producers lies in the market prices of respective commodities. The results we get for the cost of capital impact heavily depend on our assumption on commodity price processes (trend and volatility). For each commodity, we model the daily prices with an autoregressive process of order 1 (AR1) in which the current value is based on the immediately preceding value (Deaton and Laroque, 1996; Michaelides and Zhang, 2022), as shown in the equation below.

$$p_{t+1} = k \cdot (1 - \rho) + p_t \cdot \rho + \varepsilon_{t+1}, \varepsilon_{t+1} \sim N(0, \sigma_\varepsilon^2) \quad (4)$$

where p_t is the natural logarithm of a commodity price at time t, k and ρ are calibrated coefficients, and ε_{t+1} is an error term. σ_ε^2 is the variance of the error term and is the key term that defines the volatility of future commodity prices.

We calibrate this model (determine coefficient and distribution parameters of the error) to the daily WTI oil prices over the period from January 2013 to May 2023 and generate 10,000 simulations of the daily future commodity price paths. The resulting paths reflect the historical data: the price mean reverts to the long-term average ($66) and mimics the historic volatility. But since the actual path and the associated risk would depend on the starting price, we, therefore, run three scenarios with different “today’s” prices (anchor price): (1) we use the historic mean of $66/bbl, (2) low scenario with anchor price is set at the average shale oil cost of $58/bbl (Dallas Fed, 2023), and (3) high scenario with anchor of $85/bbl to reflect the high price environment at the time of analysis.

We assume all hedges are done on a monthly basis. For each simulated daily price path we produce average monthly prices. To avoid the technical specificities of the market (storage/convenience yields), and, most importantly, to ensure that hedges are priced on market, we define the monthly futures levels as corresponding monthly commodity prices averaged across 10,000 simulations (Figure 1).

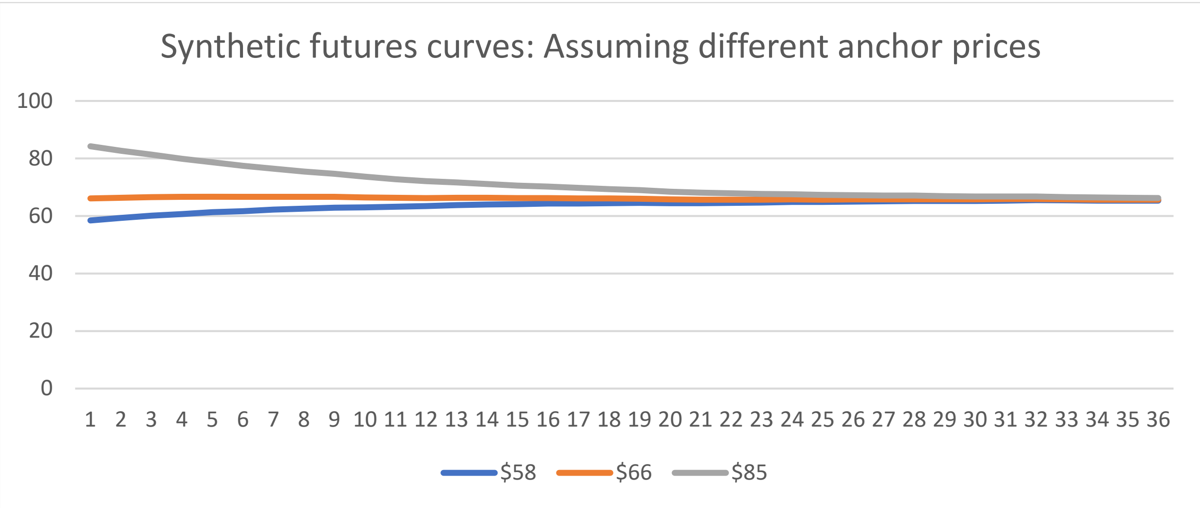


Figure 1 Synthetic simulated oil future curves

Model of Cost of Capital

We set up a three-year DCF model for an average oil producer in this sector which allows us to isolate one variable – the hedging of production, to quantify its impact. The key factors that affect the results are costs, revenues and discount factors. There are however some additional assumptions we make to ensure the model's likeness and functionality.

1. We calculate the total capital amount required upfront (CAPEX) to produce $ProdVol_t$ volume of oil per month for the following three years. To achieve that, we use risk-free discounting (at the prevailing US Treasury rates) of the CAPEX-equivalent share of the total cost per barrel (TC_t) (i.e. net of monthly OPEX).

$$CAPEX = \sum_{t=1}^{T} DF_t^{rf} \ ProdVol_t \ (TC_t - OPEX_t)$$

where DF_t^{rf} is the risk-free discount factor in month t, $ProdVol_t$ is the production volume (in barrels of oil) in month t, TC_t is the total monthly production cost in month t, $OPEX_t$ is the operating cost in month t (per bbl).

2. We solve for the breakeven IRR under the assumption of 100% hedged revenues over the given time frame as well as under fully unhedged and 50% hedged scenarios.

$$CAPEX = \sum_{t=1}^{T} \frac{ProdVol_t \ (P_t^n - OPEX_t)}{(1 + IRR^n)^t}$$

where P_t^n is the average realised price of the commodity in month t for a simulation n. In the case of a fully hedged scenario, P_t^n would be the futures price for the corresponding month, F_t, and independent of any given price simulation.

The fully hedged return IRR^H is our base-case IRR, i.e. the return that the investors are expected to receive if they take no market risk.

3. After exposing the said producer to the market risk, the revenues and thus the profits and the rate of return are uncertain, and we calculate and examine the distribution of the differences between the unhedged (or partially hedged) and fully hedged IRR.

$$\Delta^n = IRR^n - IRR^H$$

This is the extra return (or loss) that the producers experience if they do not hedge their production.

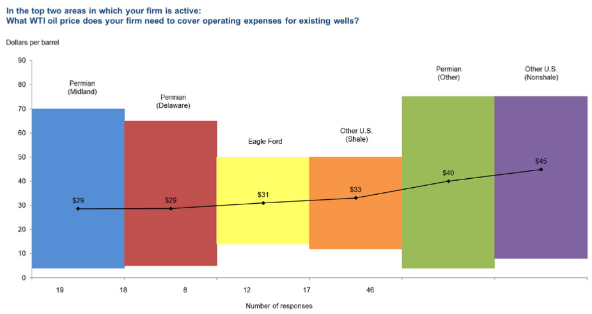
Model assumptions:

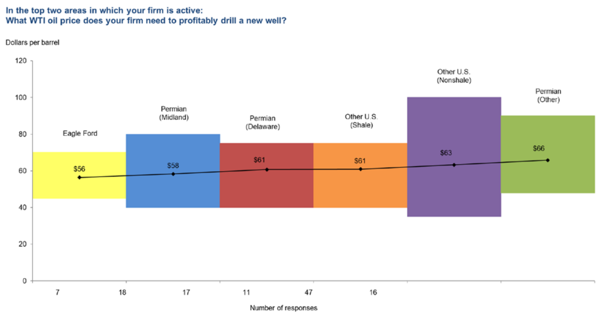
- Time horizon: T = 36 months

Most firms operate and plan far beyond a three-year period, however, our observations show that companies *hedge* up to 3 years ahead, therefore, beyond this point all firms would face and manage the same market risk. This assumption means that we do not model the full company's worth, but only the value of the next 3 years of their cashflows. We therefore compute "total capital" as defined in step 1 to be able to compare the capital to the expected return.

- The total cost of oil extraction *TC* is $58/bbl, of which operating cost *OPEX* is $29/bbl. We assume a 2% annual inflation rate.

These two figures are as reported by the Federal Reserve Bank of Dallas in the Energy Slideshow. They are the midpoint answers by producers in Permian (Midland) fields to the questions "What WTI oil price does your firm need to profitably drill a new well?" and "What WTI oil price does your firm need to cover operating expenses for existing wells?" (Dallas Fed,2023).



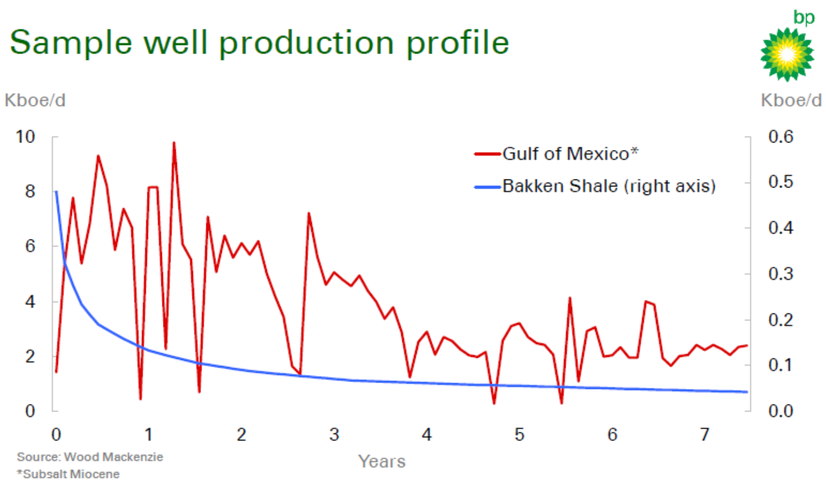


- Recognising the limitation of constant production volume, we introduce two further model specifications. It is underlined by the understanding that if firms experience losses in a low-commodity-price environment and have the flexibility to reduce or stop production, they would do so.

VolAdj0. Constant production: we assume the production is inelastic, and the firms maintain a constant level of production over the 3-year examination period (reference case)

VolAdj1. OPEX-based production adjustment: assuming the firms have paid the full capital cost, they will produce in month *t* as long as the observed price in month *t-1* is above the operating expenditures at *t*, or zero otherwise. We assume technical flexibility and zero cost of turning production on and off on a monthly basis.

VolAdj2. Total-cost-based production adjustment: This scenario is most reflective of the shale oil industry and its specificities. It is well established that the shale industry (hydraulic fracturing and horizontal drilling) plays a role as a marginal producer, and daily production from individual shale wells declines by around 75% in its first year of production, necessitating continuous drilling (and therefore capital expenditure) by the oil producers in this sector.



For the model, we assume the following production volume adjustment mechanism:

- Everybody produces full volume ($ProdVol^{Max}$) in the first month.

From month 2 to 36,

- if $P_{t-1}^{n} \geq TC_{t-1}$, the firm keeps producing in month *t* at exactly the same level $ProdVol^{Max}$;

- if $P_{t-1}^{n} < TC_{t-1}$, but $P_{t-1}^{n} \geq OPEX_{t-1}$, in the next month, the firm stops drilling new wells (i.e. investing new capital) but keeps producing from already operational assets, although the volume diminishes at a 75% annualised rate. If that occurs, then by month 13, the production volume would drop from an initial 4m bbl/month to 1m bbl/month;

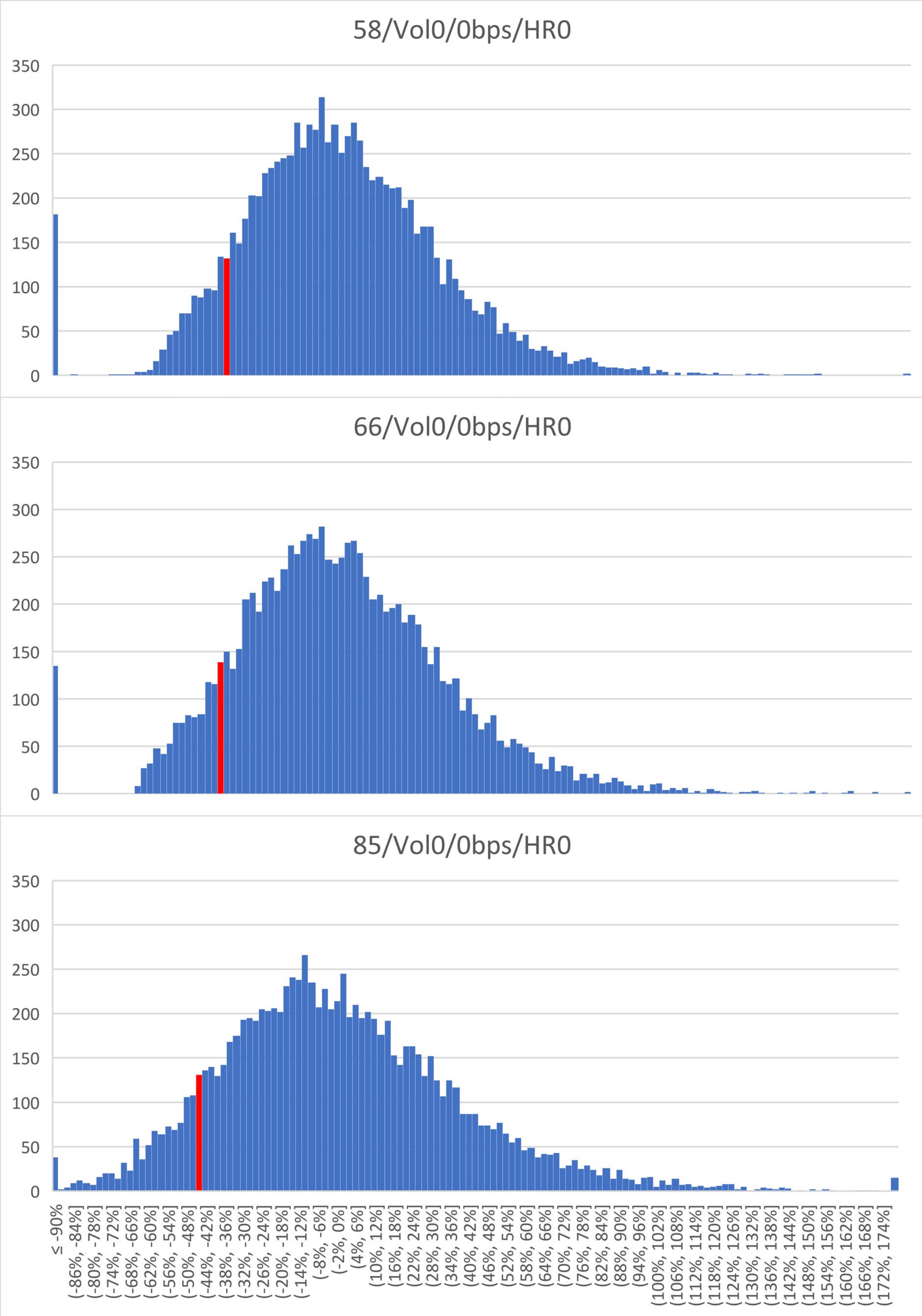
- if $P_{t-1}^{n} < OPEX_{t-1}$, the following month the firm stops all operations and does not produce;

- if, after a full stop in operations, in any subsequent month the price goes above the operating costs, the firm can resume extraction activities based on the last produced amount;

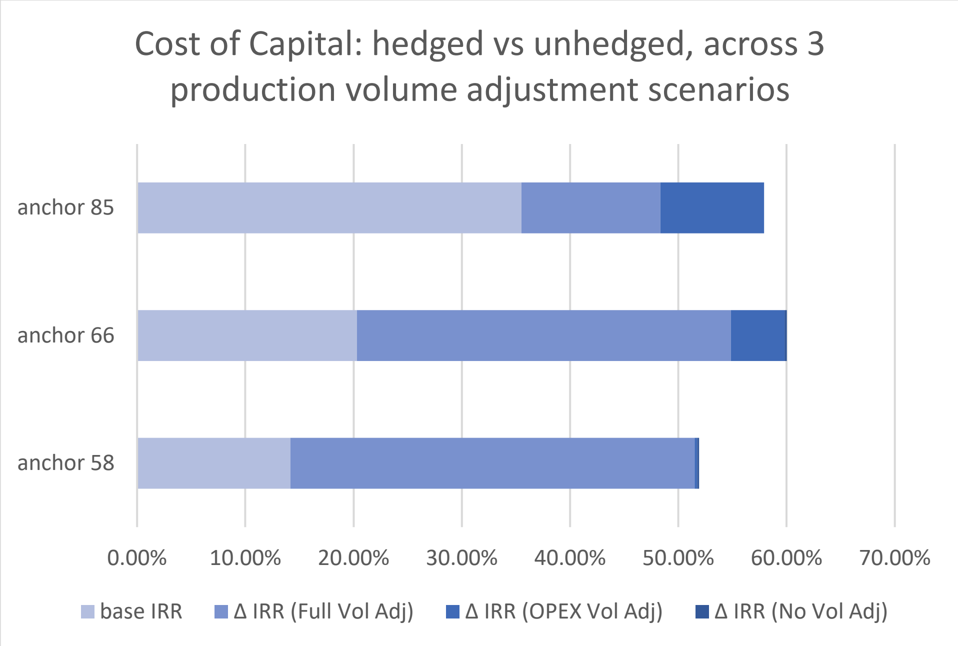
- if at any point the price goes above the total cost, the firm will resume drilling activity the following month, adding a maximum volume of $ProdVol^{Max}\ (1 - \sqrt[12]{0.25})$) per month, up to a maximum of $ProdVol^{Max}$. This is the amount of the first production decline from the maximum volume when the company stops drilling new wells;

- we assume no acquisition activities and no expansion of production beyond $ProdVol^{Max}$.

We have run 210,000 simulations across 21 scenarios, the results of which are presented below. Each simulation is a possible future path of oil price, and thus the profit or loss from a typical firm's operations in addition to what such a firm would yield if it fully hedged its production. The distribution of such outcomes across 10,000 simulations provides an understanding of the uncertainty faced by funders of such projects. There's about a 50/50 chance of losing versus winning; however, there's a wide spread between the outcomes.


58/Vol0/0bps/HR0
350
300
250
200
150
100
50
0
66/Vol0/0bps/HR0
350
300
250
200
150
100
50
0
85/Vol0/0bps/HR0
350
300
250
200
150
100
50
0
≤ -90%
(-86%, -84%]
(-80%, -78%]
(-74%, -72%]
(-68%, -66%]
(-62%, -60%]
(-56%, -54%]
(-50%, -48%]
(-44%, -42%]
(-38%, -36%]
(-32%, -30%]
(-26%, -24%]
(-20%, -18%]
(-14%, -12%]
(-8%, -6%]
(-2%, 0%]
(4%, 6%]
(10%, 12%]
(16%, 18%]
(22%, 24%]
(28%, 30%]
(34%, 36%]
(40%, 42%]
(46%, 48%]
(52%, 54%]
(58%, 60%]
(64%, 66%]
(70%, 72%]
(76%, 78%]
(82%, 84%]
(88%, 90%]
(94%, 96%]
(100%, 102%]
(106%, 108%]
(112%, 114%]
(118%, 120%]
(124%, 126%]
(130%, 132%]
(136%, 138%]
(142%, 144%]
(148%, 150%]
(154%, 156%]
(160%, 162%]
(166%, 168%]
(172%, 174%]

Facing such uncertainty, investors are likely to require additional returns. The typical expectation is that investors demand return to ensure they are in the money with 90% probability. Due to the way we define Δ, we are seeking to eliminate the worst 10% of the losses, or P10 of the Δ distribution. To recover the investment in 90% of the cases the risk premium for underwriting unhedged commodity price risk would be equal to -P10 of the Δ distribution, in excess to the reference IRR (fully hedged scenario).



To put it in numbers, in the medium starting price scenario ($66), if a firm fully hedged its production in the futures market, the rate of return it would achieve from its operations would be 20.32%. But if this firm decided to take full market risk, and not hedge any output at all, assuming an inelastic production function, the lender would ask for a 39.70% additional return to protect from the worst scenario.

In the data, we see that firms that hedge only do so partially, in order to achieve a targeted balance between some guaranteed revenues to demonstrate to the lenders, and some potential upside for the equity holders. If a firm is only to hedge 50% of its output, and face the market risk for the other 50%, the additional premium would be approximately half of the fully unhedged scenario at 18.97% (partial hedging eliminates the far ends of the distribution).

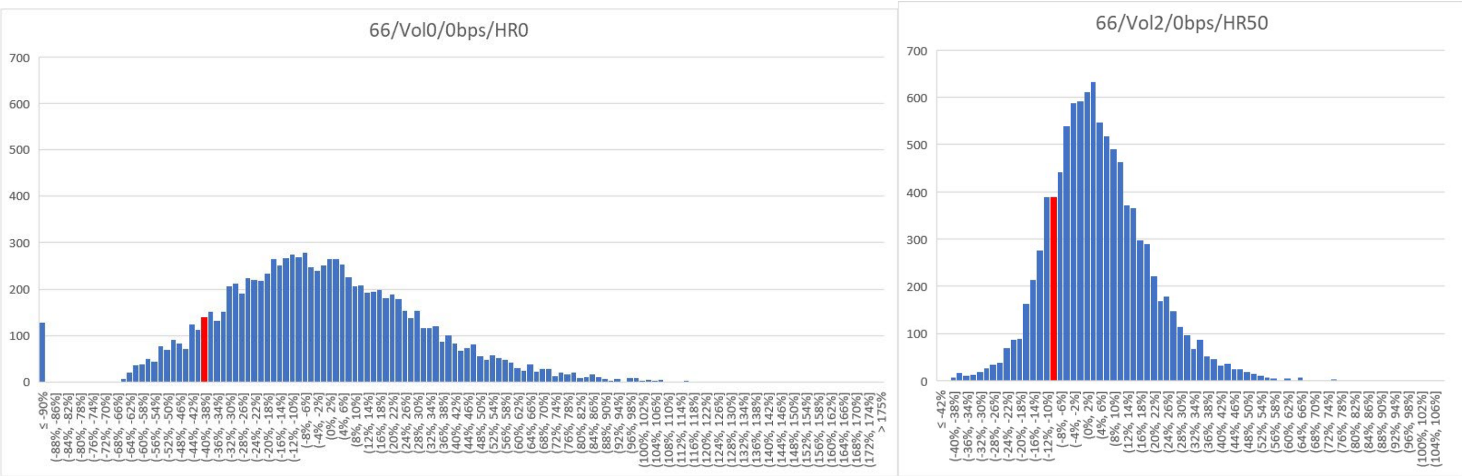


Figure 2 Delta distribution, price anchor $66

In the case of a high anchor price, a fully hedged company would deliver more than double the return of the same company in a low price environment. The premium for underwriting the market risk is higher, justified by the fact that there is much more return to lose. The risk in all cases can be mitigated by adjusting the production output in reaction to the price environment. OPEX-based adjustment does not deliver tangible savings, but if the firms can be flexible about capital investment into drilling, it reduces the tails of the distribution, especially the loss end, and can reduce the unhedged premium by up to 15%.

Scenario short name	Credit Spread	Anchor Price	Hedge Ratio	Vol Adj	Hedged IRR	-P10
58/0bps/HR0/Vol0	0	58	0	0	14.17%	37.75%
66/0bps/HR0/Vol0	0	66	0	0	20.32%	39.70%
85/0bps/HR0/Vol0	0	85	0	0	35.49%	44.72%
58/0bps/HR0/Vol1	0	58	0	1	14.17%	37.58%
66/0bps/HR0/Vol1	0	66	0	1	20.32%	39.50%
85/0bps/HR0/Vol1	0	85	0	1	35.49%	44.66%
58/0bps/HR0/Vol3	0	58	0	2	14.17%	37.33%
66/0bps/HR0/Vol3	0	66	0	2	20.32%	34.52%
85/0bps/HR0/Vol3	0	85	0	2	35.49%	30.20%
58/0bps/HR50/Vol0	0	58	50	0	14.17%	17.95%
66/0bps/HR50/Vol0	0	66	50	0	20.32%	18.97%
85/0bps/HR50/Vol0	0	85	50	0	35.49%	21.75%
58/0bps/HR50/Vol1	0	58	50	1	14.17%	18.98%
66/0bps/HR50/Vol1	0	66	50	1	20.32%	19.84%
85/0bps/HR50/Vol1	0	85	50	1	35.49%	22.43%
58/0bps/HR50/Vol3	0	58	50	2	14.17%	17.35%
66/0bps/HR50/Vol3	0	66	50	2	20.32%	12.51%
85/0bps/HR50/Vol3	0	85	50	2	35.49%	7.26%
66/900bps/HR0/Vol0	900	66	0	0	31.73%	44.17%
66/900bps/HR0/Vol1	900	66	0	1	31.73%	44.14%
66/900bps/HR0/Vol3	900	66	0	3	31.73%	38.70%

When calculating the total capital (CAPEX) required to enable production, we discounted the capital costs at the prevailing US Treasury rates. We stress-test this assumption by replicating the results using a credit spread of 900 basis points in addition to risk-free. The result is that the total capital figure (discounted at a higher rate) is smaller, and therefore the hedged return is higher, while the unhedged distribution is wider, requiring an even higher premium for undertaking market risk.

In all of the scenarios – across various anchor prices, production volume adjustment mechanisms, and hedge ratios – the results are significant. There is a substantial premium to be demanded by the funders for undertaking commodity price risk.

While we build this argument on an example of a pure-play oil company, the conclusion is not exclusive to oil. Various scenarios showcase how different price environments and production flexibility impact the outcomes for any commodity producer. What we find is that the impact is material across all scenarios, prohibitively raising the cost of borrowing funds and thus putting production ability at risk.

Carbon accounting discussion

We presented evidence that commodity derivatives positions should be subject to carbon accounting due to their role in facilitating commodity production. However, designing a precise blueprint for calculating carbon emissions behind any particular commodity derivative contract is beyond the scope of this paper. There are however many similarities and differences with other GHG accounting frameworks that we would like to bring to the readers' attention.

While the methodologies for calculating the environmental impact of various commodities are being developed e.g. S&P Global Sustainable1 Commodity Environment Data Set, it is challenging to define how much of associated emissions can be attributed to any position or trade. First, any commodity derivative contract has a maturity date and therefore refers to an amount of commodity to be produced/delivered or referenced (if cash settled) at that point in time, not a continuum of operation of a corporation. So the derivative contracts with different maturities may be supporting the production of different batches of a commodity. Further questions arise on the implications of calculating the percentage of "underlying asset value" for the purposes of carbon accounting. Second, there are different derivatives, which go far beyond vanilla forwards, futures, options and swaps. We need a robust approach to avoid any carbon arbitrage or misrepresentation.

When it comes to commodities, the interplay between the tenor of a contract, the holding period and the treatment of long and short positions comes into focus, but it is not exclusive to derivatives. There are shortcomings in the current carbon accounting standards for other asset classes as well, e.g. in our equity example above, the financial firm held the stock for 364 days of the fiscal year but sold it off a day before the end of such fiscal year, the associated emissions would be zero. In the case of derivatives, many will mature before the end of the fiscal year. Should carbon accounting be based on end-of-year reporting principles or on a compounding basis (emissions enabled and financed throughout the year)?

Long vs Short position treatment deserves its own chapter. In short, in finance, the netting of long and short positions is widely used for the purposes of risk calculations. Should the same principle be applied to carbon accounting, unintended consequences may arise, such as net negative financed emissions, which do not reduce the emissions in the real economy.

We need more analysis on how each of these factors would impact financial institutions and what would be the best way to calculate the emissions for any derivative position.

And finally, the commodities' climate impact is not static. If mining and drilling activities can be decarbonised either through electrification, innovative technologies, or carbon removal, then not only emissions of the corporations involved in these activities but also the carbon footprint of commodities themselves can be updated accordingly. There needs to be more research and debate on what it would mean for scope 3 emissions (positive and negative externalities from the end use of commodities) and further methodologies developed.

It is important to note that zero emissions do not necessarily mean zero impact. Wider environmental issues (e.g. air, water and soil pollution, water stress) and social implications of commodity extraction and production should also be considered.

Conclusion

The commodities sector is facing an unprecedented transformation over the next 30 years as the world navigates the warming climate. If the energy transition is successful, there will be a fundamental shift from fossil-fuel-based energy domination. For example, the S&P GSCI determines the weight of commodity components in part based on the dollar value of global commodity production. This results in a 50-60% allocation to fossil-fuel-based energy commodities in 2022-23. To the extent Metals become increasingly required for renewable energy and low-carbon technologies, it is reasonable to believe the dollar value will increase relative to fossil-fuel-based commodities. Financial firms face the challenge of navigating their commodity portfolios within the sustainability strategy while supporting energy security, while commodity manufacturers face managing greenhouse gas emissions that result from extraction and use.

This paper builds a necessary foundation for carbon accounting for commodity derivatives. We apply the basis of risk transfer: commodity derivative traders and investors provide liquidity to producers, who by hedging their production have easier and cheaper access to capital.

The data show that producers cumulatively are net short in the derivative market, hedging their naturally long exposure. Many producers report it directly in their filings with regulators and investors, while some do not hedge at all (e.g. many oil "majors" or national oil companies). For many smaller firms, the impact of hedges on financials is material. The overall cost increase depends on many factors, including the volatility of the underlying commodity and diversification of production. But absent such hedges, debt financing could be unachievable, and the cost of funds would rise significantly, potentially making commodity production uneconomical.

The development of methodologies to calculate emissions facilitated by derivatives positions is critical to net zero strategy planning and risk management. Great care and analysis need to be applied in the development of a formulaic approach, to ensure a fair representation of financial positions as well as ensuring there are no loopholes to abuse the rules to underreport the true carbon exposure. Outstanding issues include the treatment of curve or outright short positions, the role of contract maturity and a potential for double, if not triple, counting of emissions (if emissions associated with any unit of a commodity are reported on scope 1, 3 and derivatives levels). However, with the growing role of commodities in climate transition, financial firms need tools to understand the carbon exposure of their commodities positions and the role those play in climate transition.

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