STRANDED ASSETS

PROGRAMME

SMITH SCHOOL OF ENTERPRISE AND THE ENVIRONMENT

UNIVERSITY OF OXFORD

Cognitive biases and Stranded Assets: Detecting psychological vulnerabilities within International Oil Companies

Working Paper

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About the Stranded Assets Programme

The Stranded Assets Programme at the University of Oxford's Smith School of Enterprise and the Environment was established in 2012 to understand environment-related risks driving asset stranding in different sectors and systemically. We research how environment-related risks might emerge and strand assets; how different risks might be interrelated; assess their materiality (in terms of scale, impact, timing, and likelihood); identify who will be affected; and what impacted groups can do to pre-emptively manage and monitor risk.

We recognise that the production of high-quality research on environment-related risks is a necessary, though insufficient, condition for these factors to be successfully integrated into decision-making. Consequently we also research the barriers that might prevent integration, whether in financial institutions, companies, governments, or regulators, and develop responses to address them.

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Executive summary

Shareholders who invest in international oil companies (IOCs) need to respond to the trend of increasing 'density' of capital expenditures (capex) (Rook and Caldecott 2015). More capital is being concentrated in fewer larger projects. With a larger volume of capex being spread across a smaller number of projects, IOCs require a deeper understanding of the potential risks facing individual projects. Increasing capex density means that IOCs cannot rely exclusively – or even primarily – on the moderating effects of diversification to 'even out' performance.

But even if more resources are allocated to risk management, this may be offset by the greater likelihood of being harmed by any of a plethora of cognitive biases. Some of these potential psychological errors are listed below and become more likely as projects become more costly, complicated, and of lengthier duration. Such cognitive biases by IOC leadership, which could grow with rising capex density, can increase the risk of asset stranding.

The purpose of this paper is to equip shareholders with a novel toolkit for detecting where risks from cognitive bias are likely to be most severe among IOCs. This toolkit augments (and should be read in conjunction with) earlier work on capex density among IOCs (see Rook and Caldecott (2015)).

Examples of cognitive biases and how they can impact capex projects

Bias / Effect / Fallacy	Brief description and likely impact on capex project decisions
Availability bias	Tendency to overestimate probability of outcomes that readily come to mind and underestimate those that do not. Should cause rare and unfamiliar project risks to be underestimated or altogether neglected.
Choice-supportive bias	Tendency to recall the outcomes of one's past choices as more positive than they actually were. Would tend to make past projects seem either more successful or less disastrous than they were and inflate confidence.
Clustering illusion	Tendency to overweight the significance of 'patterns' in performance, for example to see streaks of positive outcomes in a random sample as non-random. May cause confusion between effects of luck and true skill.
Hard-easy effect	Tendency for confidence in a decision or choice to increase as the decision or choice becomes more difficult. Should induce excessive confidence in the success of large, complex, and long-duration projects.
Hindsight bias	Tendency to view past outcomes as being more predictable beforehand than they actually were. Would have the effect of causing a belief that future problems can be spotted and corrected more easily than they can.
Hot-hand fallacy	Tendency to believe that recent success indicates a higher likelihood of future success, even if recent outcomes were due more to luck than to skill.

	Should create overconfidence in managers that may not deserve it.
Hyperbolic discounting	Tendency for individuals to be excessively 'present-biased' in decisions, and be very impatient in the near term but disproportionately patient in the long term. Could cause massive distortions in cost-benefit analysis.
Illusion of control	Tendency to overstate or be overconfident in one's ability to exert control over outcomes that may be beyond one's capacity to influence. Would cause a belief that some projects are far less risky than they are.
Normalcy bias	Tendency to neglect or not prepare for events (especially disasters) that have not occurred previously (opposite of the so-called 'Peso problem'). Should cause extreme negative scenarios to be heavily underweighted.
Omission bias	Tendency to view inaction/non-intervention as less harmful (and less worthy of blame) than direct action that causes harm (related to a preference for the status quo). Should often discourage whistle-blowing.
Optimism bias	Tendency to distort the perceived likelihood of favourable or positive outcomes by judging them to be more probable than less favourable or positive ones. Should cause negative scenarios to be overly-discounted.
Ostrich effect	Tendency for the likelihood that a negative outcome gets ignored or neglected to increase with its degree of negativity. Would cause project managers to ignore the most unfavourable outcomes, even when likely.
Planning fallacy	Tendency to underestimate the time that it takes to complete a task (also known as 'duration neglect') and focus instead on its more salient costs and benefits, irrespective of time. Should make overruns more likely.
Post-purchase rationalising	Tendency to try to convince oneself and others that a particular expenditure was a good decision, even if it resulted in a loss or did not deliver expected benefits. Would cause lack of ownership for mistakes.
Pro-innovation bias	Tendency to exhibit undue enthusiasm for the benefits of a novel technology or method, without taking into full consideration its potential or actual costs. Could downplay riskiness of new technologies.
Small-sample bias	Tendency to be overly comfortable or confident in making decisions or draw conclusions based on insufficient samples of evidence. Would cause undue faith that a few past successes can indicate future success.
Sunk-cost fallacy	Tendency to accept an argument that present and future expenditures can be justified by the amount of past expenditure, even when past costs should

	not be a factor. Would cause bad projects to not be abandoned.
Survivorship bias	Tendency to concentrate on those outcomes that were successes, and to disregard or discount those outcomes that were failures because they are less visible. Would distort risks associated with possible outcomes.
Time-space myopia	Tendency to focus on those concerns (especially risks) whose effects are nearest in both time and space to the decision maker. Would make long-term projects in distant locations seem less risky than they actually are.

Cognitive biases and Stranded Assets

As asset stranding involves the premature or unexpected write-downs, devaluations, or conversion to liabilities of assets, there is always the potential that stranding occurs (or is exacerbated) due to improper risk management. Inadequate risk management may be a direct result of cognitive biases in decision-making, and psychology may thus be a root cause of some asset stranding.

As extensive psychological research demonstrates that cognitive biases are worsened when risks are unfamiliar (see, e.g.: Diebold, Doherty, and Herring (2010); Clark (2011); Taleb (2012)), we may expect that the significance of psychological error will increase when companies are faced with environment-related risks, which are often poorly understood and mispriced (Caldecott et al., 2013).

Directly testing for the presence of biases, errors, and fallacies in IOC decision processes would be difficult, if not impossible. As such, we suggest that shareholders focus on two cognitive forces: groupthink and salience. These two forces have the advantage of capturing the effects of many cognitive biases at once, and are typically far easier to detect. We recognise that shareholders have limited resources (especially time) and imperfect information, and we therefore have devised a set of tools that permit rapid diagnosis of the 'psychological' vulnerabilities within IOCs based upon public data.

Below we set out two diagnostic tools for groupthink and salience. We have applied these to the six major IOCs – BP, Chevron, ConocoPhillips, ExxonMobil, Royal Dutch Shell, and Total – and have ranked these companies based on their susceptibility to groupthink and salience. These tools are meant as a first step in rapidly identifying IOCs that exhibit characteristics that predispose them to biased decision-making. These tools should be applied at an early stage of shareholder engagement with IOCs.

Groupthink

Groupthink can exacerbate a majority of the cognitive biases, errors, and fallacies listed above. Social dynamics in a group can lead to dysfunctional outcomes; that is, people can sometimes make decisions as a group that are starkly different from those decisions they would make individually. Some of the main motivations that drive groupthink are a desire for consensus and conformity among group members.

Groupthink can be harmful for capex projects by IOCs because it tends to mitigate or eliminate dissenting viewpoints (e.g., it tends to reduce the effectiveness of someone playing the role of 'devil's advocate'). When it comes to weighing up risky outcomes that have not yet occurred (or else only rarely happen), groupthink can cause such remote possibilities to be heavily discounted.

Groupthink also tends to lead to insular thinking and causes unwarranted overconfidence among group members in the validity of decisions adopted by the group. Given these negative properties of groupthink, it is worrying to realise that IOCs exhibit a substantial number of the antecedent conditions that can give rise to groupthink:

1. **Structural faults**: members' backgrounds are overly similar and this homogeneity leads to a lack of diverse viewpoints; a lack of methodological standards (e.g., in situations of technological novelty, such as in engaging in 'pioneering' oil and gas projects with new techniques); there is a large degree of secrecy or lack of visibility, allowing groups to operate in an insulated or semi-insulated way.

2. **Situational context**: the decision-making environment is highly stressful and/or competitive, and groups feel that their right to operate is somehow challenged; recent performance has involved significant failures or setbacks; the decisions that must be made are inherently complex; moral dilemmas further complicate choices.

3. **Strong cohesion**: there is excessive priority placed on consensus and coordination among group members, and individual views are subjugated to a collective ethic.

Detecting groupthink

An immediate challenge for shareholders is how to discern when groupthink is actually taking place in IOC decision-making. There is no practical way to directly detect whether groupthink is occurring without being present when decisions are made, and such presence is almost always unworkable. Instead what should be sought is an indirect method for determining when conditions exist that might promote groupthink.

An *in-group* is a particular social category to which some individual belongs (and identifies herself as belonging), and an *out-group* is one to which she does not belong (and, moreover, recognises that she does not belong). The balance of in-groups to out-groups strongly influences groupthink. That is, groupthink is most likely when all members of a group (or some influential majority) belong to the same relevant in-group.

We have used the Jaccard distance tool to explore the relative balance of in-groups and out-groups of Boards of Directors at six IOCs: BP, Chevron, ConocoPhillips, ExxonMobil, Royal Dutch Shell, and Total. We consider five qualities of Board members: gender, age, tenure, nationality, and degree of experience outside the oil and gas industry. These qualities are a small selection of those that might matter for Board diversity, and that could potentially bear upon groupthink. Nonetheless, we assert that these five qualities are major contributors to social classification, and they capture important elements of the social dynamics that could lead to groupthink. Moreover, these qualities are all readily available from public reports by IOCs, and are to a large extent objective in nature.

The following statistics on Jaccard distance are generated for the six IOC Boards across the five qualities that are considered. Scores nearer to zero correspond to a stronger lack of diversity – i.e., *homogeneity* – and that scores closer to one indicate a higher degree of diversity – i.e., *heterogeneity*.

Two Boards in particular have scores for Jaccard distance that are significantly below their peers: Chevron and ExxonMobil. Interestingly, the third American IOC in the group, ConocoPhillips, also shows typical Jaccard distance scores below 0.500, which indicates that the composition of the Board of Directors is more homogenous than it is diverse. We expect that the Boards of Chevron and ExxonMobil (and, to a lesser extent, ConocoPhillips) may be more susceptible to groupthink than are their peer IOCs.

BP ranks higher than all of its peers apart from Royal Dutch Shell. A straightforward explanation for BP's improved standing with respect to Board composition may be that, in the wake of its involvement in the Deepwater Horizon incident of 2010, substantial Board turnover occurred (nine of the 14 BP Board members are

new to the Board since 2010), and BP's focus has been in introducing greater diversity of perspective and experience to its uppermost leadership.

Jaccard distance score for six IOC boards - lower number means less board diversity

Company	Mean	Median	Mode
BP	0.514	0.600	0.600
Chevron	0.300	0.200	0.200
ConocoPhillips	0.461	0.400	0.200
ExxonMobil	0.309	0.200	0.400
Royal Dutch Shell	0.530	0.600	0.400
Total	0.508	0.600	0.600
AVERAGE	***0.437***	***0.433***	***0.400***

While none of the IOC Boards examined should be extolled for diversity (none of the scores were much better than 0.500; in particular, all six Boards had far fewer female than male members), the American Boards are noticeably more homogenous than are the non-American Boards (i.e., BP, Shell, and Total). Two dimensions on which American Boards seem to especially lag their non-American counterparts is in diversity of nationality, and age breadth. For example, the Board of Chevron had no members without American citizenship, and ExxonMobil had only one of its dozen members without American citizenship (ConocoPhillips was only slightly more diverse, with two of its 12 members being of non-American nationality; one of these members is, however, still North American, as he is a Canadian citizen).

Furthermore, the age ranges of the American Boards is typically less than that of their non-American peers; of note, the difference between the eldest and youngest ages of members for both Chevron and ExxonMobil is 16 years, whereas it is 38 for Total. Given that significant results in psychological research find significantly different attitudes toward risk across nationality and age profiles, the homogeneity of American Boards in these respects is worrying, and could serve to increase the propensity for groupthink (or, at the very least, it does nothing to decrease the likelihood of groupthink).

Although any Board may be judged in terms of its gross membership, most corporate Boards also involve committees that are in charge of particular Board-level tasks, such as executive compensation, audits, public/environmental policy, and ethics (as well as further, company-specific concerns). Most IOC Boards have between four and six such (permanent) committees, and only a select subset of Board members are typically part of any one committee (although many members are on more than one committee). Hence, one can understand committees as further forms of 'clique' within a Board; and if such cliques are relatively homogenous in composition, then this possibility may greatly increase the potential for groupthink.

Salience

The other cognitive force that we consider, and suggest as a useful tool for rapid diagnostics, is salience. The basic idea behind salience is straightforward: when making judgments and other choices, people pay disproportionately more attention to some elements of the decision problem (whether payoffs, risks, timescales, probabilities, etc.) than they do to other aspects; those elements that receive more attention do so because they 'stand out'. In a series of recent studies in behavioural economics, Bordalo, Gennaioli, and Shleifer (BGS) (2012; 2013a; 2013b; 2015) show how the cognitive force of salience can subsume many of the aforementioned psychological biases, errors, and fallacies.

A key idea behind salient thinking is that many judgments and choices are made comparatively, and that the alternatives against which comparisons are made strongly affect the outcomes of the decision process. This realisation is pivotal in the face of increasing capex density because the effects of salience usually become more pronounced when fewer items are compared; by having fewer capex projects in their portfolios, the effects of salience on IOCs increase.

And it is vital to realise that groupthink and salience can exacerbate one another. For example, recent poor performance by an IOC will be judged relative to the performances of its peers: bad performance will appear even worse if others do not do nearly as badly, but will seem less unsuccessful if others also struggle. Salience may be either positive or negative: strong underperformers may tend to feel embattled, and therefore engage in forms of groupthink, whereas strong outperformers may feel emboldened by their superior results and comparative standing, which thereby could also induce groupthink.

For example, with a slight drop in the price of oil or gas, most projects may underperform, although some projects will underperform less badly than others. These 'less bad' projects will look far better than they really are because of the comparative nature of salience, and therefore may be allocated more resources (e.g. additional investment) than is deserved on their own merit. Such additional resources then will tend to improve the performance of these 'less bad' projects, and may increase their scale, which should tend to make them even more salient relative to other projects in the portfolio and possible attract even more resources to them. Meanwhile, managers in charge of these 'less bad' projects may also receive substantial (albeit not fully warranted) credit for 'artificially enhanced' performance, and have excess confidence placed in them (or overconfidence in themselves) in the future.

Detecting salience

Here, we show how the simple form for the salience function specified by Bordalo, Gennaioli, and Shleifer (2012) can be used as a tool for rapidly diagnosing which IOCs may be the most strongly predisposed to cognitively biased decision-making about which capex projects to pursue. To demonstrate the tool's pragmatism, we apply it to the actual public data of the six main IOCs: BP, Chevron, ConocoPhillips, ExxonMobil, Royal Dutch Shell, and Total. The selection of data to which we apply the salience tool is standard for much of the financial analysis that shareholders of IOCs tend to focus on: annual revenue, earnings (both overall and per share), capex, dividends, and reserve replacement figures.

In this subsection, we demonstrate the salience tool by ranking six IOCs (BP, Chevron, ConocoPhillips, ExxonMobil, Royal Dutch Shell, and Total) relative to one another based upon six characteristics of performance that are of general interest to most shareholders. These six characteristics are: total annual revenue; total annual net earnings; total annual capital expenditures (capex); annual earnings per share; annual dividends per share; and annualised reserve replacement ratios. All of these figures are extracted from the three latest annual reports (FYE 2014, 2013, and 2012) for each of the six companies. For the reader's convenience, these figures are all assembled together in tables that appear below. (Reserve replacement ratios are on proven reserves excluding acquisitions and disposals.)

Overall Revenue			
$USD (millions)			
	2014	2013	2012
BP	358,678	396,217	388,074
Chevron	211,970	228,848	241,909
ConocoPhillips	55,517	58,248	62,004
ExxonMobil	411,939	438,255	480,681
Shell	421,105	451,235	467,153
Total	212,018	227,969	234,216
Average	278,538	300,129	312,340
Maximum	421,105	451,235	480,681
Minimum	55,517	58,248	62,004
Range	365,588	392,987	418,677

Overall Net Earnings			
$USD (millions)			
	2014	2013	2012
BP	4,003	23,758	11,251
Chevron	19,241	21,423	26,179
ConocoPhillips	6,869	9,156	8,428
ExxonMobil	32,520	32,580	44,880
Shell	14,874	16,371	26,712
Total	4,250	11,521	13,836
Average	13,626	19,135	21,881
Maximum	32,520	32,580	44,880
Minimum	4,003	9,156	8,428
Range	28,517	23,424	36,452

Overall Capital Expenditures			
$USD (millions)			
	2014	2013	2012
BP	22,546	24,520	23,222
Chevron	35,407	37,985	30,938
ConocoPhillips	17,085	15,537	14,172
ExxonMobil	38,537	42,489	39,799
Shell	31,854	40,145	32,576
Total	30,509	34,431	29,475
Average	29,323	32,518	28,364
Maximum	38,537	42,489	39,799
Minimum	17,085	15,537	14,172
Range	21,452	26,952	25,627

Earnings Per Share (Diluted)			
$USD			
	2014	2013	2012
BP	0.20	1.23	0.58
Chevron	10.14	11.09	13.32
ConocoPhillips	5.51	7.38	6.72
ExxonMobil	7.60	7.37	9.70
Shell	2.36	2.60	4.26
Total	1.86	4.94	6.02
Average	4.61	5.77	6.77
Maximum	10.14	11.09	13.32
Minimum	0.20	1.23	0.58
Range	9.94	9.86	12.75

Dividends Per Share			
$USD			
	2014	2013	2012
BP	0.39	0.37	0.33
Chevron	4.21	3.90	3.51
ConocoPhillips	2.84	2.70	2.64
ExxonMobil	2.70	2.46	2.18
Shell	1.86	1.78	1.71
Total	3.00	3.24	3.05
Average	2.50	2.41	2.24
Maximum	4.21	3.90	3.51
Minimum	0.39	0.37	0.33
Range	3.82	3.54	3.18

Organic Reserve Replacement Ratios			
	2014	2013	2012
BP	63%	129%	77%
Chevron	89%	85%	112%
ConocoPhillips	124%	179%	156%
ExxonMobil	111%	106%	124%
Shell	46%	123%	85%
Total	107%	89%	75%
Average	90%	119%	105%
Maximum	124%	179%	156%
Minimum	46%	85%	75%
Range	78%	94%	81%

Using the above figures, we can calculate salience rankings for each of the IOCs across these six characteristics. A table that shows such salience rankings appears below. Note that a lower ranking (e.g., 1 versus 2) corresponds to higher salience for the IOC in question than that for its peers with a higher number (for example, Overall Net Earnings for ConocoPhillips in 2013 were more salient than were those of the other five IOCs against which it is compared).

Salience Rankings																		
	Overall Revenue			Overall Net Earnings			Overall Capex			Earnings Per Share			Dividends Per Share			Organic Reserve Replacement Ratios		
Company	2014	2013	2012	2014	2013	2012	2014	2013	2012	2014	2013	2012	2014	2013	2012	2014	2013	2012
BP	6	4	6	1	4	3	3	3	3	1	1	1	1	1	1	2	5	3
Chevron	4	6	5	5	6	6	4	5	5	2	3	2	2	2	2	6	2	6
ConocoPhillips	1	1	1	4	1	1	1	1	1	6	4	6	5	5	5	3	1	1
ExxonMobil	3	3	2	3	2	2	2	2	2	5	5	4	6	6	6	4	4	5
Shell	2	2	3	6	5	5	5	4	4	4	2	3	3	4	4	1	6	4
Total	5	5	4	2	3	4	6	6	6	3	6	5	4	3	3	5	3	2

ConocoPhillips' salience is driven by its strong outperformance (see high scores under revenue, net earnings, and capex,), whereas BP's salience (see high scores under earnings per share, dividends per share, and RRR) stems from its pronounced lagging behind its IOC peers on the characteristics studied. With respect to cognitive bias, and particularly groupthink, both ConocoPhillips and BP may be more susceptible than their peers, but from distinct causes. For example, leadership at ConocoPhillips might feel that its strong showing relative to competition makes it less vulnerable, and may drive both overconfidence and inattentiveness to unforeseen risks (or at least more so than for less salient performers). Meanwhile, BP's situation may be characterised by its leadership feeling embattled due to its recent failures, which could create pressures necessary for groupthink, inattention to unfamiliar risks, and improper allocations of scarce resources.

Hence, a recommendation for shareholders would be to focus more energy and time on exploring what leadership at BP and ConocoPhillips may be doing to combat biased decision-making, relative to resources spent on other IOCs that are less salient.

Shareholder responses

We provide a 'tiered ranking' of IOCs based upon the outputs of analyses conducted (i.e., using the salience function and Jaccard distance). Tier 1 companies showed themselves as relatively vulnerable to cognitive bias based on analyses here: BP; Chevron; ConocoPhillips; and ExxonMobil. We further subdivide Tier 1 into two sub-tiers, Tier 1-S and Tier 1-J, that correspond with those companies that scored worst on salience and groupthink, respectively. Tier 2 is comprised of the two companies – Shell and Total – that demonstrated themselves as less predisposed to vulnerability from cognitive bias based on the dimensions tested and tools used in this paper.

- Tier 1-S: BP; ConocoPhillips
- Tier 1-J: Chevron; ExxonMobil
- Tier 2: Royal Dutch Shell; Total

Demanding Explicit Disclosure

Lobbying for explicit disclosure of the steps and protocols that IOC leadership teams have in place to guard against biased thinking – especially under increasing capex density – may be one possible remedy. Shareholders may be entitled to such information, and may be able to demand it from IOCs. Future work may explore whether or not there appears to be legal grounds to require IOCs to report what protocols they formally have in place to guard against cognitive errors (like groupthink) (and if there is a breach of duty to shareholders in not doing so).

Requesting Board Diversity

Boards of Directors are meant to safeguard the interests of the companies they represent, as well as shareholders' interests as owners of those companies. Board diversity should be a top priority for IOCs, especially in light of the trend of increasing capex density. We suggest that shareholders make their voices strongly and clearly heard when it comes to demanding that deep consideration be granted to the ways in which Boards are constructed, and attention paid to novel, useful dimensions of heterogeneity.

1. The problem

Shareholders who invest in international oil companies (IOCs) face a problem that is both subtle and challenging: how to respond to the trend of increasing 'density' of capital expenditures (capex) by IOCs (Rook and Caldecott 2015). The problem of rising capex density entails a widespread pattern among IOCs of more capital being invested in fewer larger projects; the average size of capex projects is increasing and the average number of capex projects is not increasing proportionally.

Increasing capex density poses a potential threat to shareholders because it can alter the risk profile of an IOC equity investment, but in ways that are not necessarily visible or readily quantifiable based upon public disclosures alone (for a detailed exposition of this threat, see Rook and Caldecott (2015)). In particular, increased capex density impacts shareholders through reducing the extent of project-based diversification by IOCs: more capital spent on fewer projects means that performances of individual projects in an IOC's portfolio offset one another to a weaker degree than would be so for less capex density (and greater project-based diversification).

Nevertheless, impacts of reduced project-based diversification need not be all bad. For example, outperforming projects may not have their positive results offset as strongly by the negative results of underperforming projects (see Litterman (2003)). Hence, it is possible that, with proper risk management, increased capex density may be more of an opportunity for shareholders than a threat. Part of the challenge faced by shareholders, however, lies in determining whether proper risk management is in place.

Discouragingly, it is difficult for shareholders to determine if any IOC has suitable risk-management systems in place to responsibly cope with greater density in its capex. And this difficulty stems in part from the heightened propensity for cognitively-biased decisions by IOC leadership when planning and/or making choices regarding large, complex, and long-term projects (see: Kahneman and Lovallo (1993); Clark, Dixon, and Monk (2009)). The likelihood of committing a psychological misstep grows as any given decision becomes: 1) larger in the scale of its costs and payoffs; 2) more complex or complicated; and 3) longer in its duration. All three of these features characterise the capex projects that are leading IOCs to increase the density of their capital expenditures, which marks them as prime candidates for biased decisions that may harm shareholders. Yet most shareholders cannot witness the vast majority of the decision processes and inputs used to select which projects to pursue and how to manage the associated risks (shareholders usually only see the outcomes of such decisions, and even then often only as an aggregation of outcomes, e.g., in the form of quarterly or annual financial reports). Hence, shareholders may be substantially in the dark on true risks of their IOC investments.

The purpose of this paper is to equip shareholders (and other concerned readers) with an immediately deployable toolkit for rapidly detecting where risks from cognitive bias are likely to be most severe among IOCs. This toolkit augments (and should be read in conjunction with) earlier work on capex density and evenness among IOCs (see Rook and Caldecott (2015)). Furthermore, pragmatism is a chief motivator behind the toolkit presented in this paper; we recognise that shareholders have limited resources (especially time) and imperfect information, and we therefore have devised a set of tools that permit rapid diagnosis of IOCs based upon public data. As such, we do not focus on the detection of individual cognitive biases, but instead concentrate on detecting two cognitive forces that both give rise to, and also are expressions of, several simultaneous biases: salience and groupthink. We describe how these two forces are interrelated, and can help to exacerbate each other.

1.1 Cognitive bias risks and asset stranding

Cognitive bias risks by IOC leadership could have material implications for asset stranding. As asset stranding involves the premature or unexpected write-downs, devaluations, or conversion to liabilities of assets, there is always the potential that stranding occurs (or is exacerbated) due to improper planning for, and management of, the risks to which assets are exposed (especially environment-related risks connected with climate change). This

improper planning and management in many instances may be a direct result of cognitive biases in strategic decision-making, and psychology may thus be a root cause of some asset stranding. Since extensive psychological research has demonstrated repeatedly that cognitive biases are often worsened when risks are unfamiliar (see, e.g.: Diebold, Doherty, and Herring (2010); Clark (2011); Taleb (2012)), we may expect that the impact of cognitive biases may in many cases be to heighten the likelihood and severity of asset stranding simply because the risks underlying stranding are mostly unfamiliar (for example, many of the threats from climate change have not been experienced previously by many of those who are vulnerable to them and as a result these threats are addressed in a biased fashion during decision-making). Hence, while the specific subject matter of this paper is concerned with international oil companies, much of its content may in fact be generalised to other organisations that are likewise susceptible to forms of asset stranding.

1.2 Overview

The rest of this paper adopts the following structure. Section 2 briefly reviews some ideas behind capex density and evenness that appear in Rook and Caldecott (2015), and discusses how such ideas connect to the cognitive forces of salience and groupthink. Section 3 discusses a method for detecting which IOCs may be most prone to cognitive bias, based upon their relative positioning against their IOC peers. That section also presents scores and rankings of IOCs along an indicative set of key performance indicators. Section 3 also explores how the concepts that underpin this method can be used to explain continual increases in capex density by individual IOCs based on relative project performances. Section 4 proposes a method for detecting which Boards of Directors for IOCs may be most susceptible to cognitive biases that both cause and stem from groupthink. The Boards of Directors at BP, Chevron, ConocoPhillips, ExxonMobil, Royal Dutch Shell, and Total are analysed and compared to each other with that method. Section 5 suggests some specific actions that shareholders (and other parties) could take as a consequence of findings that arise from applying the diagnostic toolkit in this paper. Section 6 provides a summary of the paper, and mentions possibilities for future research.

2. Capital escalation and cognitive biases

2.1 Threats from increasing capex

As was mentioned in the introduction, increasing capex density by IOCs is a subtle and challenging trend with which IOC shareholders have to cope. On the one hand, the decreased diversity of projects that an increase in capex density brings may carry some financial upsides for investors: if there are proportionally more outperforming projects as a result of decreased diversification then returns may improve. Yet, on the other hand, shareholders should not be concerned solely with realised performance (i.e., those specific outcomes and financial performance that actually occur), but also possible and expected performances.

Dealing additionally with possible and expected performance injects some complications because it relies upon counterfactuals; that is, in considering possible and expected performance, shareholders must deal with not only what actually happens but also what alternatively could have happened instead (on some challenges of this counterfactual reasoning, consult Taleb (2011)). Such considerations are at the heart of sound risk management, but often get subjugated to realised performance by not only shareholders, but also the leadership teams of IOCs; for example, shareholders, management teams, and Boards may tend to worry less about threats that fail to materialise, but were genuine possibilities, than those that do happen.

This fixation on actual occurrences stems largely from a desire for objectivity: people typically prefer to make decisions based on what they can observe and measure (e.g., Deming (1993)) rather than on what they must estimate and/or conjecture, because estimation and conjecture are widely understood to involve subjectivity and be predisposed to biases. Problematically, however, focusing unduly (or, in extreme cases, exclusively) upon what is 'objectively' observable or measurable (e.g., past outcomes) introduces its own set of biases, and these are often even worse than those biases connected with subjective estimation and conjectures about what could have, although so far has not yet, happened.

The generality of such preferential treatment of the observable over the possible exacerbates many threats posed by increases in capex density and unevenness by IOCs (see Rook and Caldecott (2015) for definitions of, and functional metrics on, these ideas). With a larger volume of capex being spread across a smaller number of projects, IOCs must have a deeper understanding of the potential risks facing individual projects because they cannot rely on the moderating effects of diversification to 'even out' realised performance and outcomes; hence, they should devote greater resources (e.g., time and effort) to identifying and estimating the scale and likelihood of the potential hazards faced by their capex projects than they would do if they faced less capex density.

But a worrying realisation is that, even if more resources are allocated to risk management as capex density increases (and project-based diversification decreases), any increase in allocated risk-management resources may be partially (or entirely) offset by greater likelihood of committing a psychological error that goes along with higher capex density (as a result of projects being more costly, complicated, and of lengthier durations). Worryingly, higher capex density may invite not just one type of error, but rather a plethora of cognitive errors and biases, and a table below offers a selective distillation of some of the most relevant biases, effects, and fallacies that have been well-identified within cognitive psychology and behavioural economics; some classic references from which are drawn include: Kahneman, Slovic, and Tversky (1982); Kahneman and Tversky (2000); Gigerenzer and Selten (2001); and Gilovich, Griffin, and Kahneman (2002)).[1]

[1] See also: Tversky (2004).
[2] Recognise, however, that the sentiments of large groups are not immune to bias or fallibility, they just may be

Table 1: Examples of cognitive biases and how they can impact capex projects

Bias / Effect / Fallacy	Brief description and likely impact on capex project decisions
Availability bias	Tendency to overestimate probability of outcomes that readily come to mind and underestimate those that do not. Should cause rare and unfamiliar project risks to be underestimated or altogether neglected.
Choice-supportive bias	Tendency to recall the outcomes of one's past choices as more positive than they actually were. Would tend to make past projects seem either more successful or less disastrous than they were and inflate confidence.
Clustering illusion	Tendency to overweight the significance of 'patterns' in performance, for example to see streaks of positive outcomes in a random sample as non-random. May cause confusion between effects of luck and true skill.
Hard-easy effect	Tendency for confidence in a decision or choice to increase as the decision or choice becomes more difficult. Should induce excessive confidence in the success of large, complex, and long-duration projects.
Hindsight bias	Tendency to view past outcomes as being more predictable beforehand than they actually were. Would have the effect of causing a belief that future problems can be spotted and corrected more easily than they can.
Hot-hand fallacy	Tendency to believe that recent success indicates a higher likelihood of future success, even if recent outcomes were due more to luck than to skill. Should create overconfidence in managers that may not deserve it.
Hyperbolic discounting	Tendency for individuals to be excessively 'present-biased' in decisions, and be very impatient in the near term but disproportionately patient in the long term. Could cause massive distortions in cost-benefit analysis.
Illusion of control	Tendency to overstate or be overconfident in one's ability to exert control over outcomes that may be beyond one's capacity to influence. Would cause a belief that some projects are far less risky than they are.
Normalcy bias	Tendency to neglect or not prepare for events (especially disasters) that have not occurred previously (opposite of the so-called 'Peso problem'). Should cause extreme negative scenarios to be heavily underweighted.
Omission bias	Tendency to view inaction/non-intervention as less harmful (and less worthy of blame) than direct action that causes harm (related to a preference for the status quo). Should often discourage whistle-blowing.

Optimism bias	Tendency to distort the perceived likelihood of favourable or positive outcomes by judging them to be more probable than less favourable or positive ones. Should cause negative scenarios to be overly-discounted.
Ostrich effect	Tendency for the likelihood that a negative outcome gets ignored or neglected to increase with its degree of negativity. Would cause project managers to ignore the most unfavourable outcomes, even when likely.
Planning fallacy	Tendency to underestimate the time that it takes to complete a task (also known as 'duration neglect') and focus instead on its more salient costs and benefits, irrespective of time. Should make overruns more likely.
Post-purchase rationalising	Tendency to try to convince oneself and others that a particular expenditure was a good decision, even if it resulted in a loss or did not deliver expected benefits. Would cause lack of ownership for mistakes.
Pro-innovation bias	Tendency to exhibit undue enthusiasm for the benefits of a novel technology or method, without taking into full consideration its potential or actual costs. Could downplay riskiness of new technologies.
Small-sample bias	Tendency to be overly comfortable or confident in making decisions or draw conclusions based on insufficient samples of evidence. Would cause undue faith that a few past successes can indicate future success.
Sunk-cost fallacy	Tendency to accept an argument that present and future expenditures can be justified by the amount of past expenditure, even when past costs should not be a factor. Would cause bad projects to not be abandoned.
Survivorship bias	Tendency to concentrate on those outcomes that were successes, and to disregard or discount those outcomes that were failures because they are less visible. Would distort risks associated with possible outcomes.
Time-space myopia	Tendency to focus on those concerns (especially risks) whose effects are nearest in both time and space to the decision maker. Would make long-term projects in distant locations seem less risky than they actually are.

There are myriad ways in which management and oversight teams (e.g., Boards of Directors) might err when making decisions about increasingly large, complex, and lengthy capex projects. Moreover, many of these biases may occur simultaneously; while some might partially offset one another, more often biases like those above tend to mutually worsen one another.

Furthermore, testing for the (actual or likely) presence of multiple instances of the above biases, errors, and fallacies in IOC decision processes would be difficult, if not impossible. As such, we instead embrace a pragmatic stance and suggest that shareholders focus on two cognitive forces, salience and groupthink, rather

than on individual cognitive biases. These two forces have the advantage of capturing the effects of many biases at once, and are typically far easier to detect; we present simple tests for doing so in Sections 3 and 4. First, however, it will be useful to review some of the main features of this pair of forces.

2.1 Salience and Groupthink

The basic idea behind salience is straightforward: when making judgments and other choices people pay disproportionately more attention to some elements of the decision problem (whether payoffs, risks, timescales, probabilities, etc.) over other aspects; those elements that receive more attention do so because they are relatively more salient (i.e., they 'stand out' more) than other elements that are less so, and therefore receive less attention and are thus (partly or entirely) neglected. In a series of recent studies in behavioural economics, Bordalo, Gennaioli, and Shleifer (BGS) (2012; 2013a; 2013b; 2015) show how the cognitive force of salience can subsume many of the aforementioned psychological biases, errors, and fallacies. The power of the approach to studying salience proposed by BGS is enhanced by their use of a simple mathematical function for salience, of which we make use in Section 3 in formulating a test for salient thinking among IOCs.

Briefly, it is worthwhile to cover some of the potential consequences of relying excessively on salience in decision-making for capex projects in the oil and gas industry. A key idea behind salient thinking is that many judgments and choices are made comparatively, and that the alternatives against which comparisons are made strongly affect the outcomes of the decision process; hence, salient thinking embeds the notion that people's choices are always context dependent and unavoidably relative in nature. This basic fact captures a characteristic of not only the way that IOCs conduct operations, but the way in which modern businesses in general operate: decisions about changes are continually undertaken, and these decisions on whether or not to adopt a particular change are always made comparatively (e.g., does management make a candidate change, or does it pursue the status quo, and if it does change, then is Change A better or worse than Change B?) (see Bushong, Rabin, and Schwarstein (2015) on this topic of comparative decision-making). This realisation is pivotal in the face of increasing capex density because the effects of salience usually become more pronounced when fewer items are compared; by having fewer capex projects in their portfolios, the effects of salience on IOCs increase.

To understand this phenomenon, consider the following basic intuitive example. Consider two capex projects: Project A and Project B. Project A has been achieving its performance benchmarks in recent months, whereas Project B has been strongly underperforming its benchmarks. When faced with a capital (re)allocation decision, IOC leadership may be inclined in such a situation to allocate more capital to Project B to bring it "back on track"; in this case, the strong underperformance of Project B is more salient than that of Project A, which should attract more attention to it, and give it an edge over Project A in terms of its weight in decision-making by leadership. Nevertheless, if instead of two projects, there had been several more (say, e.g., Projects C, D, E, and F as well), then the typical decision inclination by leadership may have been 'reframed', and the outcome different. For example, if Projects A, C, D, E, and F were all achieving their benchmarks, whereas B had been strongly underperforming its benchmarks, then the salience of Project B becomes somewhat dampened: while it stands out for being the only strong loser in the portfolio of six capex projects, it is now a 'minority' project, and more disposed in capital (re)allocation decisions to be denied additional funds rather than granted them. A substantial volume of psychological research confirms that this pattern of cognitive bias is indeed prevalent, even among experienced decision makers, and that a similar outcome could be expected if, for example, Project B had been a strong outperformer relative to its benchmark-meeting peers, instead of an underperformer.

And the effects of salient thinking may enhance, and in turn be enhanced by, another cognitive force that covers a significant number of the previously mentioned cognitive biases, errors, and fallacies: groupthink. An early exponent of the groupthink phenomenon was Janis (1971; 1972; 1982), who noticed the fact that social dynamics in a group can lead to dysfunctional decision outcomes; that is, people can sometimes make decisions as a group that are starkly different from those decisions they would make individually (see also Kahneman (2011) and the review by Esser (1998); contrast the findings about behaviour and decision-making in small groups of around a

dozen or less members, however, with findings on large-group decision-making, e.g., 'crowdsourcing' (Surowiecki 2004)[2]). Some of the main motivations that drive groupthink are a desire for consensus and conformity among group members (along with what is termed in social science as homophily; see, famously, Schelling (2006)). Groupthink can be harmful for decisions on endeavours like capex projects by IOCs because it tends to mitigate or eliminate dissenting viewpoints (e.g., it tends to reduce the effectiveness of a group member playing the role of 'devil's advocate' by considering possibilities that contradict the average opinion or position in the group). When it comes to weighing up risky outcomes that have not yet occurred (or else only rarely happen), groupthink can cause such remote possibilities to be heavily discounted.

Groupthink also tends to lead to insular thinking and causes unwarranted overconfidence among group members in the validity of decisions adopted by the group. And this effect only increases when groups are made of 'experts' and 'professionals' (see, e.g.: Telock (2005)). Given these negative properties of groupthink, it is worrying to realise that many IOCs exhibit a substantial number of the antecedent conditions that Janis identifies as giving rise to groupthink:

1. **Structural faults**: members' backgrounds are overly similar and this homogeneity leads to a lack of diverse viewpoints; there also tends to be a lack of methodological standards to follow that prevent some less obvious risks being overlooked (as tends to happen, e.g., in situations of high technological novelty, such as in engaging in 'pioneering' oil and gas projects with techniques that are mostly new); further, there is a large degree of secrecy or lack of visibility, allowing groups to operate in an insulated or semi-insulated way shielding them from much scrutiny.

2. **Situational context**: the decision-making environment is highly stressful and/or competitive, and groups feel that their right to operate is somehow challenged; recent performance has involved significant failures or setbacks; the decisions that must be made are inherently complex; moral dilemmas further complicate choices.

3. **Strong cohesion**: there is excessive priority placed on consensus and coordination among group members, and individual views are subjugated to a collective ethic.

It is alarming to recognise how many of these preconditions seem to characterise the situations faced by the leadership of IOCs. Inarguably, IOCs operate in a challenging, complex, and competitive space, and considerable secrecy surrounding some of their decisions and dealings exists (and is often excused, for instance, as necessary for competitive advantage in negotiating or operating). Moreover, the backgrounds of many IOC managers and other employees are typically fairly homogenous, given the technical standards of the work they must undertake (and while some engineering, environmental, and other regulatory standards do exist for more familiar methods, some of the most innovative projects lack such standards to a comparable degree). Additionally, many IOCs have experienced some poor performance or failures recently (e.g., BP Deepwater Horizon), and moral and ethical concerns connected to climate change are now a commonplace challenge that most IOCs must come to address. Finally, especially at the Board level, primacy of cohesion and collective function under a desire for 'efficiency' may dampen the degree to which members may adopt a suitable 'outside view' which exposes them to the so-called 'planning fallacy', whereby projects take longer, and are more costly and risky than is initially expected (see Kahneman 2012).

And it is vital to realise that groupthink and salience can exacerbate one another. For example, recent poor performance by an IOC will be judged relative to the performances of its peers: bad performance will appear even worse if others do not do nearly as badly, but will seem less unsuccessful if others also struggle. Likewise, an IOC cutting its dividend to shareholders might become even more salient if that IOC already pays a significantly lower dividend than its peers. We therefore note that situations of groupthink are likely to be more prevalent among those IOCs which are more salient to shareholders along dimensions that shareholders

[2] Recognise, however, that the sentiments of large groups are not immune to bias or fallibility, they just may be less so than small groups (see, classically: Akerloff and Shiller (2009)).

concentrate on in analysing IOCs, such as the scale of earnings (including per share earnings), dividends, reserve replacement ratios, and capital expenditures (among others). And such salience may be either positive or negative: strong underperformers may tend to feel embattled, and therefore engage in forms of groupthink, whereas strong outperformers may feel emboldened by their superior results and comparative standing, which thereby could also induce groupthink. Likewise, strong groupthink may accentuate the effects of salience, because it will generally decrease the likelihood that any member calls attention to less salient elements.

In the next two sections, we introduce tools for identifying those IOCs that may be experiencing the conditions for salience or groupthink that could dispose them to biases set out in Table 1.

3. Salience Detection and Relative Performance

Here, we show how the simple form for the salience function specified by Bordalo, Gennaioli, and Shleifer (2012) can be used as a tool for rapidly diagnosing which IOCs may be the most strongly predisposed to cognitively biased decision-making about which capex projects to pursue. To demonstrate the tool's pragmatism, we apply it to the actual public data of the six main IOCs: BP, Chevron, ConocoPhillips, ExxonMobil, Royal Dutch Shell, and Total. The selection of data to which we apply the salience tool is standard for much of the financial analysis that shareholders of IOCs tend to focus on: annual revenue, earnings (both overall and per share), capex, dividends, and reserve replacement figures.

We hasten to comment that this salience tool, along with the index tool presented in Section 4, are diagnostic heuristics: they are meant as a first step in rapidly identifying IOCs that exhibit characteristics that predispose them to biased decision-making; they do not concretely prove or disprove whether or not such biased thinking is indeed going on. We therefore perceive these tools as applying to the early steps that shareholders may take in engaging IOCs. Section 5 spells out some later steps that might be taken, based on what these tools indicate. Now let us turn to the mechanics of how the salience tool works.

3.1 Salience Calculations

Consider an IOC, represented by the variable i. Let a characteristic of i be denoted by x_i. Such a characteristic might be, e.g., the earnings per share of company i in a particular year, or its reserve replacement ratio for a given year. Let that same characteristic for another IOC j that is a peer of i be denoted by x_j. The salience of any IOC i on the characteristic x is determined by comparing the value of x_i to the average value of that characteristic among the peers of i, where that average excludes x_i. We can easily calculate that exclusive average according to:

$$f(\bar{x}_{-i}) = \frac{1}{N-1}\sum_{j \neq i} x_j \qquad [1]$$

In Equation 1 above, $f(\bar{x}_{-i})$ indicates the average value of the characteristic for the peers of company i (excluding i), and N is the total number of IOCs considered (including i).[3] A salience score for each IOC considered (that is, i as well as all of its $N-1$ peers) can then be readily calculated as:

$$s\big(x_i, f(\bar{x}_{-i})\big) := \frac{|x_i - f(\bar{x}_{-i})|}{|x_i| + |f(\bar{x}_{-i})| + \theta} \qquad [2]$$

In Equation 2, $\theta \in \mathbb{R}_+$ is an arbitrary, but strictly positive, constant. Its exact value is immaterial to calculating salience, so long as the same value is used for each company to which Equation 2 is applied. For convenience in this paper, we use the value $\theta = 0.1$. Equation 2 can then be used to rank companies from most to least salient on the characteristic x, whereby a smaller value for $s\big(x_i, f(\bar{x}_{-i})\big)$ corresponds with a lower rank.

We now apply the above formulae to a selection of actual public data from IOCs.

[3] See Bordalo, Gennaioli, and Shleifer (2012) for technical properties of all formulae that are in this section.

3.2 Ranking IOCs on Salience

In this subsection, we demonstrate the salience tool by ranking six IOCs (BP, Chevron, ConocoPhillips, ExxonMobil, Royal Dutch Shell, and Total) relative to one another based upon six characteristics of performance that are of general interest to most shareholders. These six characteristics are: total annual revenue; total annual net earnings; total annual capital expenditures (capex); annual earnings per share; annual dividends per share; and annualised reserve replacement ratios. All of these figures are extracted from the three latest annual reports (FYE 2014, 2013, and 2012) for each of the six companies. For the reader's convenience, these figures are all assembled together in tables that appear below. (Reserve replacement ratios are on proven reserves excluding acquisitions and disposals.)

Overall Revenue

$USD (millions)	2014	2013	2012
BP	358,678	396,217	388,074
Chevron	211,970	228,848	241,909
ConocoPhillips	55,517	58,248	62,004
ExxonMobil	411,939	438,255	480,681
Shell	421,105	451,235	467,153
Total	212,018	227,969	234,216
Average	278,538	300,129	312,340
Maximum	421,105	451,235	480,681
Minimum	55,517	58,248	62,004
Range	365,588	392,987	418,677

Overall Net Earnings

$USD (millions)	2014	2013	2012
BP	4,003	23,758	11,251
Chevron	19,241	21,423	26,179
ConocoPhillips	6,869	9,156	8,428
ExxonMobil	32,520	32,580	44,880
Shell	14,874	16,371	26,712
Total	4,250	11,521	13,836
Average	13,626	19,135	21,881
Maximum	32,520	32,580	44,880
Minimum	4,003	9,156	8,428
Range	28,517	23,424	36,452

Overall Capital Expenditures

$USD (millions)	2014	2013	2012
BP	22,546	24,520	23,222
Chevron	35,407	37,985	30,938
ConocoPhillips	17,085	15,537	14,172
ExxonMobil	38,537	42,489	39,799
Shell	31,854	40,145	32,576
Total	30,509	34,431	29,475
Average	29,323	32,518	28,364
Maximum	38,537	42,489	39,799
Minimum	17,085	15,537	14,172
Range	21,452	26,952	25,627

Earnings Per Share (Diluted)

$USD	2014	2013	2012
BP	0.20	1.23	0.58
Chevron	10.14	11.09	13.32
ConocoPhillips	5.51	7.38	6.72
ExxonMobil	7.60	7.37	9.70
Shell	2.36	2.60	4.26
Total	1.86	4.94	6.02
Average	4.61	5.77	6.77
Maximum	10.14	11.09	13.32
Minimum	0.20	1.23	0.58
Range	9.94	9.86	12.75

Dividends Per Share			
$USD			
	2014	2013	2012
BP	0.39	0.37	0.33
Chevron	4.21	3.90	3.51
ConocoPhillips	2.84	2.70	2.64
ExxonMobil	2.70	2.46	2.18
Shell	1.86	1.78	1.71
Total	3.00	3.24	3.05
Average	2.50	2.41	2.24
Maximum	4.21	3.90	3.51
Minimum	0.39	0.37	0.33
Range	3.82	3.54	3.18

Organic Reserve Replacement Ratios			
	2014	2013	2012
BP	63%	129%	77%
Chevron	89%	85%	112%
ConocoPhillips	124%	179%	156%
ExxonMobil	111%	106%	124%
Shell	46%	123%	85%
Total	107%	89%	75%
Average	90%	119%	105%
Maximum	124%	179%	156%
Minimum	46%	85%	75%
Range	78%	94%	81%

Using the above figures, we can calculate salience rankings for each of the IOCs across these six characteristics. A table that shows such salience rankings appears below. Note that in the below table of salience rankings that a lower ranking (e.g., 1 versus 2) corresponds to higher salience for the IOC in question than that for its peers with a higher number (for example, Overall Net Earnings for ConocoPhillips in 2013 were more salient than were those of the other five IOCs against which it is compared). (For simplicity, none of these dimensions is given any more weight than other dimensions; this equal weighting reflects the fact that some investors may focus on some dimensions more strongly than others, but that this focusing may vary from one investor to the next. Future empirical work might benefit from studying in detail which dimensions of salience typically dominate other ones.)

Salience Rankings																		
	Overall Revenue			Overall Net Earnings			Overall Capex			Earnings Per Share			Dividends Per Share			Organic Reserve Replacement Ratios		
Company	2014	2013	2012	2014	2013	2012	2014	2013	2012	2014	2013	2012	2014	2013	2012	2014	2013	2012
BP	6	4	6	1	4	3	3	3	3	1	1	1	1	1	1	2	5	3
Chevron	4	6	5	5	6	6	4	5	5	2	3	2	2	2	2	6	2	6
ConocoPhillips	1	1	1	4	1	1	1	1	1	6	4	6	5	5	5	3	1	1
ExxonMobil	3	3	2	3	2	2	2	2	2	5	5	4	6	6	6	4	4	5
Shell	2	2	3	6	5	5	5	4	4	4	2	3	3	4	4	1	6	4
Total	5	5	4	2	3	4	6	6	6	3	6	5	4	3	3	5	3	2

What is interesting to note about the above rankings is that they are remarkably stable, given the sometimes drastic fluctuations in the figures reported in earlier tables. Note particularly that the average salience ranking for the IOCs across the six characteristics for all three years is as follows: ConocoPhillips 2.67; BP 2.72; ExxonMobil 3.67; Royal Dutch Shell 3.72; Chevron 4.06; Total 4.17. For the six characteristics in 2014 alone, the average ranking is: BP 2.33; ConocoPhillips 3.33; Royal Dutch Shell 3.50; ExxonMobil 3.83; Chevron 3.83; Total 4.17. For 2013 the average ranking is: ConocoPhillips 2.17; BP 3.00; ExxonMobil 3.67; Royal Dutch Shell 3.83; Chevron 4.00; Total 4.33. For 2012 the average ranking across the six characteristics is: ConocoPhillips 2.50; BP 2.83; ExxonMobil 3.50; Royal Dutch Shell 3.83; Total 4.00; Chevron 4.33. Hence, overall, BP and ConocoPhillips vie with one another for being the most salient companies.

What is intriguing to note, however, is that BP and ConocoPhillips are salient on the above characteristics, but for starkly different reasons. ConocoPhillips' salience is driven by its strong outperformance, whereas BP's

salience stems from its pronounced lagging behind peers on the characteristics studied. With respect to cognitive bias, and particularly groupthink, both ConocoPhillips and BP may be more susceptible than their peers, but from distinct causes. For example, leadership at ConocoPhillips may feel that its strong showing relative to competition makes it less vulnerable, and may drive both overconfidence and inattentiveness to unforeseen risks (or at least more so than for less salient performers). Meanwhile, BP's situation may be characterised by its leadership feeling embattled due to its recent failures, which could create pressures necessary for groupthink, inattention to unfamiliar risks, and improper allocations of scarce resources.

Hence, a recommendation for shareholders would be to focus more energy and time on exploring what leadership at BP and ConocoPhillips may be doing to combat biased decision-making, relative to resources spent on other IOCs that are less salient. Section 5 discusses some possibilities for doing so in greater detail. For now, readers are asked to recall the fact that the remuneration schemes for many top IOC executives are geared toward rankings relative to peers, although not using the salience scores introduced above. Instead, those executive remuneration structures involve rankings on characteristics (some of which are those appearing above), and compensation being tiered according to, for example, whether the IOC in question is first, second, third (etc.) in rank. An interesting evolution for such compensation schemes might be to take into account not simply ordinal rank (as they now do) but also the degree of difference (e.g. salience).

Comparisons with peers is not, however, the only way that salience might affect the decision-making by IOCs. As the next subsection suggests, relative performances among the capex projects of any single IOC may create contrast effects driven by salience.

3.3 Impacts of Project-Level Salience

This brief subsection discusses how salience (as a pervasive feature of human cognition) may partly drive the tendency for increasing capex density that can be seen among IOCs. Given the fact that project-level data for IOCs' capex projects are not readily available to the general public, our arguments are mostly stylised, and do not rely on specific values (readers interested just in applications may wish to skip directly to Section 4 at this point).

To begin, recognise that salience is always relative to the 'comparison set', that is, the focal value being considered as well as the alternatives against which it is contrasted. In the case of a portfolio of capex projects at an IOC, this comparison set is generally all of the projects in which the IOC is currently engaged, or else may possibly be considering. If one applies Equations 1 and 2 from Subsection 3.2 to the project portfolio of an IOC (wherein the projects replace companies, and characteristics are associated with projects and may include, e.g., project size, return on investment, or duration), then it should be fairly obvious that any particular project will tend to be more salient if it is compared with projects that are on average worse than it on some relevant characteristic. That is, a capex project that would be considered only mediocre in isolation may instead be perceived as excellent if it is compared with projects that are all underperforming (i.e., are at least slightly worse than mediocre). It is not difficult to see how this phenomenon can induce a 'rich-get-richer' process of resource allocation. For example, with a slight drop in the price of oil or gas, most projects may underperform, although some projects will underperform less badly than others. These 'less bad' projects will look far better than they really are because of the comparative nature of salience, and therefore may be allocated more resources (e.g. additional investment) than is deserved on their own merit. Such additional resources then will tend to improve the performance of these 'less bad' projects, and may increase their scale, which should tend to make them even more salient relative to other projects in the portfolio and possible attract even more resources to them. Meanwhile, managers in charge of these 'less bad' projects may also receive substantial (albeit not fully warranted) credit for 'artificially enhanced' performance, and have excess confidence placed in them (or overconfidence in themselves) in the future.

And given the fact that resources available to IOCs are not unlimited, this general impact of salience from slight initial differences could eventuate in increased capex density through what is popularly known as 'inefficient

internal capital markets' (i.e., the processes by which a firm apportions its capital resources are not based fully on the risk-adjusted expected returns of a project or division, but by other factors – such as salience or managerial influence – that serve to create and reinforce inefficiency in how capital is spent within the firm). This salience-driven explanation for increased capex density is, however, only part of the story, as there are surely also forces of constrained supply at work (i.e., the number of new potential projects available to IOCs is increasingly limited). Nevertheless, this role of salience in explaining capex density remains both plausible and substantial, and should concern shareholders considerably because, unlike the supply component of the story, inefficient internal capital allocation is under the control of IOCs.

Rook and Caldecott (2015) offer a number of solutions for partly remedying this situation. What they do not address extensively, however, is the role that groupthink may have in exacerbating the influences of salience, and how salience can worsen groupthink. The next section of this paper explores that topic in detail, and proposes a detection tool.

4. Detecting Groupthink and Board Composition

Some of the fundamentals underpinning groupthink were covered in Section 2. But an immediate challenge concerning groupthink for shareholders (and indeed any external party) is how to discern when groupthink is actually taking place in IOC decision-making. Bluntly, there is no practical way to directly detect whether groupthink is occurring without being present when decisions are made by IOC leadership, and such presence is in almost all cases unworkable. Instead what should be sought is an indirect method for determining when the appropriate conditions exist that might promote groupthink. It is such a method that we now present. And to understand how this approach works, it is important to see how groupthink stems from the balance of in- and out-group dynamics.

In-groups and out-groups are concepts from sociology and social psychology that have recently found their way into the thriving field of (social) network analysis (also called graph theory). These designations are popular partly because they are straightforward to understand: an in-group is a particular social category to which some individual belongs (and identifies herself as belonging), and an out-group is one to which she does not belong (and recognises that she does not belong). Hence, in-groups and out-groups are determined relative to a target individual, and may vary with both the individual being considered, as well as the social categories (e.g., age, gender, occupation) that are used to distinguish in-groups from out-groups. And it is the balance of in-groups to out-groups that strongly influences groupthink. That is, groupthink is most likely when all (or some influential majority) members of a group belong to a relevant in-group.

One convenient statistic for measuring this in-group/out-group balance that underpins much of groupthink is Jaccard distance. Below, we describe how this simple statistic functions, and then use it to examine the composition of IOC Boards of Directors.

4.1 Jaccard Distance

Consider two individuals a and b who belong to a group of N people. Each person is identified by a number $Q \in \mathbb{Z}_+$ of *qualities* (e.g., age, gender), and each specific quality q_a for any person a has a number of levels (for example the quality gender has two levels, female and male; levels need not be seen as ordered, and in most cases are not ordered). (It should be obvious that any one person has a massive number of qualities associated with them; here we only consider a limited number of qualities as being relevant, and the number of relevant quantities dictates how large is the integer variable Q.) Two individuals a and b are said to belong to the same in-group for a quality if $q_a = q_b$ (e.g., if both a and b are female) but belong to different in-groups for the quality when $q_a \neq q_b$.

Let $p_{A,B}$ be the number of in-groups of which a and b are both members for the set of qualities Q. Hence, $0 \leq p_{a,b} \leq Q$. If $p_{A,B} = 0$ then a and b do not belong to any of the same in-groups, but when $p_{a,b} = Q$ they belong to all of the same relevant in-groups. Thus, we would expect groupthink to be more likely when $p_{a,b}$ is nearer to Q than when it is closer to zero. Jaccard distance is a convenient way of capturing this relationship, and it relies on the Jaccard index, which is expressed via notation above in the following way:

$$j(a,b) \coloneqq \frac{p_{a,b}}{Q} \qquad [3]$$

It should be noted that the Jaccard index $j(a,b)$ is 'symmetric' in that $j(a,b) = J(b,a)$ for any two individuals a and b. With the Jaccard index, Jaccard distance is then defined as:

$$d_j(a,b) \coloneqq 1 - j(a,b) \qquad [4]$$

Using Jaccard distance makes determining the in-group/out-group balance between two people straightforward: if $d_j(a,b) = 0$ then there is no 'social distance' between a and b because they are both members of all of each other's in-groups; but $d_j(a,b) = 1$ means that neither a nor b share any of the same in-groups. Likewise, values of $d_j(a,b) < 0.5$ mean that a and b share more in-groups than memberships that they do not share, while $d_j(a,b) > 0.5$ indicates that the pair share fewer in-groups than those they do not share. Hence, we should expect that groupthink is more probable when $d_j(a,b)$ is relatively low for most pairs of individuals in a group of size N when Q qualities are deemed relevant.[4]

It should be noticed that Jaccard distance is best applied when groups are not terribly large, because the methodology demands that $Q \cdot \frac{N!}{2(N-2)!}$ comparisons be made.[5] Hence, this methodology is suitable for comparing the in-group/out-group balances of Boards of Directors (as is done in the next subsection) because these are of modest sizes. Notice that each individual in a group will have $N-1$ Jaccard distances associated to her (because it makes sense to compare her to all other group members but not to herself). For comprehensiveness, we recommend that, in applying Jaccard distance for diagnosing situations where groupthink may exist, mean, median, and mode statistics for the $\frac{N!}{2(N-2)!}$ Jaccard distances that must be calculated for a group of size N. The use of mean, median, and mode gives a better picture of how distributed the Jaccard distances are among group members (and using any one of these statistics in isolation may provide a distorted view).

4.2 In-Group/Out-Group Balance of IOC Boards

In this subsection we use the Jaccard distance tool to explore the relative balance of in-groups and out-groups of Boards of Directors at six IOCs: BP, Chevron, ConocoPhillips, ExxonMobil, Royal Dutch Shell, and Total. We consider five qualities of Board members: gender, age, tenure, nationality, and degree of experience outside the oil and gas industry. We recognise that these qualities are only a small selection of those that might matter for Board diversity, and that could potentially bear upon groupthink. Nonetheless, we assert that these five qualities are major contributors to social classification, and while they are far from exhaustive they capture important elements of the social dynamics that could lead to groupthink. Moreover, these qualities are all readily available from public reports by IOCs, and are to a large extent objective in nature. To allow readers to check our calculations for themselves, all of the underlying data on Board members for the six IOCs studied is reproduced within an Appendix to this paper.

Construction of the five quality variables is as follows. Gender and nationality are perhaps the most straightforward, because they clearly interpreted as discrete categories. Given the typical ages of Board members (usually between 50 and 70 years old), we suggest that two Board members are in the same age in-group if they are within ten years of age of one another. For tenure, we divide the distribution of tenures for all members of any single Board into quartiles, and identify two members that are in the same quartile as being part of the same tenure in-group. This approach controls for the fact that Boards may go through periods of rapid turnover, but also have some longer-tenured members. Finally, we construct the experiences variable as having three levels. One level involves Board members that have no substantive professional experience outside the oil and gas industry. The second level involves those that have worked in the oil and gas industry, but also have substantive experience outside it. The third level involves members who have only experience outside of the oil and gas industry. We suspect that this experience variable may have a strong impact on groupthink as oil and gas 'outsiders' may have a much different perspective on the riskiness of capex projects than do those on the 'inside'.

[4] Readers familiar with graph theory may see that this technique is similar to the idea of degree distribution.
[5] Here the 'bang' symbol (!) has its mathematical interpretation as the factorial of the quantity preceding it.

Based on the methodology described above, the following statistics on Jaccard distance are generated for the six IOC Boards across the five qualities that are considered. (Readers should bear in mind that scores nearer to zero correspond to a stronger lack of measured diversity – i.e., *homogeneity* – and that scores closer to one indicate a higher degree of measured diversity – i.e., *heterogeneity* – for those IOC Boards that were studied in this research.)

Company	Mean	Median	Mode
BP	0.514	0.600	0.600
Chevron	0.300	0.200	0.200
ConocoPhillips	0.461	0.400	0.200
ExxonMobil	0.309	0.200	0.400
Royal Dutch Shell	0.530	0.600	0.400
Total	0.508	0.600	0.600
AVERAGE	***0.437***	***0.433***	***0.400***

From the above table, several observations immediately stand out. Firstly, two Boards in particular have scores for Jaccard distance that are significantly below the average mean, median, and mode values for their peers: Chevron and ExxonMobil. Interestingly, the third American IOC in the group, ConocoPhillips, also shows typical Jaccard distance scores below 0.500, which, like Chevron and ExxonMobil, indicates that the composition of the Board of Directors is more homogenous than it is diverse (at least along the five qualities dimensions that were explored in this study). Hence, we can conclude that, for those three American IOCs, Board members share more in-groups than out-groups for the five qualities examined. As was stated earlier, having a higher quotient of in-groups than out-groups for a decision-making body such as a Board of Directors can be problematic in that it can drastically increase the likelihood for groupthink biases. Ergo, we should expect that the Boards of Chevron and ExxonMobil (and, to a lesser extent, ConocoPhillips), may be more susceptible to groupthink than are their peer IOCs.

Another observation that is apparent from the above presentation of Jaccard distances is the fact that BP ranks higher than all of its peers apart from Royal Dutch Shell. This positioning stands in contrast to the analytical findings from the previous section, where BP vied with ConocoPhillips for having the highest salience scores in most dimensions of performance. A straightforward explanation for BP's improved standing with respect to Board composition may be that, in the wake of its involvement in the Deepwater Horizon incident of 2010, substantial Board turnover occurred (nine of the 14 BP Board members are new to the Board since 2010), and BP's focus has been in introducing greater diversity of perspective and experience to its uppermost leadership. This shift may partly mitigate the effects due to BP's high salience ranking (see Section 3) in helping BP's key decision makers and overseers to reduce the bias in their judgments. Conversely, the ranking of ConocoPhillips near the bottom of both salience and Jaccard distance measures may signify that shareholders should be wary of the increased possibility of biased thinking at that company, especially in light of higher capex density.

Yet the above results also underscore what could be a business-cultural phenomenon of broader import: the fact that American Boards of Directors may be less diverse than some of their overseas peers. While none of the IOC Boards examined should be extolled for diversity (none of the scores were much better than 0.500; in particular, all six Boards had far fewer female than male members), the American Boards are noticeably more homogenous than are the non-American Boards (i.e., BP, Shell, and Total). Two dimensions on which American Boards seem to especially lag their non-American counterparts is in diversity of nationality, and age breadth. For example, the Board of Chevron had no members without American citizenship, and ExxonMobil had only one of its dozen members without American citizenship (ConocoPhillips was only slightly more diverse, with two of its 12 members being of non-American nationality; one of these members is, however, still North American, as he is a Canadian citizen). Furthermore, the age ranges of the American Boards is typically less than that of their non-American peers; of note, the difference between the eldest and youngest ages of members for both Chevron and ExxonMobil is 16 years, whereas it is 38 for Total. Given that significant results in psychological research find significantly different attitudes toward risk across nationality and age profiles, the homogeneity of American Boards in these respects is worrying, and could serve to increase the propensity for groupthink (or, at the very least, it does nothing to decrease the likelihood of groupthink) (consult, e.g.: Blais and Weber (2006)).

Of course, there are certainly other dimensions of qualities that help determine Board diversity and may either amplify or mitigate the propensity for groupthink. Some other candidate dimensions are, for example: alma mater or degree studied; other shared Board memberships; shared political or charitable affiliations; and recreational interests. Readers may wish to perform their own analyses that incorporate additional factors such as those mentioned above. Furthermore, the methodology adopted so far has given equal weighting to the five dimensions studied; this approach is an obvious simplification, and it may well be that some dimensions contribute more to combating groupthink than do others. For now, however, we maintain the simplified approach as it keeps analysis tidy.

Nevertheless, in attempting to approach the problem of analysing Board diversity and predisposition to groupthink in a rigorous way, we seek to explore the impact of a further dimension of heterogeneity in Board structure: committee co-membership. Although any Board may be judged in terms of its gross membership, most corporate Boards also involve committees that are in charge of particular Board-level tasks, such as executive compensation, audits, public/environmental policy, and ethics (as well as further, company-specific concerns). Most IOC Boards have between four and six such (permanent) committees, and only a select subset of Board members are typically part of any one committee (although many members are on more than one committee).

Hence, one can understand committees as further forms of 'clique' within a Board; and if such cliques are relatively homogenous in composition (i.e., the Jaccard distances between their members are relatively low), then this possibility may greatly increase the potential for groupthink. Such a threat is buoyed by the realisation that members belong to particular committees as a result of their 'expertise' relevant to that committee. Consequently, the recommendations of a committee to the Board at large usually carry substantial weight, and may exert material influence on the Board's decisions. But, if committees themselves lack diversity, their recommendations may be tainted by groupthink. Contrastingly, if committees have relatively homogenous members, then groupthink may become increasingly less likely, as groupthink may be less commonplace in smaller groups (which committees are in relation to the larger Board) with members of mixed backgrounds and perspectives.

We therefore conjecture that if IOC committees are proportionally more diverse than the wider Boards of which they are subcomponents, then there should be a slight increase in the measured Jaccard distances as a result of including a 'committee co-membership' dimension to the five earlier dimensions. To facilitate analysis of this hypothesis, we add a further variable that adds to the five earlier dimensions, and is equal to one if two members are both part of at least one committee together, but zero if they are on no committees together. Re-running the earlier Jaccard distance analysis with this added variable generates the table of statistics below (the parenthetical numbers are those from the five-dimension analysis run earlier, and are included for the reader's convenience in making comparisons).

It should be evidence from the above figures that, apart from Chevron, adding the committee co-membership variable makes little impact on the Jaccard distance statistics for IOC Boards. This finding can be interpreted as meaning that, on average, committees of IOC Boards are practically no better off than the Boards at large in terms of diversity, and hence are no less immune than their respective Boards at large to the threat of groupthink (a comparable interpretation is that the committees are not likely contributing to any noticeable extent to the reduction in groupthink for the Boards to which they belong). The exception of Chevron is notable, in that it is the only IOC Board with a (modestly) significant increase in its Jaccard distance statistics as a result of including this committee co-membership dimension (those other Boards with some improvement to their Jaccard distance statistics only saw very slight improvements, in terms of raising the figures; yet these increases were minimally significant). That said, it is still observable that, even with its modest improvement, Chevron's Board still remains in the bottom two (along with ExxonMobil) among its peers with respect to Jaccard distance values.

4.2 Synthesis and Caveats on Jaccard Distance

Overall, the results from the Jaccard distance analysis in this section are not terribly encouraging, and suggest that groupthink may be a threat on many IOC Boards due to the fact that there are proportionally more in-groups shared between members than there are out-groups on the six dimensions explored. In particular, the scores from the Jaccard analysis were noticeably worse for the Boards of the American IOCs than for the non-American IOCs; resultantly, shareholders of Chevron, ConocoPhillips, and ExxonMobil may especially wish to pursue action paths that might help to address and remedy concerns about whether leadership at those IOCs is making strides to guard against biased thinking in decision-making, particularly with respect to risk management for both individual capex projects, as well as the construction of portfolios of capex projects. The next section of this paper presents a number of recommendations to shareholders on how to engage IOC leadership about these issues.

Before proceeding to those recommendations, however, we pause to reinforce the heuristic nature of these tools (as the tone of communications by shareholders to the leadership teams at IOCs should be tempered by an appreciation for this heuristic character): the tools in this section and earlier ones are meant as diagnostic expedients, and cannot by themselves prove or disprove the existence of cognitively biased decision-making. Instead, their role is to empower shareholders by shining a figurative torch on areas of potential concern; and because most shareholders are not able to directly witness the decision processes of IOC leadership, such tools are a pragmatic approach to a problem that has previously not had any other realistic solutions. In light of these considerations, we reiterate that tools like the salience function and Jaccard distance should be used by shareholders (along with other concerned parties) to initiate conversations, and other forms of engagement, with IOC managers and Boards (for more ideas on these pursuits, see Sullivan and Mackenzie (2006). We now turn to some further 'next steps' that concerned shareholders may wish to take after making use of these diagnostic tools.

4.3 Historical Capex Forecasting Deviations

In practical terms, some readers may question whether measures such as those given above have any visible expression in historical data. While any such visibility is only an indirect test of whether factors such as salience and groupthink (and the tools for examining them that we have presented here) are actually driving capex patterns among IOCs, there is some rather pronounced evidence that this situation is in fact true. Most IOCs (especially American IOCs) issue regular guidance on the next year's capital expenditures in their annual filings. We have reproduced both these guidance figures and the actual capex values from the subsequent year for 2016-2014 for those four IOCs that regularly issue guidance in their annual reports (BP, Chevron, ConocoPhillips, and ExxonMobil). As discussed below, some rather noticeable patterns are observable from these reported values.

Table 2: Historical capex – actual and guidance – for selected IOCs

Capital Expenditures ($USD Billions)	BP	Chevron	Conoco-Phillips	ExxonMobil	Aggregate	Average
2006						
Actual	16.9	16.6	15.6	19.9	69.0	17.3
YoY Change	*21.7%*	*49.5%*	*34.2%*	*12.4%*		*29.5%*
Guidance	11.0	14.8	11.2	18.0	55.0	13.8
% Gap	*53.7%*	*12.2%*	*39.3%*	*10.6%*		*28.9%*
2007						
Actual	19.2	20.0	11.8	20.9	71.9	18.0
YoY Change	*13.5%*	*20.5%*	*-24.4%*	*5.0%*		*3.7%*
Guidance	18.0	19.6	12.3	20.0	69.9	17.5
% Gap	*6.6%*	*2.0%*	*-4.1%*	*4.5%*		*2.3%*
2008						
Actual	21.7	22.8	19.1	26.7	90.3	22.6
YoY Change	*13.0%*	*14.0%*	*62.0%*	*27.8%*		*29.2%*
Guidance	21.5	22.9	14.3	27.5	86.2	21.6
% Gap	*0.9%*	*-0.4%*	*33.6%*	*-2.9%*		*7.8%*
2009						
Actual	20.0	22.2	10.9	27.1	80.2	20.0
YoY Change	*-7.8%*	*-2.6%*	*-43.1%*	*1.5%*		*-13.0%*
Guidance	20.5	22.8	11.7	27.5	82.5	20.6
% Gap	*-2.4%*	*-2.6%*	*-7.2%*	*-1.5%*		*-3.4%*
2010						
Actual	18.2	21.8	9.8	32.2	82.0	20.5
YoY Change	*-8.9%*	*-1.8%*	*-10.1%*	*18.8%*		*-0.5%*
Guidance	20.0	21.6	10.5	27.5	79.6	19.9
% Gap	*-8.9%*	*0.9%*	*-7.0%*	*17.1%*		*0.5%*
2011						
Actual	19.6	29.1	13.3	36.8	98.7	24.7
YoY Change	*7.5%*	*33.5%*	*35.9%*	*14.3%*		*22.8%*
Guidance	20.0	26.0	12.8	35.0	93.8	23.5
% Gap	*-2.1%*	*11.9%*	*3.6%*	*5.1%*		*4.7%*
2012						
Actual	24.0	34.2	14.2	39.8	112.1	28.0
YoY Change	*22.3%*	*17.5%*	*6.8%*	*8.1%*		*13.7%*
Guidance	22.0	32.7	13.3	37.0	105.0	26.3
% Gap	*8.9%*	*4.6%*	*6.6%*	*7.6%*		*6.9%*
2013						
Actual	24.6	41.9	15.5	42.5	124.5	31.1
YoY Change	*2.7%*	*22.5%*	*9.6%*	*6.8%*		*10.4%*
Guidance	24.5	36.7	14.7	38.0	113.9	28.5
% Gap	*0.4%*	*14.2%*	*5.7%*	*11.8%*		*8.0%*
2014						
Actual	22.9	40.3	17.1	38.5	118.8	29.7
YoY Change	*-6.9%*	*-3.8%*	*10.0%*	*-9.3%*		*-2.5%*
Guidance	24.5	39.8	16.7	37.0	118.0	29.5
% Gap	*-6.6%*	*1.3%*	*2.3%*	*4.2%*		*0.3%*
Average YoY Change						
2010-2014	*3.3%*	*13.6%*	*10.4%*	*7.7%*		*8.8%*
2006-2014	*6.3%*	*16.6%*	*9.0%*	*9.5%*		*10.4%*
Average Gap						
2010-2014	*-1.7%*	*6.6%*	*2.2%*	*9.2%*		*4.1%*
2006-2014	*5.7%*	*6.1%*	*8.2%*	*6.6%*		*6.6%*
% Difference (Actual)						
2014 v 2006	*35.4%*	*142.8%*	*9.5%*	*93.7%*		*72.2%*

Note: Midpoints are taken as guidance figures wherein ranges are reported; where vague guidance (e.g., occasionally ExxonMobil) is issued so that next year's capex is expected to be approximately the same as the reported year's, the reported year's value is rounded to the nearest whole billion (USD) and used as the guidance value for the next year.

One of the most striking features of these values is the trend of recent divergence in capex that they demonstrate. Notice that in 2006 the annual capital expenditures of the four IOCs were very similar in scale (i.e., between USD 15.6 and 19.9 billion), whereas in 2014 the range between the greatest amount of capex (Chevron at USD 40.3 billion) and the least (Conoco-Phillips at USD 17.1 billion) had yawned massively (such that Chevron's capex in 2014 was more than double Conoco-Phillips'). What is further surprising is the enormity of growth in many IOCs' capex, especially Chevron and ExxonMobil. Yet perhaps another feature that is flagrantly visible is the greater accuracy that BP has as compared to its three American counterparts in forecasting its own capital expenditures. Especially in recent years, BP appears to be far more proficient than its American peers in issuing guidance for its next year's capex that is near the actual value of expenditure for that subsequent year (in fact, since 2010 BP has actually *overestimated* its capex guidance values). What is most alarming about these deviations from guidance (which can reach 20-30%, or more, above forecasted values) is that they are for relatively short horizons: only the next 12 months. These wild deviations in some cases suggest a lack of sufficient control by IOC leadership of their capex patterns, and reinforces many of the concerns that have been aired in this paper regarding cognitive biases.

And while it may be expected that greater variability in capex should be expected as any IOC increases in size (as is true with most companies, even outside of the oil and gas industry), what is perhaps worrying is that the percentage variability in forecasting error for some IOCs does not seem to be remaining constant in proportion to size; that is, investors should be concerned that, even though IOCs are growing, they may not be improving their ability to control the pace or costliness of such growth. Such fears should be even more troubling if the industry takes a turn to acquisitive, rather than simply organic, growth, as it seems to be showing some interest in doing.[6]

[6] See, for instance, Adams (2015).

5. Pragmatic Action Paths for Concerned Shareholders

This section furnishes a succinct listing (and cursory discussion) of some of the most pragmatic action paths that concerned shareholders (and other interested parties) may wish to pursue to help to mitigate the threats posed by cognitive bias in IOC decision-making (especially under the growing trend of increased capex density among IOCs). To situate the analysis, we provide a 'tiered ranking' of IOCs based upon the outputs of analyses conducted in the previous two sections (i.e., using the salience function and Jaccard distance). Tier 2 is comprised of the two companies – Shell and Total – that demonstrated themselves as less predisposed to vulnerability from cognitive bias based on the dimensions tested and tools used in this paper. While shareholders should still be vigilant, the approaches that they may wish to use on these IOCs possibly differ from the Tier 1 companies, which showed themselves as relatively vulnerable to cognitive bias based on analyses here: BP; Chevron; ConocoPhillips; and ExxonMobil. We further subdivide Tier 1 into two sub-tiers, Tier 1-S and Tier 1-J, that correspond with those companies that scored worst on salience and Jaccard statistics, respectively.

- Tier 1-S: BP; ConocoPhillips
- Tier 1-J: Chevron; ExxonMobil
- Tier 2: Royal Dutch Shell; Total

Based on such tiers, we propose the following action paths as potential future remedies.

5.1 Initial Inquiry

Most IOCs have mechanisms in place for concerned shareholders to make inquiries about corporate performance and governance systems. These mechanisms usually take the forms of, e.g., designated investor-relations teams to field questions by shareholders and specific avenues for posing inquiries to Boards of Directors. Posing questions to IOC leadership through either venue would seem suitable for any Tier; after all, most IOCs do not make explicit public disclosures about the steps they pursue to alleviate the likelihood and severity of biased decision-making (e.g., through fixed protocols in meetings that foster healthy scepticism, or binding use of particular risk analysis formats) and shareholders have a right to know whether or not such methods are used.

If the results from these initial stages of inquiry prove unsatisfactory, then shareholders may wish to escalate their concerns by taking more aggressive action paths, such as attempting to secure space on the Board's agenda for these matters to be dealt with, or placing these concerns as a formal item on the agenda at an annual general meeting (another alternative could be raising relevant questions on quarterly earnings calls). Collective action on these paths will likely produce more effective impact than individual activity, and shareholders (particularly those owning large positions) may wish to collaborate in ensuring that IOC leadership is paying the appropriate level of attention in addressing concerns arising on potential cognitive bias.

If, however, these initial attempts at inquiry continue to yield unsatisfying answers (or non-response) from IOC leadership, then alternative paths may be needed.

5.2 Demanding Explicit Disclosure

Lobbying for explicit disclosure of the steps and protocols that IOC leadership teams have in place to guard against biased thinking – especially under increasing capex density – may be one possible remedy for shareholders who are unsuccessful at having their concerns addressed through initial inquiry steps; in fact, it may pose a pragmatic path even if such initial inquiries are satisfactory, as the presence or absence of such

protocols may pose a material risk to the business performance of IOCs themselves. As such, shareholders may be entitled to such information, and may be able to demand it from IOCs. While we only speculate here that such entitlement is indeed justified, future work may explore whether or not there appears to be legal grounds to require IOCs to report what protocols they formally have in place to guard against cognitive errors (like groupthink) (and if there is a breach of duty to shareholders in not doing so).

5.3 Requesting Board Diversity

A third potential action path pertains mostly to Tier 1-J companies, but could apply to any of the IOCs studied: requesting greater Board diversity. Corporate Boards of Directors are meant to safeguard the interests of the companies they represent, as well as shareholders' interests as owners of those companies. Part of this responsibility in stewardship involves considering threats and challenges to the company from diverse perspectives that should help to prevent biased decision-making; yet diversity of perspective seems suspect if all Board members come from too similar backgrounds, and the potential for groupthink that results from this homogeneity is antithetical to the very raison d'être for corporate Boards. It thereby seems crucial that Board diversity be a top priority for IOCs, especially in light of the trend of increasing capex density. And while some strides may have been made in recent years in injecting more diverse members into Boards, the primacy placed on 'group cohesion' (as is evident from many of the public disclosures by IOCs in discussing their governance systems and Board selection and control mechanisms) may do more to induce groupthink that guard against it. We suggest that shareholders make their voices strongly and clearly heard when it comes to demanding that deep consideration be granted to the ways in which Boards are constructed, and attention paid to novel, useful dimensions of heterogeneity.

6. Summary and Future Research

This paper has been concerned with the topic of cognitive bias in the decision-making of the leadership of international oil companies (IOCs). The matter of psychological bias in such decisions is perhaps more relevant now than ever before for such companies because of a trend toward increasing density in the capital expenditures among IOCs; that is, IOCs are tending to spend more on a volume of projects that is proportionally either stagnating or declining. The result is that project size is increasing, and with it the risk profiles of IOCs' portfolios of capex projects may likewise be changing, although not necessarily for the better. In previous research (Rook and Caldecott (2015)) we explored this concern for intensifying capex density. Here, however, we are more concerned with the risk-management capabilities among IOCs, and whether these management systems for dealing with risk are robust to various forms of cognitive bias.

We have suggested that, indeed, a large number and diversity of cognitive biases, errors, and fallacies may accompany the increased density of capex by IOCs. Yet we further recognise that identifying these myriad biases, errors, and fallacies poses an enormous task for shareholders. A core proposal of this paper is that many of these biases can in fact be subsumed by two cognitive forces, salience and groupthink, that are both powerful as well as likely in the dealings of IOCs. Two diagnostic tools – relying on a salience function and Jaccard distance – were proposed to tease out the relative likelihood that either of these related cognitive forces may be impacting (or come to impact) the decision-making by IOC leadership teams.

Based on the preliminary analysis contained in this paper, we can make the assertion that the null hypothesis of cognitive bias not being present among IOCs cannot be comfortably refuted; various signs point to IOCs being predisposed to committing flawed decisions and exposed to psychological errors in judgment. In particular, the American IOCs (Chevron, ConocoPhillips, and ExxonMobil) may be at especial risk with respect to these vulnerabilities. To help shareholders address these possible threats, we have suggested three main action paths that might be gainfully pursued to force change. Future research should, in the first instance, seek to expand and elaborate upon, this initial list of feasible remedies.

Moreover, there exist a number of other clearly visible items for future exploration that we wish to highlight in closing. First, the present work has been mostly aimed at introducing new tools, and future work should look to apply these (and other tools) for diagnosing propensity for cognitive bias to larger data sets. To keep the analysis simple, we have only examined IOC financial and operational performance (in Section 3) using the past three years of reported data. Next stages of work in evolving the salience function could look at longer time series of data, and could conduct comparative analysis with other industries in order to arrive at more comprehensive benchmarks of relative performance.

Secondly, the tools and analysis used in this paper have (purposely) been 'distanced' in nature; that is, they do not rely on any form of interaction or 'close dialogue' with IOCs themselves (see Clark (1998) on the merits of such approaches in corporate research). This tack was adopted to advantage those shareholders that might not have such dialogue capabilities readily available to them, but nonetheless wish to conduct pragmatic analyses of IOCs' risk propensities. Nevertheless, future extension to this research project should look to bolster the methods and analysis here with more interpersonal investigation (e.g. interviews) with IOC leadership teams. Such deepened investigation should only enhance the richness of the chains of causality touched on in this paper (and further elaborated in Rook and Caldecott (2015)).

Thirdly, future research that might aid both IOCs and their shareholders could lie in a more penetrating investigation, and, ideally, quantification (however rough) of the specific escalations of risk that accompany increased capex density. In particular, looking at how the risk profile of capex-project portfolios among IOCs changes as a consequence of increased density could allow a more fine-grained analysis of the specific cognitive biases (and severity thereof) that heightened capex density brings.

In all, we see this paper and its sibling (Rook and Caldecott (2015)) as driving forward a new branch of investigation into corporate stewardship and governance that should help both the public and private good.

Appendix: IOC Board Compositions

IOC	Surname	Forename	Gender	Age	Tenure	Nationality	Non-IOC Professional Experience	Committee Membership					
BP								Audit	Safety, Ethics, & Environmental Assurance	Remuneration	Gulf of Mexico	Nomination	Chairman's
	Svanberg	Carl-Henric	Male	62	2009	Swedish	Major					x	x
	Dudley	Bob	Male	59	2009	American	None						
	Anderson	Paul	Male	69	2010	American	None		x		x	x	x
	Boeckmann	Alan	Male	66	2014	American	Minor		x		x		x
	Bowman	Frank	Male	70	2010	American	Major		x		x		x
	Burgmans	Antony	Male	68	2004	Dutch	Major		x	x		x	x
	Carroll	Cynthia	Female	58	2007	American	Minor		x			x	x
	David	George	Male	72	2008	American	Major	x	x	x	x		x
	Davis	Ian	Male	63	2010	British	Major			x	x	x	x
	Dowling	Ann	Female	62	2012	British	Major		x	x			x
	Gilvary	Brian	Male	53	2012	British	None						
	Nelson	Brendan	Male	65	2010	British	Major	x				x	x
	Nhelko	Phutuma	Male	54	2011	South Afric	Major	x					x
	Shilston	Andrew	Male	59	2012	British	Major	x					x

IOC	Surname	Forename	Gender	Age	Tenure	Nationality	Non-IOC Professional Experience	Committee Membership			
Chevron								Audit	Public Policy	Board Nominating and Governance	Management Compensation
	Watson	John	Male	58	2010	American	None				
	Cummings	Alexander	Male	58	2014	American	Major	x			
	Kirkland	George	Male	64	2010	American	None				
	Deily	Linnet	Female	69	2006	American	Major		x		x
	Denham	Robert	Male	69	2004	American	Major		x	x	
	Gast	Alice	Female	56	2012	American	Major	x			
	Hernandez	Enrique	Male	59	2008	American	Major			x	x
	Huntsman	Jon	Male	55	2014	American	Major		x		x
	Moorman	Charles	Male	63	2012	American	Major	x			
	Sharer	Kevin	Male	67	2007	American	Major	x			
	Stumpf	John	Male	61	2010	American	Major	x			
	Sugar	Ronald	Male	66	2005	Canada/US	Major	x			
	Thulin	Inge	Male	61	2015	Sweden/US	Major		x	x	
	Ware	Carl	Male	71	2001	American	Major			x	x

IOC	Surname	Forename	Gender	Age	Tenure	Nationality	Non-IOC Professional Experience	Committee Membership					
ConocoPhillips								Audit & Finance	Executive	Human Resources & Compensation	Directors' Affairs	Public Policy	
	Armitage	Richard	Male	69	2006	American	Major				x	x	
	Auchinleck	Richard	Male	62	2002	Canadian	None		x	x	x		
	Bunch	Charles	Male	61	2014	American	Major	x					
	Copeland	James	Male	70	2004	American	Major	x	x				
	Faraci	John	Male	64	2015	American	Major	x					
	Freeman	Jody	Female	51	2012	American	Major			x		x	
	Huey Evans	Gay	Female	61	2013	USA/UK	Major	x					
	Lance	Ryan	Male	52	2012	American	None		x				
	Murti	Arjun	Male	44	2015	American	Major	x					
	Niblock	Robert	Male	51	2010	American	Major		x	x	x		
	Norvik	Harald	Male	67	2005	Norwegian	None		x	x		x	
	Wade	William	Male	71	2006	American	None			x	x		

IOC	Surname	Forename	Gender	Age	Tenure	Nationality	Non-IOC Professional Experience	Committee Membership					
ExxonMobil								Audit	Board Affairs	Compensation	Finance	Public Issues & Contributions	Executive
	George	William	Male	72	2005	American	Major	x			x		x
	Reinemund	Steven	Male	67	2007	American	Major		x			x	x
	Fishman	Jay	Male	62	2010	American	Major			x		x	
	Boskin	Michael	Male	69	1996	American	Major			x		x	x
	Frazier	Kenneth	Male	60	2009	American	Major		x			x	
	Fore	Henrietta	Female	66	2012	American	Major		x			x	
	Tillerson	Rex	Male	63	2004	American	None				x		x
	Faulkner	Larry	Male	70	2008	American	Major	x			x		
	Burns	Ursula	Female	56	2012	American	Major	x			x		
	Brabeck-Letmathe	Peter	Male	70	2010	Austrian	Major	x			x		
	Weldon	William	Male	66	2013	American	Major		x	x			
	Palmisano	Samuel	Male	63	2006	American	Major		x	x			x

IOC	Surname	Forename	Gender	Age	Tenure	Nationality	Non-IOC Professional Experience	Committee Membership			
Shell								Nomination & Succession	Audit	Corporate & Social Responsibility	Remuneration
	Ollila	Jorma	Male	65	2006	Finnish	Major	x			
	Wijers	Hans	Male	64	2009	Dutch	Major	x			
	Van Beurden	Ben	Male	57	2014	Dutch	None				
	Henry	Simon	Male	54	2009	British	None				
	Elliott	Guy	Male	60	2010	British	Minor	x	x		
	Goh	Euleen	Female	60	2014	Singaporean	Major		x		
	Holliday	Chalres	Male	67	2010	American	Major			x	x
	Kleisterlee	Gerard	Male	69	2010	Dutch	Major		x		x
	Sheinwald	Nigel	Male	62	2012	British	Major			x	
	Stuntz	Linda	Female	61	2011	American	Major		x		
	Woertz	Patricia	Female	62	2014	American	Minor			x	
	Zalm	Gerrit	Male	63	2013	Dutch	Major			x	x

IOC	Surname	Forename	Gender	Age	Tenure	Nationality	Non-IOC Professional Experience	Committee Membership			
Total								Governance & Ethics	Strategic	Compensation	Audit
	Desmarest	Thierry	Male	70	1995	French	Minor	x	x		
	Artus	Patrick	Male	64	2009	French	Major	x		x	
	Barbizet	Patricia	Female	60	2008	French	Major		x		x
	Blanc	Marc	Male	61	2014	French	Minor				
	Brock	Gunnar	Male	65	2010	Swedish	Major	x	x	x	
	Coisne-Roquette	Marie-Christine	Female	59	2011	French	Major			x	x
	Collomb	Bertrand	Male	73	2000	French	Major	x			
	Desmarais	Paul	Male	61	2002	Canadian	Major				
	Idrac	Anne-Marie	Female	64	2012	French	Major	x			
	Keller	Charles	Male	35	2013	French	None				x
	Kux	Barbara	Female	61	2011	Swiss	Major	x	x		
	Lamarche	Gerard	Male	54	2012	Belgian	Major		x		x
	Lauvergeon	Anne	Female	56	2000	French	Major		x		
	Pebereau	Michel	Male	73	2000	French	Major			x	

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