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Measuring organizational resilience: Tracing disruptive events facing unconventional oil and gas enterprise performance in the Americas

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ABSTRACT

Over the last few decades, organizations have to cope with high uncertainties and extreme events like the Covid-19 pandemic, demand collapse, or supply chain disruptions with different capabilities to handle them. This work provides empirical evidence to test organizational resilience to deal with turbulent environments by studying firms' performance in unconventional oil and gas development in North America and Latin America. The 2014–2015 and 2019–2020 hydrocarbon price collapse allow us to measure resilience potential based on the organizational recovery after suffering a disruptive event. Only in the US, oil and gas output increased 10 million barrels of equivalent oil per day, despite high costs, low returns, and growing funding needs. Companies had to innovate, adapt, and manage uncertainty to optimize production, reduce costs and risk exposure, and generate positive cash flows. The fragile disappeared, the robust and resilient survived, and the antifragile thrived. This paper aims to define customary indicators to measure organizations' resilience after an extreme event. It also provides a scale that offers an approach to rank organizations and contrasts the most distinctive managerial attributes for successful and failed companies to deal with uncertain environments.

1. Introduction

Today organizations have to deal with a series of emerging risks, extreme events like the Covid-19 pandemics, complexity involving supply chain disruptions, among others, and high uncertainties characterized by lack of information and ambiguity about emerging situations [1]. Digital interconnectivity offers the possibility of improving efficiency at the expense of reducing resilience. However, it increases the likelihood of having systemic risks, defined as those with the impact to break down the entire system. Complex Adaptive Systems (CAS) can incorporate organizational strategies like agility, flexibility, and options formulation to cope with systemic risks [2].

Emerging risks, Black Swans, complexity, ambiguity, and extreme events are impossible to model since they do no represent historical data. Thus, it impairs the ability to make predictions and make decisions based on their occurrence or the organization's strength to cope. For making decisions to handle such risks, people typically use the concept of the availability heuristic. They assess the likelihood of risks by asking how readily examples come to mind, despite their substantial limitations [3].

With the awareness that these risks are impossible to predict, there is an increased need to identify succeeding organizations in such environments. They should have implemented antifragile protective investment strategies like adaptation, agility, resilience, and uncertainty recognition. The management to maintain high-level performance, focusing on minimizing the effect of negative consequences and considering uncertainty as a key variable with possibilities of potential damage and growth opportunities simultaneously [4].

In recent years, after the publication of the book Antifragile, things that gain from disorder [3], the possibility to apply resilience strategies to risk management received more recognition. This new concept aims to withstand an extreme event without affecting the overall results, learn, adapt, and take advantage of the opportunities to improve performance and grow. The caveat is the lack of case studies involving real-life antifragile organizations. Nevertheless, the concept is so appealing that several researchers and practitioners analyzed it [6–8]. Scholars have demonstrated its application to engineering antifragile systems. Designing cognitive cyber-physical systems that can learn from their experience, adapt to unforeseen events they face, and grow more robust in the face of adversity [9]. It resembles the real options approach that arose 30 years ago, with lots of documented cases, several of them in the oil and gas (O&G) industry [10]. The challenge is to demonstrate that

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antifragility can be measured and applied successfully to organizations [11,12].

After recent theoretical works, a research gap is to have a heuristic test to measure organizational resilience and time to recovery after a disruptive event, incorporating the antifragility concept [13,14,15]. This work contributes to resilience knowledge by addressing the following research questions:

1. How to measure organizational resilience after a disruptive event?
2. Which are the main strategies antifragile firms adopt to cope with high uncertainty, ambiguity, and extreme events?

We test the hypothesis to utilize selected customary financial and operational metrics to measure organizational resilience after a disruptive event. For this purpose, the authors analyze the performance of 77 companies in the US (50), Canada (24), and Latin America (3), 56 mergers and acquisitions, and 26 firms that went bankrupt during 2015–2020, which belong to the UOG sector.[1] We evaluate a series of financial and operational performance-risk indicators and select the most appropriate to classify the companies according to their resilience level of evolution. Additionally, we assess the operational resilience performance of 24 organizations in Argentina (18), Colombia (5), and Chile (1), executing UOG exploration and development.

The comparison between antifragile and fragile organizations helps understand success drivers and the key aspects to avoid failure. Companies need to identify the critical attributes required to deal with systemic risks, which are increasingly common nowadays. Our analysis suggests that firms with the ability to develop resilience attributes to cope with high uncertainty are more prepared to evolve and successfully manage it.

2. Literature review

This paper offers an empirical test for three (3) theoretical works: the Maturity Model for Organizational Resilience (MMOR), the antifragility concept applied to organizations, and the framework to integrate risk management and performance. Appendix A includes the definitions discussed.

2.1. Organizational resilience

Several approaches exist for resilience conceptualization. For this study, we focus on resilience at the organizational level. We adopt the organizational resilience definition as the measurable combination of characteristics, abilities, capacities, or capabilities that allow an organization to withstand known and unknown disturbances and survive. There are three main lines of thinking for organizational resilience i) As a feature of an organization, ii) As an outcome of the organization's activities, iii) As a measure of the disturbances that an organization can tolerate [13]. The authors contemplate combining the last two since we evaluate organizational response to extreme events by observing a firm's performance before and after them.

Several authors consider resilience the ability to recover from disruption and return to the previous condition [16–18]. Others consider resilience a magnitude, depending on the quantity of disturbance to stand and survive [19,20]. Finally, another approach goes beyond and believes the organization can take advantage of the situation, survive, and emerge stronger and grown [21–23]. As a result, the organization reaches its goals and captures the opportunities to take advantage of the competitor's weaknesses [24,25].

Strategic resilience defines the organization as able to withstand extreme events and turn threats into opportunities [26]. Taleb [5] introduced the concept of antifragility, defined as a system's capability to face stressors, shocks, and volatility and thrive.

In an antifragile system, when extreme events occur, the impacts are only beneficial. The frequency distribution of outcomes places heavy weight on large positive values, with limited downside while having exposition to upside risk. In an enterprise context, those systems are rare and not studied in depth. The antifragility concept adds the idea of linking variation, uncertainties, and risk at the stress level to the positive and negative risks related to future behavior and an increase in performance [27].

There are three classes of antifragility based on the way a firm's performance behaves during an attack. We focus on Class III systems, where antifragile gain occurs at the beginning of the extreme event and persists after it ends. Thus, antifragile organizations can maintain the performance or adapt through a period of adverse conditions and achieve better performance after it finishes [28].

Other research has discussed how antifragility is also helpful for high complexity and uncertainty, without a Black Swan to trigger it. In megaprojects, a strong interaction of failure activities can lead to catastrophic outcomes and are not only a result of a single event. It is then possible to detect early warning signals and proactively handle those risks through learning and knowledge management [29].

2.2. Maturity model for organizational resilience

Resilience evolves within organizations according to their ability to adapt to cope with uncertainties and stressors. Taleb [3] defines the Triad to differentiate the three response levels to extreme events, Fragile, Robust, and Antifragile. He utilizes nature as the best example of a system that evolves in response to abrupt changes by destroying, replacing, and regenerating. He also describes organisms that get stronger through continuous external stressors, such as vaccines, exercise, or bones to an external load.

Other authors describe the differences between robustness and resilience. A Robust organization can withstand continuous stressors but fail to recover after an extreme event [30,31]. IBM, Blockbuster, Nokia, Xerox, and Kodak are examples of Robust companies that once were leaders of their sectors but could not survive technological innovations and customer preferences changes. On the other side, Amazon, Apple, and Netflix are examples of firms with the ability to innovate, adapt, and thrive due to uncertainty and abrupt changes.

The MMOR incorporates the developments from Taleb, stressing that resilience is not a static concept. Organisms and systems evolve with time from Fragile to Antifragile according to their abilities to withstand disturbances and extreme events. Taleb introduced the antifragility concept to organizational resilience evolution. According to its capabilities, organizational resilience can be at the next levels to deal with extreme events: Fragile, Robust, Resilient, and Antifragile [14]. Our work demonstrates that the opposite is also possible. Organizations may execute bad decisions in response to uncertainty and decline from Antifragile to Fragile.

2.3. Performance-risk indicators

Resilience measurement research based on the organizational recovery after an extreme event is limited. It is challenging to assess an organization's response to external shocks since it could seem appropriate in the short term, but it may be irrelevant or counter-effective in a long time. Henry et al. [32] and Erol et al. [33] suggest measuring resilience considering Recovery and Loss in terms of time or output. However, they do not state how to evaluate them.

Performance management involving uncertainty and risk appetite to

[1] The UOG sector represents a growing segment of the O&G industry. It comprises firms devoted to explore and develop unconventional oil and gas resources through the hydraulic fracturing technique, also known as fracking. UOG exploitation firms are Global Majors, Independents, and National Oil Companies (NOC). Along with this paper, we refer to O&G uncertainties as those generally occurring, which encompass the UOG sector.

contribute to strategy execution set the basis for enterprise risk management [34]. The measurement of resilience based on organizational outcomes such as Operating Income to Sales, Key Performance Index (KPIs), Accidents Injury Rate, and Return on Equity (ROE) constitute examples from the literature. However, they lack assessment and empirical evidence [14].

Research measuring organizational antifragility is limited. The dynamic system model of antifragility for CAS offers the ability to learn from experiences by forming new emergent structures previously unknown [35]. A framework to measure antifragility, including additional criteria, is presented by Kennon et al. [11]. Both studies present hypothetical survey results with no actual data and no further applications.

The effects of climate change and the investor's and public request to involve standardized Environmental, Social, and Governance (ESG) metrics offers an example of the need to integrate performance and risk management beyond safety. Limited research exists on this emerging challenge. Gunasekaran et al. [36] include sustainability as a primary attribute for resilience. The energy return on investment indicator, which allows the combination of the energy return ratio with the financial return ratio applied to UOG development in North America, is one of the few current proposals [37]. Unfortunately, with the Canadian exception, the O&G industry has been slow to adopt standardized ESG metrics and goals.

There are strong parallels between performance management and risk management; the former is useful for tracking performance goals, and the second is to maintain performance considering uncertainties. Enterprise Risk-Based Performance Management is an approach that facilitates maximizing value and competitive advantage to stakeholders, both in commercial and public sector organizations. Observable indicators, like injury frequency rates or the number of gas leakages or oil spills, are helpful to demonstrate risk reduction [38].

Applying performance-risk metrics is particularly useful in low knowledge situations that offer growth opportunities, giving weight to vulnerabilities, resilience, and antifragility. A Robust/Resilient/Antifragile behavior provides competitive advantages and superior outcomes for organizations exposed to opportunity or loss [39].

3. Methods

We follow a three-step approach to identify, rank, and evaluate the studied firms. First, we select the industry and period representing resilience and antifragility behavior; then, we define a sample with the most representative UOG companies in North America and Latin America. Finally, we test different customary financial and operational metrics to evaluate the firm's resilience behavior following the MMOR model to select the most appropriate to reflect resilience evolution through the sample.

3.1. *Unconventional oil and gas development*

The O&G industry routinely has to deal with high uncertainties, megaproject execution, political and exploratory risks. It faces additional challenges to obtaining the social license to operate, ESG goals setting and accomplishment, climate change, and energy diversification concerns. Additionally, firms are under constant pressure to reduce costs and generate positive returns and cash flows under distressing hydrocarbon prices. Managers and decision-makers possess engineering risk assessment capabilities but fail when dealing with the social factors associated with UOG [40].

To evaluate the organizational resilience level after an extreme event, we select the UOG sector during two extreme events that happened during 2014–2016 and 2019–2020. The first event is the O&G industry market crash after several years of high hydrocarbon prices, which reached over $100/bbl in 2014 and decreased to nearly $26/bbl in 2016. Previous years were characterized by firms' orientation to growth to seize the opportunity through acquisitions, megaprojects, and exploratory commitments, fueled by abundant capital resources flow from the markets. As a result, there was cost inflation and a steady reduction in return to investment. The second is the Covid-19 pandemic Black Swan, which reduced hydrocarbon demand affecting commodity prices and investor's confidence.

Additional to the price bumps, the UOG firms suffered from treatment, disposal, and transportation constraints. Moreover, a natural consequence of accelerated production growth is the lack of infrastructure to handle additional oil, natural gas, and water inflows. Consequently, production costs and price differentials increased, leaving companies with lower cash flows and rising concerns on methane emissions and earthquakes in some regions, and growing public protests because of the activity.

The situation worsens at the western Canada sedimentary basins due to permit delays to build new pipelines generated oil production bottlenecks. Companies had to limit growth in 2018–2019 and endure significant price discounts since authorities restricted production output. As a result, Apache (APA), Shell (RDS), Marathon (MRO), and Devon Energy (DVN) sold their assets and left the country. Encana rebranded itself in 2019 to become Ovintiv (OVV) and changed its domicile to the US, transforming it into a smaller fish in a bigger pond.

UOG firms' market capitalization was harmed severely during both extreme events. The S&P 500 composition's energy sector relevance by equity capitalization reduced from 26% during the energy crisis in the 1980s to 4% on December 31th, 2019. The US became the biggest oil producer globally, reaching energy security, but investors demanded capital discipline, free cash flow generation, and visible ESG commitment. Consequently, capital markets avoided initial public offerings, equity offerings, and debt issuances, the fuel that propelled growth during the golden years.

The race to increase reserves and production and adopt new operational methods evidenced weaknesses in the regulation and unpreparedness from several companies to observe Generally Accepted Good Engineering Practice [41]. As a result, they fall short of responding appropriately to ambiguity, high uncertainty, and complexity [42].

Given those challenges, UOG offers a remarkable example of industry and firms' resilience. The 2014–2016 oil price downturn forced companies to trigger innovations, efficiencies, and collaboration. They applied a trial and error approach to learning, collaboration, a shift towards a 'factory approach,' and, as a result, a significant increase in production output and cost reduction. Tight oil breakevens reduced by 45% from an average of $76/bbl in 2014 to a range of $37–47/bbl in 2019, thanks to structural efficiency gains from applying the hydraulic fracturing technique [43]. Fig. 1 shows the increase in production output and, at the same time, the rig reduction at the Bakken and Permian basins after the price collapse.

Production and development costs are a proxy for measuring innovation and technology adoption, but it is necessary to isolate factors like economies of scale and cost inflation. UOG exploitation costs increased during 2011–2014. However, after 2015 they reduced steadily with a learning curve of 3.989% for a sample of 30 US companies due to technology development and productivity gains [44]. Similarly, companies transfer UOG know-how and best practices to other countries. For example, unit capital costs were reduced in Argentina by 36% during 2011–2014 and in a range of 9–40% in China during 2013–2017 through joint ventures composed by US companies and NOCs or local firms [45].

Trial and error, project execution excellence, flexibility, collaboration to increase output, and simultaneously reducing costs after an extreme event, among others, constitute a relevant set of factors representing organizational resilience behavior. However, several firms exhibited an inadequate response to both price collapses. As a result, they filed for bankruptcy, were acquired, or required substantial capital inflows to survive. The Covid-19 pandemic offered an additional opportunity to evolve after changing the 'production growth' focus for 'returning cash' to increasingly disillusioned investors.

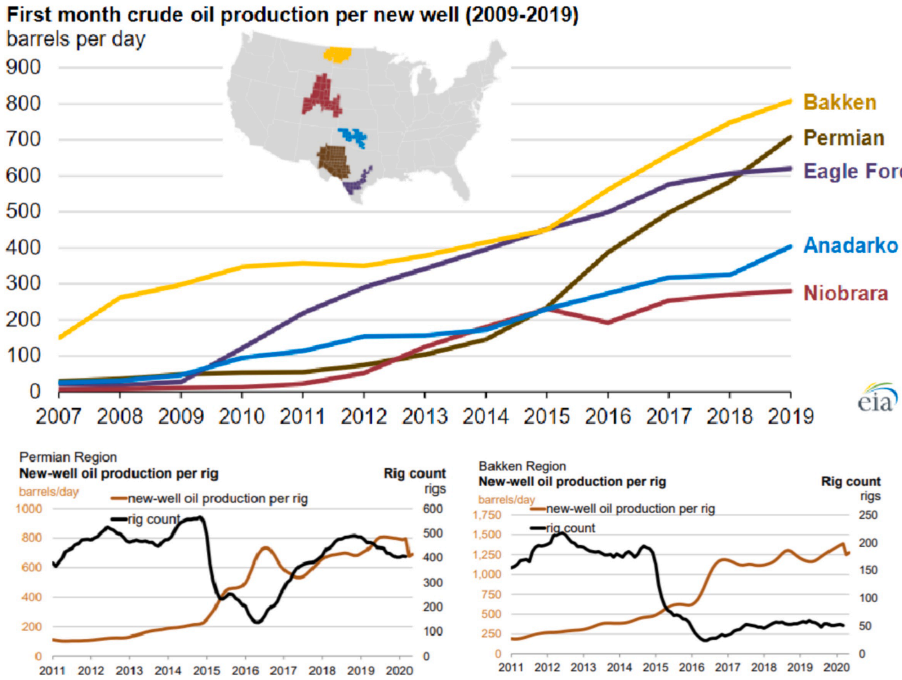

Fig. 1. Oil industry antifragility response to oil price downturn. Source: EIA, 2020.

3.2. Company selection

Global Majors, Independents, and NOCs exploit unconventional hydrocarbon resources worldwide in 60 countries, focusing mainly on organic shale, extra-heavy oil, and coalbed methane for wealth generation and energy security assurance. Most of the activity concentrates on North America, Latin America, Middle East, Asia, and Australia. The countries with the most significant unconventional oil and gas output are the United States, Canada, Argentina, Australia, China, and Oman [46].

The authors evaluate UOG public companies' information in the United States, Canada, Argentina, and Colombia to test this study's hypothesis. We collect and evaluate financial and operational data from 77 firms and their subsidiaries, focusing the study on those with market capitalization superior to $1 billion by December 31th, 2019. In addition, we include several representative independent companies with a lower market capitalization in Canada (12) and the US (12) to enrich the analysis. Table 2 and Appendix C show peer groups and the companies selected.

To evaluate Fragile companies, we review 215 bankruptcy filings in the US and 18 in Canada for 2015–2020, from *Haynes and Boone, Oil Patch Bankruptcy Monitor*. We select the 49 filings with total secured and unsecured debt higher than $1 billion, finding reliable financial information for 26 companies. Additionally, we analyze 56 of the most relevant UOG asset and firm transactions in North America during 2009–2020. The sources of financial and operational data are *Gurufocus*, *FracFocus*, and *Wood Mack* databases.

UOG activity in Latin America is focused mainly on Argentina and Chile, with some of Colombia's exploratory efforts. With few exceptions, companies execute projects through joint ventures between NOCs and Global Majors. ENAP-Sipetrol Chiles' NOC is performing development activities alone in legacy assets taking advantage of the Argentinean experience. Independents focus on North America, diversifying activities across several basins, the US and Canada. Since financial information is not available for branches, the analysis centers exclusively on their operational outcomes.

Table 1
Selected Resilience Indicators.

Resilience Indicators			
Category	Fragile	Robust -Resilient	Antifragile
Financial	Altman's Z score		
	Payout Ratio	EBITDA	Z-Score Recovery
	Debt/EBITDA	Gross Margin	EBITDA growth
Operational	Breakeven price		
	Production		Production growth
	Injury rate		
ESG	GHG Emissions		
	Energy use		
	Fresh water use		
	Land impact		
Value	Cash Flow Generation		
	Market Capitalization		
	ROIC / ROCE		
	TSR		

[1]EBITDA: Earnings Before Interest, Taxes, Depreciation, and Amortization.
[2]ROIC: Return on Invested Capital.
[3]ROCE: Return on Capital Employed.
[4]TSR: Total Shareholder Return.

3.3. Metric selection

Enterprise Risk-Based Performance Management emphasizes the utilization of traditional metrics to evaluate resilient behavior [38]. Appendix B summarizes the most accepted O&G industry indicators grouped in seven (7) categories. It is far from having an industry ESG metrics consensus. Hence, we include the utilized proposals to date.

There is a deep division among investors and operators regarding the proper metrics for enterprise value creation. On the corporate finance side, there are four (4) cornerstones for value i) generate cash flows at rates of return exceeding the cost of capital; ii) generate cash flows, not by rearranging investors' claims on those cash flows; iii) the stock market obeys to changes in the stock market's expectations, not just the company's actual performance, and iv) the value of a business depends on who is managing it and what strategy they pursue [47]. On the operational side, the value metrics focus on: i) oil and gas reserves growth, ii) oil and gas production growth, and iii) operational and

Table 2
Peer Group companies and main relevant financial attributes.

Peer Groups	Quantity (N=77)	Five-year CAGR[1] (%)					
		Market Capitalization	ROIC	Gross Margin	CFFF[2]/MC[3]	EBITDA	Z-Score
Canadian Integrated	4	4.1	6.6	11.9	10.6	−7.4	−15.9
Canadian Seniors (> $1bn MC)	8	−5.8	7.4	33.0	2.5	−4.5	−74.7
Canadian Juniors (<$1bn MC)	12	−10.3	6.4	34.4	6.8	−14.8	−98.9
Global Majors	7	3.5	2.5	11.7	27.2	5.4	−18.1
International Independents	5	−1.2	5.9	20.6	12.3	−2.3	−42.9
US Independents (>US 1B MC)	26	1.6	6.1	23.3	−5.%	9.2	−35.4
US Independents (<US 1B MV)	12	−10.5	8.9	30.6	−101.2	3.1	−138.1
Latin American NOCs	3	25.2	5.1	3.0	109.8	10.9	−5.8
p−value		0.004	0.005	0.003	0.001	0.006	
Correlation Coefficient		0.964	−0.714	−0.840	0.792	0.213	
Determination Coefficient		0.929	0.510	0.706	0.627	0.046	

[1] CAGR: Compound Average Growth Rate.
[2] CFFF: Cash Flow From Financing Activities.
[3] MC: Market Capitalization.

development cost.

In our view, the organizational resilience level for the firms should incorporate both approaches. However, since operational output depends on price and market fluctuations, financial data is more reliable in the medium term. Nevertheless, the selected indicators shall reflect firms' objectives to satisfy both investors' requirements and stakeholders' intense scrutiny. As a result, we incorporate four (4) metric categories: i) Financial; ii) Operational; iii) ESG; and iv) Value. Table 1 shows the selected indicators. We evaluate several metrics to identify the most suitable for resilience measurement under the MMOR and find the shadowed ones are more useful to rank and classify the resilience level.

The primary metric defined to measure resilience in this study is the multivariate discriminant Altman's Z-Score model. During the last five decades, the model demonstrates its power in predicting bankruptcy and financial distress, performing, and adapting well to the international context, compared to other hazard models [48]. Despite the data to develop the original model originated during 1946–1965 for manufacturing firms, the results are good enough to avoid using different coefficients developed over other industries. Unfortunately, there are few references for the application of Altman's Z-Score to energy firms. However, the case analysis of Suzlon Energy Ltd for the 2014–2018 period offers a close resemblance to the present study [49].

Altman's Z-Score utilization as a performance and strategic assessment indicator started in 2006. The metric proved its strength to yield insight into enterprise profitability and growth over more traditional ones [50]. However, the model application to measure resilience under extreme events has limited use. Nevertheless, a case demonstrates the correlation between the Z-Score and employees' creative involvement and its contribution to organizational resilience [51].

Following the antifragility definition, the resilience indicator may utilize an additional metric reflecting growth, such as EBITDA or oil and gas production increase. The first includes the price realizations and the ability to transport and commercialize hydrocarbons in better conditions due to strategic decisions through the value chain. The former is more straightforward, especially for projects and subsidiaries, where consolidated financial reports are unavailable.

An additional factor considered is cash flow generation. There was significant funding to the sector for UOG growth. Firms raised about $22 billion from equity and debt financing in 2018, less than half the total in 2016, and almost one-third of what they obtained in 2012. It was a fundamental reason for several companies in financial distress conditions to avoid filing for bankruptcy despite the low hydrocarbon prices. Only 27% of US Independent oil peer-group, including asset sales, hedging, and divestitures, had positive cash flows in 3Q 2018. Hence, an additional requirement for resilience is cumulative Cash Flow from Financing (CFFF) for the evaluated 2015–2019 period to be positive.

Investors and the public are requesting more actions to reduce gas flaring, water and land use, carbon benchmarking, climate risks, and ESG goals. As a result, it will be necessary to incorporate an ESG metric to involve the firm's sustainability commitment in the medium term. The most prevalent indicator is GHG Scope 1 and 2 emissions intensity. Appendix C exhibits GHG for Canadian companies adjusting 2018 corporate ESG reported values according to asset bases [52].

GHG emission may contribute to resilience and performance management in the medium term as more companies commit to reporting and independent organizations standardize measurements. Methane emissions are estimated to be 25 times more potent as a warming agent and critical for meeting Paris agreements. Canada committed to reducing methane emissions by 40% of 2012 levels by 2025. It started in 2019 the Fugitive Emission Management Program Effectiveness Assessment, becoming a clean-tech leader in methane and CO2 emissions reduction.

Similarly, the DuPont Bradley Curve could contribute to measuring safety resilience behavior. DuPont's firm classification as Reactive, Dependent, Independent, and Interdependent resembles the Fragile, Robust, Resilient, and Antifragile MMOR classification.

4. Empirical results and discussion

Strategies evolved in response to stakeholder needs. Growth versus cash flow generation is the primary requirement from the market to the companies. During 2009–2019 firms lured investors with leverage, stock acquisitions, and organic growth after aggressive land acquisition. Organizations focused on efficiencies and cost control after the price crisis from 2014 to 2015. When excess cash was available, companies distributed it to shareholders through share buybacks and dividends.

By contrast, after 2019, companies started to respond to investors' pressure to prioritize returns, debt reduction, and ESG goals. As a result, strategies focused on cash flow generation at the expense of growth. To achieve this industry need, firms utilized hedging, capital expenditure optimization, debt refinancing and payment, no leveraged acquisitions, dividend and production curtailment, and midstream project cancellation. Excess cash would distribute by variable dividends depending on the current oil price and financial results.

Given the differences in size, scope, geographic span, diversification, and product type for the companies within the defined peer groups in this study, it is not reasonable and statistically significant to individually contrast the 77 firms analyzed. Appendix C has the most relevant financial information for the UOG companies and peer groups considered. Instead, we compare the averages of some selected financial five-year median values. Table 2 summarizes the average results for the peer groups' p-values and coefficients. There is a strong correlation between Z-Score and market capitalization variation, suggesting that Z-Score is a good proxy for evaluating value generation perceived by stockholders in the medium term. Additionally, ROIC and gross margin increase for all the peer groups, reflecting the efficiency gains. It contrasts with Z-Score reduction, especially for smaller companies, due to an overall deterioration in financial strength resulting from indebtedness to fuel growth, low hydrocarbon prices due to extreme events, and high operational costs.

4.1. United States

Altman's Z-Score in 2014 allows us to rank the companies according to their resilience level. Fig. 2 shows the resilience classification for Global Majors and the US Independents before the first extreme event. One year of production growth for 2015–2016 fits the criteria for antifragility. Firms in red are those filing for bankruptcy during 2015–2020.

The resilience level scale from Fig. 3 follows Table 2 and Appendix C financial and operational metric evolution for the five-year evaluation period. Antifragile firms have a Z-Score higher than 3.0 in 2014. They exhibit a recovery time, Z-Score equal to or higher than the initial value, between one (1) to three (3) years, with Occidental Petroleum (OXY)'s exemption after its leveraged 2019 Anadarko acquisition. Similarly, they show positive cumulative five-year CFFF and EBITDA CAGR. EOG Resources (EOG) experienced a sharp UOG production increase during the 5-years. ConocoPhillips (COP) and the other Global Major's antifragile behavior reflects the US UOG asset portfolio's relevance and the diversification possibilities through the downstream infrastructure that characterize UOG vertical integrated companies.

By contrast, Resilient and Robust companies with Z-Score higher than 1.0 and lower than 3.0 did not recover despite consistent output growth, reflecting a lower 5-year ROIC increase rate associated with efficiency gains than antifragile ones. While 13% of Robust firms filed for Chapter 11 bankruptcy in the next six years, none of the Resilient did it.

71% of firms holding a Z-Score lower than 1.0 within the analyzed sample filed for bankruptcy in one (1) to five (5) years, and three (3) ones with Z-Score lower than 2.0 did it after 2015. However, these results are not conclusive since they depend not only on the firms' operational strengths but also on the possibility of obtaining external financing through asset sales, equity raising, and indebtedness.

Two (2) companies with market capitalization higher to $1 billion by the end of 2018 filed for bankruptcy in 2Q-2020. From them, the Chesapeake Energy (CHK) case is the most astonishing since the company contributed to shaping the UOG sector in the US. The CHK business model was oriented to grow at all costs and lease aggressively, hence being an innovator and first mover in several basins. The downside was the borrowing in excess. The early bet for gas and natural gas liquids development instead of oil worked for Cabot Oil and Gas (COG), but did not for CHK due to its higher costs, lower well productivity, senior debt interest obligations, and reduced gas prices.

Clear differentiation between Robust and Resilient companies is difficult to establish. The scale of 2.0 helps separate the two groups to reflect the MMOR model, which is convenient rather than a specific metric variation.

4.2. Canada

The financial stress that characterizes companies in the UOG sector is evident in Fig. 4. The UOG Canadian sector's difficulties are portrayed in Section 3.1 and reflected in Z-Score reduction for most firms. The companies with the lowest Z-Score discount are Imperial Oil (IMO) and Canadian Natural Resources (CNQ), which belong to the Canadian Integrated group, showing the relevance of vertical integration along upstream, midstream, and downstream chain value segments. It offers companies the possibility to control the whole process, diversify risks, reduce costs, and improve efficiencies. CNQ's ability to increase five-year ROIC by 9.5% and Gross Margin by 27.7% for the evaluation period reflects on keeping EBITDA CAGR and debt level constant, despite the sharp decrease in hydrocarbon prices.

Diversification is a critical factor for Canadian firms to survive. Five-year EBITDA CAGR increase for Baytex Energy (BTE) (80.6%), Vermilion Energy (VET) (15.6%), and Enerplus Corp (ERF) (10.9%) thanks their assets in the US, which helped them to invest selectively in the areas with a better margin.

4.3. Latin America

UOG exploitation in Latin America implies additional challenges compared to North America. Firms have to deal with country risk, supply chain constraints, reservoir uncertainties, lack of oil service companies and diversification possibilities, and public opinion misconceptions. Global Majors parent companies transfer financial strength to their subsidiaries and operational experience to local companies through joint ventures.

Given the lack of financial disclosed information, we define subsidiaries' organizational resilience level by combining North American firms' financial data and local production growth. We utilize firm size as a proxy when financial information is not available. For this reason, Fig. 5 results are descriptive rather than exhaustive. XOM and COP have UOG activities in Argentina, Chile, and Colombia.

Argentina's antifragile behavior follows the availability to increase

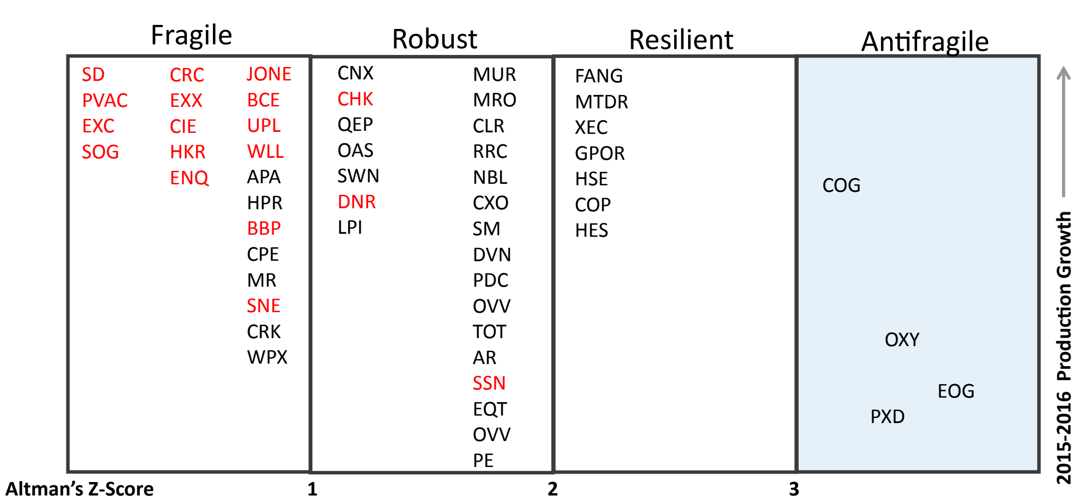

Fig. 2. Organizational resilience classification for UOG Global Majors and Independent US companies in 2014.

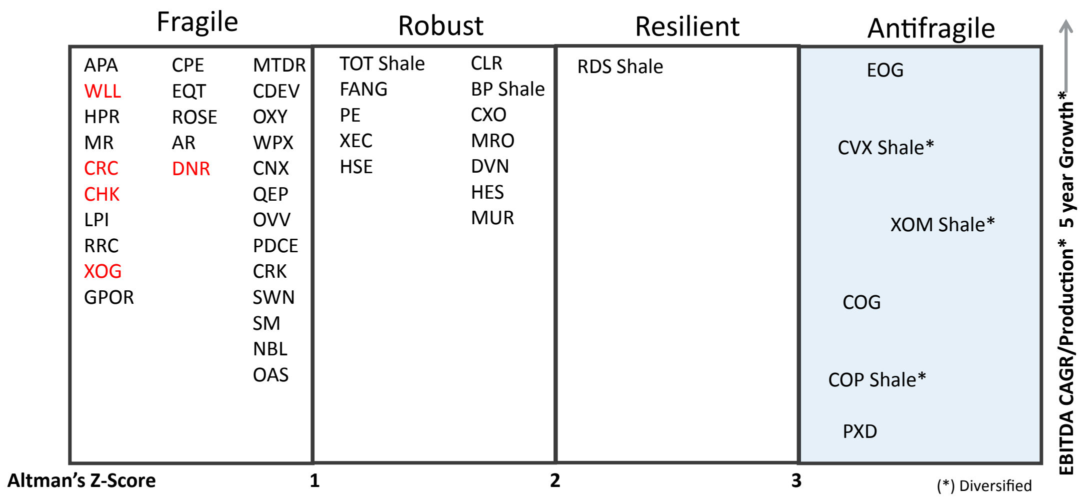

Fig. 3. Organizational resilience classification for UOG Global Majors and Independent US companies in 2019.

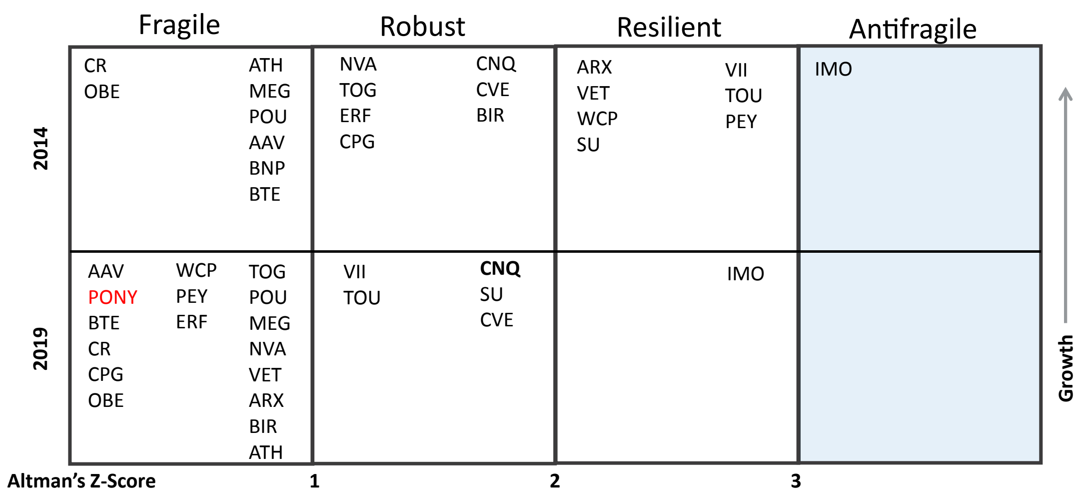

Fig. 4. Organizational resilience classification for UOG Integrated and Independent Canadian firms.

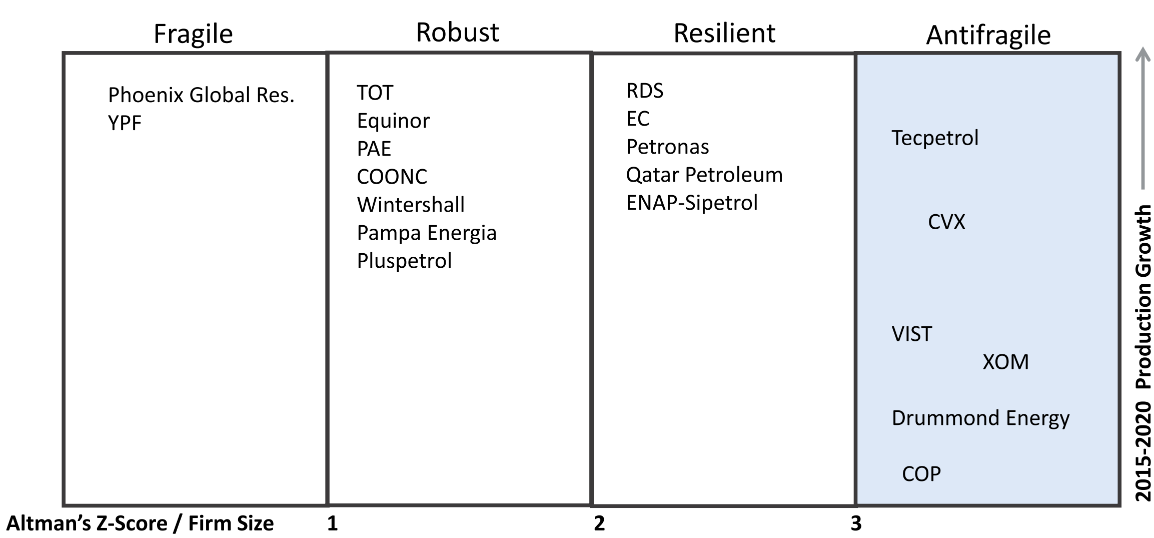

Fig. 5. Organizational resilience classification for UOG Latin American firms.

production faster than the rivals to take advantage of natural gas and oil prices and have market access before, given the infrastructure constraints. In Colombia, it reflects the ability to perform pilot tests delivering production before the regulation suspension. For Chile, resilience behavior reflects the positive output from ENAP-Sipetrol to develop natural gas resources after learning from the Argentinian experience. Another useful operational indicator for subsidiaries is the breakeven price, which offers a straightforward way to capture financial strength and the upside associated with additional oil and gas reserves. However, further research is required to test and improve the MMOR measurement proposal for international contexts.

4.4. Early responses to 2019–2020 extreme event

It is not simple to evidence resilience response to extreme events in the short term since almost all companies curtail production and reduce costs. These measures could reflect either operational flexibility or financial distress, making it challenging to evaluate. Moreover, some companies behave conservatively while others aggressively respond to the collapse hydrocarbon price crisis.

Nevertheless, it is possible to portray the leading strategies and tactics for UOG firms to face the crisis and respond to the stakeholder needs after reviewing the 2Q and 3Q 2020 reported operational and financial results. Almost all the players showed positive cash flows, thanks to a combination of tactics such as capital expenditure reduction, cost savings, hedging, and production curtailment. Some claimed annual cost reductions of up to 25%, but most are not sustainable because they depend on deflation instead of current efficiencies.

Table 3
Resilience Strategies and Tactics followed for UOG Companies in 2020.

		Companies	
Strategy	Scope	US	Canada
Switch Option	US Basins	<Bakken CLR, XOM, HES, COP, WPX >Barnett TOT, EOG	>Montney CNQ, COP
	Gas / Oil	SWN, CHK, EOG	CR, CNQ
	International	APA, HES, EOG	BTE, VET, ERF
Vertical Integration	Up/Mid/ Downstream	XOM, CVX	SU, IMP, CNQ, CVE, HSE
Cost Reduction	Deflation	All companies	All companies
	Technology	EQT, SWN, RRC, AR, CNX, FANG, PXD	BIR
	Efficiencies	MRO, PE, PXD, CXO, EOG	POU
Risk Management	Hedging	All except by COP, CLR	All except by CNQ, CVE, IMO, HSE
	Storage oil production	HES	CNQ
Scale Option	Capex Reduction	All companies	All with <20% TOU, VET, BIR, PEY, CNQ
	Decline rate moderation	PE	VII
	Production Curtailment	All companies	All companies
Improve Financial Condition	Sell Assets & ORRI	RDS, RRC, DVN, AR	
	Working capital	EOG	
	Refinancing/ Debt Payment	EQT, CNX, PXD, AR	VII, PEY
	Dividends Curtailment	RDS, WPX, CLR, BP, MRO	SU, CNQ, CVE, HSE, TORC
	Chapter 11 Bankruptcy law	WLL, XOG, CHK, CRC, DNR	
	Improve debt for liquidity	FANG, EOG, XOM, CRK, PXD	HSE, CVE, CNQ, SU
	Going Private	CLR	
	Peer Merger	DVN and WPX	CVE and HSE
Growth	Asset/Company Acquisition	CVX, COP, PXD, SWN	TOU, CNQ

Table 3 shows the companies and the different strategies depicted in the quarterly reports. Portfolio diversification becomes a critical element of resilient organizational behavior, with asset quality, size, and synergies from proximity and infrastructure access as the key elements. Fields with lower breakeven and access to the most attractive markets became a must. Companies that span through different US Basins, oil and gas assets, international exposition, or vertical integration have the flexibility to switch focus and prioritize activities according to their needs. Additionally, they have economies of scale and natural hedging for lower prices and infrastructure and market restrictions.

Ahead of the short-term tactics implemented, the strategy involves strengthening the asset portfolio to limit downside risk and take advantage of opportunities. This approach constitutes a real options portfolio [53,54]; it is common to successful firms in highly uncertain environments.

The right side of Fig. 6 updates Fig. 3 to reflect the antifragile firm short-term behavior. The best performers increased production during 2020, avoiding external financing by acquiring assets opportunistically on internal cash generation and stock deals.

Firm acquisitions: CVX to Noble Energy (NBL), CNQ to Painted Pony (PONY), COP to Concho Resources (CNX), PXD to Parsley Energy (PE), Cenovus Energy (CVE) to Husky Energy (HSE).
Asset acquisition: COP (Montney acreage to Kelt Exploration), Southwestern Energy (SWN) to CVX.

CVX, COP, PXD, and the Canadians CNQ and CVE showed a relevant production increase. XOM, EOG, and COG followed a more conservative approach and decided to keep a consistent and growing dividend at the expense of production gains. EOG and COG's strategy focuses on organic growth and seldom execute mergers and acquisitions.

Resilient companies kept and even slightly increased production output, despite the low prices and high uncertainty. The best performers were Hess Corp (HES), Diamondback Energy (FANG), Parsley Energy (PE), Antero Resources (AR), and SWN, increasing production in the US. These short-term results encourage and reflect a resilient behavior but depend on better natural gas prices and the possibility of generating positive cash flows utilizing hedging.

Canadian companies looked better prepared than their peers in the US since the crisis started early due to infrastructure limitations. Fragile companies ARC Resources (ARX), Whitecap Resources (WCP), Vermilion Energy (VET), Birchcliff Energy (BIR), and the Robust Tourmaline Oil (TOU) and Cenovus (CVE) showed resilience behavior. Additionally, CNQ exhibited antifragile behavior. Those early results suggest that the organizational resilience grading to rank Canadian companies could be adjusted once additional information from longer-term behavior is available.

Fragile organizations were those 22 UOG companies that Courts granted Chapter 11 protection during 1H 2020. Five (5) of them belong to the 77 companies in the sample for this study: Whiting Petroleum (WLL), Extraction Oil & Gas (XOG), CHK, California Resources (CRC), and Denbury Resources (DNR). 2019 Z-Score was negative for four (4) of them and 0.26 for DNR. Additionally, CVX and CNQ acquired Noble Energy (NBL) and Painted Pony (PONY) because of their natural gas assets and financial distress.

Mckinsey Global Publishing [55] conducted research considering 2020 2Q financial results from 1500 companies in North America and Europe arrives at similar conclusions after utilizing Altman's Z-Score to evaluate financial distress. 25% of the sample moved to a higher-stress category (Fragility), and only 3% improved (Antifragility). Compared with the 2009 recession results, the Z-score was more accurate for the long term than market performance. It also corroborates that Z-score evaluates three (3) resilience financial attributes: margin improvement, revenue growth, and optionality. The winners are those companies able

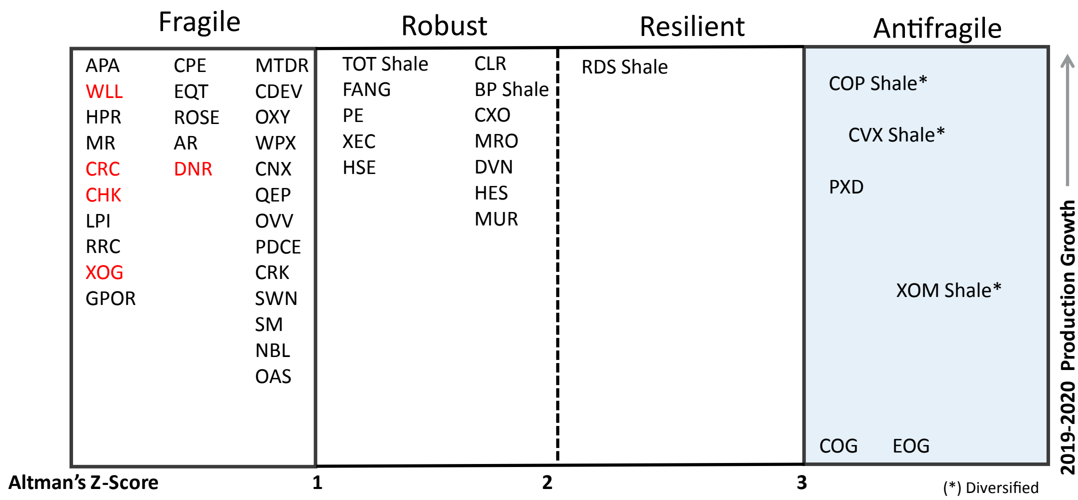

Fig. 6. Organizational resilience classification for UOG Global Majors and Independent US companies in 2020.

to expand digital and online capacities and adapt supply chains to improve resilience capabilities.

European O&G companies are at the forefront of the energy transition. BP Petroleum (BP) announced that it would grow low-Carbon investment by ten, decline upstream production by 40%, divest assets, no longer explore in new countries, and a 20% refinery throughput reduction by 2030, as concrete goals to achieve the 2050 "net zero" output. The company reduced dividends by 50% to finance these plans, which received shareholders' blessing, a step toward the future's resilient organization.

5. Conclusions

The purpose of this study is to identify and evaluate customarily financial and operational metrics useful to measure organizational resilience after a disruptive event. The two hydrocarbon price collapses from the last decade that affected the unconventional oil and gas development in North America allow us to evaluate the firm's resilience through their recovery capabilities. We find that Altman's Z-Score financial equation is the most appropriate for resilience measurement, together with a set of metrics applicable to evaluate antifragility and ESG capabilities.

We find firms that regain an Altman's Z-Score of 3.0 (three) or higher in less than three (3) years, without external financing, to be the most resilient. It matches market capitalization gain for the same companies during the evaluation period, suggesting utilizing Z-Score as a proxy for value generation. Also, together with EBITDA or production growth, it allows us to identify and measure antifragile behavior, representing the possibilities to withstand the crisis and flourish when hydrocarbon prices recover. We observe a Z-Score lower to 1.0 (one) before the crisis, meant to be in bankruptcy without additional financial funding after no more than three years.

For the international context, without detailed financial information, we propose to utilize the parent company Z-Score combined with output growth to evaluate resilience in high uncertainty environments. In Latin America, we notice that Antifragile firms have Resilient parent companies and the lowest time required for resource development and production growth.

The most relevant resilience organization observed attributes are diversification, vertical integration, optionality, flexibility, and sustainability. Firms diversify and allocate capital into lower cost, higher return, and lower-carbon assets, increasing their ability to deal with high uncertainty and energy transition. Antifragile companies are resilient and can additionally grow once the conditions exist. By contrast, Fragile organizations increase financial distress with difficulties adapting and are prone to bankruptcy after a disruptive event.

Further research is required to understand better the attributes common to antifragile organizations and the performance-risk metrics to use for subsidiaries and joint ventures. It is also relevant to have additional empirical studies to reinforce Altman's Z-Score parameter use for organizational resilience measurement and the scale utilized for resilience classification.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. . Definitions

Antifragile Organization: cannot only survive but also prosper or thrive in turbulent environments [14].

Black Swan: an event meeting three criteria i) It is an outlier as it lies outside the realm of regular expectations; ii) It carries extreme impact, and iii) Human nature makes us concoct explanations for its occurrence, after the fact, making it seem explainable and predictable [5].

CAGR: Compound Average Growth Rate [56].

CFFF: Cash Flow from Financing Activities [56].

EBITDA: net income (or earnings) with interest, taxes, depreciation and amortization added back. It can be used to analyze and compare profitability among companies and industries, eliminating the effects of financing and capital expenditures [56].

Fragile organization: is not able to withstand changing environments: it collapses [14].

Gross margin: is a company's net sales revenue minus its cost of goods sold. In other words, it is the sales revenue a company retains after incurring the direct costs associated with producing the goods it sells and the services it provides. The higher the gross margin, the more capital a company retains on each dollar of sales, which it can then use to pay other costs or satisfy debt obligations. The net sales figure merely is gross revenue, less the returns, allowances, and discounts [56].

Organizational Resilience: the measurable combination of characteristics, abilities, capacities, or capabilities that allows an organization to withstand known and unknown disturbances and survive [14].

Performance Antifragility: the ability to improve performance relative to the performance Reference Level over time following a sequence of changes in condition or events (known or unknown type of changes or events) [39].

Performance Competitive Advantage: the ability to be in a superior operating position due to high levels of Performance Resilience and Performance Antifragility [39].

Performance Resilience: the ability to regain/restore the performance Reference Level following a change in condition or event (known or unknown type of change or event) [38].

Performance-risk: deviation in performance relative to a reference level and associated uncertainties. Future performance is generally described by the triplet (O, Q, K) where O is a specified system output, Q is a measure of uncertainty associated with O, and K is the background knowledge that supports O and Q [38].

Resilient organization: is not only robust, but it is also able to survive unforeseen events [14].

Robust organization: can survive to some set of changes in the environment. However, if these changes are outside the designed parameters, the organization will probably collapse [14].

ROCE: Return on capital employed is a financial ratio used to assess a company's profitability and capital efficiency. In other words, the ratio can help to understand how well a company is generating profits from its capital [56].

ROIC: Return on invested capital is a calculation used to assess a company's efficiency at allocating the capital under its control to profitable investments. The return on invested capital ratio gives a sense of how well a company uses its money to generate returns [56].

TSR: Total shareholder return is the internal rate of return (IRR) of all cash flows to an investor during the holding period of an investment. Whichever way it is calculated, TSR means the same thing: the total amount returned to investors, including capital gains and dividends, when measuring the total return generated by stock to an investor [56].

Appendix B. . Customarily metrics in the O&G industry

1) Financial
   - i. Liquidity
     1. Strip 2020/2021 total payout ratios
     2. Current net debt/total cap metrics vs. targeted ceilings and historical peaks
     3. Funding of near-term debt maturities
     4. Liquidity positions
     5. Excess Cash Ratio
   - ii. Cash Flow
     1. Operational cash flow generation (OCF)
     2. Free cash flow generation (FCF) = OCF - Investments (before Dividends and Buybacks)
     3. Cash Flow per Share (CPFS) Y/Y Growth
     4. Cash Flow from Financing (CFFF)
   - iii. Financial distress
     1. Net Debt/EBITDA; should be $>$4.0
     2. Net Debt/adjusted EBITDAX
     3. Net Debt/Capital
     4. Payout (Post DRIP)
     5. Debt rating
   - iv. Recycle Ratio: Profit (netback: revenues – all costs including royalties, transportation, and production costs) per BOE/Cost of finding and development BOE; should be $>$1.0
   - v. Quarterly results
   - vi. Financial ratios
     1. Altman's Z-Score
     2. Tobin's q
2) Operational
   - i. Output
     1. Oil and gas production (MBOED)
     2. Production Y/Y Growth (% CAGR)
     3. Reserves incorporation (MMBOE/year)
   - ii. Efficiency
     1. Breakeven price (USD/BOE)
     2. First-month oil production per new well (BOE/well)
     3. EUR per well (BOE/well) and BOE/ft
     4. New-well oil production per rig (BOE/rig)
     5. The average cost per unit of IP (USD/production (180 days))
     6. Development cost (CAPEX/BOE)
     7. Operational cost (OPEX/BOE)
   - iii. Drilling and Completion efficiency
     1. Oil production/rig (bbl/day)
     2. Gas production/rig (Mcf/day)
     3. Hours/stage Completion

4. Lateral length/well (foot)
5. Stages/well
6. Pounds Proppant/stage
7. MM Pounds/stage/hour
8. Drilling days/1K lateral feet
9. Proppant Load (pounds)/Lateral foot
10. Weighted Average Days (Completion/Drilling)/well
11. Weighted average MM lbs. of Water & Proppant Pumped per day

3) Avoid HSE and integrity incidents
   i. FAR: Fatal Accident Rate
   ii. LTIF: Lost Time Injury Frequency
   iii. TRIR: Total Recordable Injury Rate
   iv. PSIF: Process Safety Frequency Index
   v. Disruptive event: Ratio of Recovery and Loss
4) Value creation
   i. Global Majors, Independent, and National Oil Companies
      1. ROCE: return on capital employed
      2. ROIC: return on invested capital
      3. Profitability Index: 1 + NPV10/discounted capital employed
      4. 5-year-Return (%)
      5. Dividend Yield (%)
      6. Enterprise Value (EV)
      7. Market Capitalization (MC)
      8. Enterprise Value/Market Capitalization
   ii. New ventures (Subsidiaries and Joint ventures)
      1. Production growth (BOE/year)
      2. Time to commit development (years)
      3. Investment/acreage ratio
      4. Project execution: Time, Cost, Quality
   iii. Expected Cash Flows
      1. Net Present Value (NPV)
      2. Enterprise Value/Net Present Value
5) Environmental
   i. Energy use
      1. Energy return on investment
      2. Total energy use (millions Gj)
      3. Energy intensity (Gj/m3)
   ii. Emission intensity
      1. Greenhouse Gas Emissions (GHG) Intensity Rate (tCO2e/mboe): CO2, CH4, N_20, NOx, SOx, VOC.
      2. Carbon emission per year (tCO2/year)
      3. A breakdown of emissions by source (Flaring, Venting, Fugitives, Combustion) (Mcf/day) per Mbo/day of gross oil production
      4. ESG Proprietary Indexes
         a. Upstream oil and gas carbon risk index (Verisk Maplecroft).
         b. Sustainability Overall Score (Sustainalytics).
         c. ISS (MSCI)
   iii. Water Usage
      1. WUNFS: Percentage of water use from freshwater and non-freshwater sources.
      2. Freshwater Intensity (bbl/BOE)
      3. Water Reuse Percentage.
   iv. Land use
      1. The footprint of activity (Hectares)
      2. Spill incident rate (number of spills/MMBOE)
      3. Volumes spilled/MMBOE production
      4. Pipeline incident/1000 km
   v. Executive Annual Bonus Goals Include ESG Performance
6) Social Sustainability
   i. Employment
      1. Direct employment (person-years)
      2. Local employment (%)
   ii. Nuisance
      1. Noise (dB)
      2. Traffic (%)
      3. Earthquakes (Number over threshold/year)
   iii. Public perceptions
      1. Public support (%)
      2. Media impact

iv. Local communities
1. Spending on local or domestic suppliers (%)
2. Direct community investment (%)

7) Governance
i. Equity of distribution of benefits and costs
ii. Information and monitory capacity
iii. Accountability
iv. Polycentric governance
v. Democratic inclusiveness
vi. Dispute resolution
vii. Adaptability and flexibility

Appendix C. . List of UOG Companies and Peer Groups utilized (n = 77).

Peer Group/Company	Ticker Symbol	Market Cap (MC) US$MM 2019	ROIC 5yr CAGR %	Gross Margin 5yr CAGR %	CFFF 5yr Total M$	Altman's Z 2019	Altman's Z 5yr CAGR (%)	EBITDA 5yr CAGR (%)	GHG Intensity 2018 [45] (KgCO2e/boe)
Canadian Integrated									
Canadian Natural Resources (NYSE)	CNQ	38,395	9.5	27.7%	−335	1.68	−13	−0.9	63.7
Cenovus Energy (NYSE)	CVE	12,478	10.1	17.2%	2747	1.5	−22	−24.8	50.1
Imperial Oil (NYSE)	IMO	20,250	4.1	−2.3%	−3571	2.67	−12	−13.9	100.6
Suncor Energy (NYSE)	SU	50,174	2.8	5.0%	−11,507	1.62	−19	3.6	82.3
Average Canadian Integrated		**30,324**	**6.6**	**11.9%**	**−3167**	**1.87**	**−16**	**−7.4**	
Canadian Seniors (> $1bn MC)									
ARC Resources	ARX	2891	8.5	43.0	−911	0.58	−74	−10.7	18.5
Crescent Point Energy (NYSE)	CPG	2439	−0.7	37.6	−1.254	−1.28	−210	−8.3	40.9
Enerplus Corp (NYSE)	ERF	1649	21.8	38.8	−665	0.37	−68	10.9	29.5
MEG Energy Corp	MEG	2210	5.3	4.6	−1440	0.62	−31	54.6	67.0
Seven Generations Energy Ltd	VII	2952	5.3	13.3	1352	1.35	−55	−0.8	14.4
Tourmaline Oil Corp	TOU	4138	4.1	31.5	2173	1.25	−−56	−14.4	17.4
Vermilion Energy (NYSE)	VET	3314	0.9	0.4	687	0.6	−73	15.6	28.8
Whitecap Resources	WCP	2287	14.4	94.5	625	0.48	−78	−19.0	51.0
Average Canadian Seniors		**2735**	**7.4**	**33.0**	**−101**	**0.50**	**−75**	**−4.5**	
Canadian Juniors (<$1bn MC)									
Advantage Oil & Gas	AAV	513	0.1	20.3	168	−0.2	−128	−38.5	13
Athabasca Oil	ATH	311	9.4	48.4	−298	0.5	−47	−15.3	40
Baytex Energy Corp	BTE	808	4.0	22.3	−87	−0.27	−153	80.6	45.7
Birchcliff Energy Ltd	BIR	689	4.5	15.5	695	0.52	−66	−37.1	11.3
Bonavista Energy Corp	BNP	307	19.2	152.9	−773		−100	−29.2	
Crew Energy Inc	CR	131	4.5	26.6	250	−0.3	−49	−8.8	
Nuvista Energy Ltd	NVA	919	15.1	50.0	985	0.61	−55	22.7	20.2
Obsidian Energy Ltd	OBE	68	−5.9	-2.5	−1,613	−2.2	210	23.5	
Painted Pony Energy Ltd	PONY	122	4.9	22.0	364	-0.24	−103	−42.5	
Paramount Resources Ltd	POU	985	16.1	58.6	−640	0.64	−23	−49.6	
Peyto Exploration & Development Corp	PEY	627	1.9	−2.2	−266	0.46	−83	−14.2	22.2
TORC Oil & Gas	TOG	984	4.4	22.7	457	0.66	−49	26.3	46.8
Average Cnd Juniors		**538**	**6.4**	**34.4**	**−67**	**0.02**	**−99**	**−14.8**	
Global Majors									
BP Petroleum (BPX)	BP	128,145	5.8	7.8	−18.750	1.87	−15	38.4	
Chevron Corp	CVX	226,820	1.6	−8.3	−45,171	3.19	−3.6	−11.9	
ExxonMobil Corp	XOM	295,449	−0.2	−1.6	−57,524	3.56	−23	−21.0	
ConocoPhillips	COP	70,549	13.4	25.2	−27,609	3.09	47	13.8	
Occidental Petroleum Corp	OXY	33,359	−13.0	15.8	−45,478	0.82	−74	76.3	
Royal Dutch Shell	RDS	236,318	5.6	4.8	−91,802	2.41	−18	−1.2	
Total	TOT	143,028	4.0	4.9	−22,582	1.49	−13	5.4	
Average Global Majors		**161,953**	**2.5**	**11.7**	**−44,131**	**2.35**	**−18**	**5.4**	
International Independents									
Apache Corp	APA	9647	8.5	12.2	−5218	−0.13	−115	4.1	
Husky Energy	HSE	10,473	6.9	18.9	−2351	1.18	−44	−2.3	112.6
Noble Energy	NBL	11,874	5.5	16.3	−439	0.57	−69	−70.8	
Marathon Petroleum	MRO	11,000	7.3	25.1	−1878	1.73	−9	61.2	
Hess Corp	HES	$ 20,357	1.4	30.6	1146	1.66	−20	−99.3	
Average US Independents		**12,670**	**5.9**	**20.6**	**−1748**	**1.00**	**−43**	**−2.3**	
US Independents (>US 1B MC)									
Cabot Oil & Gas Corp	COG	2587	3.0	0.2	−950	3.15	4	25.3	
Callon Petroleum	CPE	1916	1.9	20.5	2539	0.37	−44	90.2	
Centennial Res. Development	CDEV	1278	10.2	60.5	3422	0.91	−97	22.0	
Chesapeake Energy	CHK	1609	1.1	3.6	−1906	−0.7	−154	43.6	
Cimarex Energy	XEC	5185	8.4	23.4	−24	1.22	−48	40.3	

(continued on next page)

(*continued*)

Peer Group/Company	Ticker Symbol	Market Cap (MC) US$MM 2019	ROIC 5yr CAGR %	Gross Margin 5yr CAGR %	CFFF 5yr Total M$	Altman's Z 2019	Altman's Z 5yr CAGR (%)	EBITDA 5yr CAGR (%)	GHG Intensity 2018 [45] (KgCO2e/boe)
Comstock Resources	CRK	1542	20.2	102.2	963	0.68	31	−60.4	
CNX Resources	CNX	1652	3.2	51.8	−877	0.79	−41	104.7	
Concho Resources	CXO	17,425	4.6	31.8	822	1.78	−3	−31.8	
Continental Resources	CLR	12,778	6.6	20.2	−588	1.92	2	−4.4	
Devon Energy	DVN	10,414	3.7	5.8	−7217	1.71	−3	50.4	
Diamondback Energy	FANG	15,214	4.0	17.2	6885	1.32	−46	66.8	
EOG Resources	EOG	50,584	24.9	20.6	−2074	3.29	−4	81.8	
EQT Corp	EQT	2781	0.7	−12.9	5374	0.35	−77	−9.5	
Magnolia Oil & Gas	MGY	2,10	3.4	−27.6	227	2.35			
Matador Resources	MTDR	2104	5.6	19.5	2322	0.92	−61	57.9	
Murphy Oil	MUR	4099	7.3	25.8	−1862	1.57	−21	36.3	
Oasis Petroleum	OAS	1027	2.6	14.1	1696	0.54	−55	2.8	
Ovintiv	OVV	6125	2.0	−5.0	−2865	0.73	−58	7.5	
Parsley Energy	PE	5298	7.1	39,1	5134	1.32	−14	−0.3	
PDC Energy	PDCE	1676	−1.6	−11.0	1338	0.7	−60	6.4	
Pioneer Natural Resources	PXD	25,279	11.8	27.7	979	3.15	1	−1.1	
QEP Resources	QEP	1070	4.5	22.8	395	0.76	−38	42.4	
Range Resources	RRC	1203	3.8	34.4	−1244	−1.17	−162	−84.2	
SM Energy	SM	1265	5.6	25.3	1212	0.6	−66	−48.7	
Southwestern Energy	SWN	1308	9.1	3.1	−1672	0.66	−43	−11.3	
WPX Energy	WPX	5798	2.2	37.9	377	0.8	23	9.2	
Average US Independents		**−7051**	**6.1**	**23.3**	**465**	**1.14**	**−35**	**9.2**	
US Independents (<US 1B MV)									
Antero Resources	AR	935	2.0	16.5	3472	0.34	−80	−26.1	
Alta Mesa Resources	AMRQ	6							
California Resources Corp.	CRC	442	10.3	35.4	766	-0.47	12	−23.0	
Denbury Resources	DNR	720	6.0	23.2	−663	0.26	−77	70.9	
Extraction Oil & Gas	XOG	321	3.7	22.1	2652	−2.13		41.3	
Gulfport	GPOR	487	4.3	8.2	3135	−2.2	−193	18.6	
.ighPoint Resources	HPR	361	5.6	40.0	267	−0.27	−134	−7.3	
Laredo Petroleum	LPI	664	13.4	35.6	231	−0.71	−162	−22.8	
Montage Resources	MR	265	21.7	73.7	685	−0.39	−158	3.1	
Rosehill Resources	ROSE	19	7.2	42.0	517	0.4		59.2	
SRC Energy	SRCI	974	6.4	23.8	1787		−100	23.3	
Whiting Petroleum	WLL	670	13.5	4.7	−322	−0.15	−117	-36.9	
Average US Independents		**489**	**8.9**	**30.6**	**1139**	**−0.53**	**−138**	**3.1**	
Latin American NOCs									
Ecopetrol	EC	41,034	6.7	7.8	15,777	2.29	19	17.3	
Petroleo Brasileiro	PBR	103,965	0.5	9.6	−97,871	0.83	38	25.9	
YPF	YPF	4543	8.2	−8.3	−154	0.79	−52	−4.0	
Average LA NOCs		**49,847**	**5.1**	**3.0**	**−37,934**	**1.30**	**−6**	**10.9**	

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