STRANDED ASSETS

PROGRAMME

SMITH SCHOOL OF ENTERPRISE AND THE ENVIRONMENT

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Evaluating Capex Risk: New Metrics to Assess Extractive Industry Project Portfolios

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 the materiality of environment-related risks over time, how different risks might be interrelated, and the potential impacts of stranded assets on investors, businesses, regulators, and policymakers. We also work with partners to develop strategies to manage the consequences of environment-related risks and stranded assets.

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Table of Contents

Executive summary

There is a worrying disconnect between the importance of capex to the future performance of extractive companies, particularly international oil companies (IOCs); and ways that capex-related information are conveyed to investors via public disclosures and financial statements. The current practice is to report capex only in an aggregated way, making it impossible to determine how capex is distributed across projects. This leaves investors in the dark about how risky investments in extractive companies are.

The information contained in a typical IOC's public reports and disclosures falls far short of being adequate for investors to make knowledgeable and prudent assessments of the diversification strategies and practices being pursued by IOCs. While it is common practice, for example, for IOCs to report company-wide capex information along with divisional (e.g., upstream, downstream) or regional (e.g., African, North American, European) disaggregation of capex, capex figures that are disaggregated at the project level are utterly non-existent in IOC reports. Moreover, in most reports it is difficult – if not impossible – for investors to construct for themselves even basic indicators of project-level diversification, because even the total number of capex projects currently being undertaken (and their respective stages of development) are not consistently available in many IOCs' public reports.

This paper spells out the problem of capex transparency in greater detail, and examines some barriers to its resolution. It then introduces two novel, and straightforward, metrics – *capex density* and *capex evenness* – that are capable of providing greater transparency on whether or not the degree of diversification in capex by an extractive company is at a responsible level.

Capex density indicates what the average capital expenditure per project is. While this is a relatively naïve metric, it improves upon simple aggregated capex. The near impossibility of determining capex density for a typical IOC from information in its annual reports, however, indicates the degree of opacity faced by investors in properly appraising the capex activities of extractive companies. Capex density therefore serves as a stepping-stone for introducing our second metric.

Capex evenness indicates how balanced capital expenditures are across projects, accounting for the number of projects that a responsibly-diversified portfolio should have. Capex evenness represents a more comprehensive indicator and has the potential to become a potent metric by which investors can analyse IOCs.

The introduction of these metrics may be driven by both investors and leading extractive companies. Shareholders concerned with transparency over capex activities by extractive companies might lobby the management of companies to introduce capex evenness as voluntarily disclosed figures. Alternatively, they might take a more binding approach, and encourage regulators to issue guidance on disclosing such figures, or else make them required. On the company side, leading extractive companies that pursue effective and efficient levels of diversification in their capex activities might wish to showcase this dimension of outperformance (relative to peers) by voluntarily reporting capex evenness figures (and other information). Such change over time may cause laggard companies to likewise disclose such figures and take action in order to remedy any deficiencies in responsible capex conveyed by them.

Capex evenness can give more visibility on the project-based diversification practices of extractive companies than do current reporting practices. And when properly-calibrated, these more advanced metrics can serve as behavioural controls on management. Consider, for instance, the 'sunk-cost fallacy': a cognitive bias wherein those committing the bias continue to spend significant volumes of capital on projects simply because significant volumes have already been spent on (i.e., 'sunk into') the project. Logically (and empirically, as has been demonstrated experimentally), the sunk-cost fallacy worsens for larger projects. Metrics like capex evenness may help to better discipline management teams by helping to mitigate the sunk-cost fallacy.

And note furthermore that by using and publicising metrics such as capex evenness, IOC management teams may be better insulated from some downsides of other psychological missteps, such as the *planning fallacy*. The planning fallacy describes a systematic bias by people to underestimate the time needed to complete projects (see especially: Buehler, Griffin, and Ross (1994)). Quite simply, with more diversified capex and project portfolios, even if management teams experience time-overruns on projects due to the planning fallacy, the consequences of doing so will be spread across a greater number of projects, and should reduce the deleterious effects of doing so.

Furthermore, these advanced metrics may help investors to better assess the managerial and governance capacities of an extractive company to engage in the sort of capex intensity implied by capex density and evenness scores. Some extractive companies might be 'spread too thin' in terms of their relative governance capacities, and be undertaking more projects than they can possibly monitor and manage in a responsible way.

Finally, IOCs, like other very large companies, may face problems in the 'efficiency' of internal capital markets (that is, in how efficiently management is able to allocate capital within the company itself to various divisions, geographies, projects, and project managers). The problem of inefficient internal capital markets has been studied extensively in management science and organisational psychology; a recurrent finding is that 'winning' managers who are in charge of projects that are either (or both) 1) large relative to other projects, or 2) are currently (or recently) more profitable than other projects, tend to continue to be allocated disproportionately large amounts of a firm's capital. The problem with such rich-get-richer effects in internal capital allocations is that they can make the organisation as a whole less stable (even if it entrenches and reinforces 'favoured' projects and managers) and induce myopic decision-making (which can worsen when inefficient internal capital markets combine with the sunk-cost fallacy in managerial decision-making). And while these sorts of problems are serious threats to the wellbeing of IOCs and other large companies, they are very difficult for investors to observe directly. Hence, having in place metrics – such as capex evenness – that might discourage some projects (or project managers) from becoming disproportionately large and posing outsized risks and/or drains on organisational resources, is innately desirable from a governance standpoint.

1. Introduction

Capital expenditure (capex) is fundamentally important to the future prospects of most companies. And responsible patterns of capex are especially important for those companies that rely on natural-resource extraction for generating profits. Nevertheless, a worrying disconnect exists between: the importance of capex to future performance of extractive companies; and ways that capex-related information is conveyed to investors via public disclosures and financial statements. Succinctly, extractive companies must invest capex into discrete *projects* in order to maintain a capability to extract the natural resources which are fundamental to their businesses. Yet these projects can be highly diverse in terms of attendant risks: capex in some particular project may expose a company to vastly different sources and scales of risks than a comparable amount of capex in another project.

The predominant practice among extractive companies, however, is to report capex to investors only in an aggregated way such that it becomes impossible to determine how capex is being distributed across projects. This practice leaves investors in the dark about how risky investments in extractive companies are, because reporting only aggregated capex values provides readers with scant indication of how diversified such companies are.

This paper is meant to set the next stage for discussions between investors, management teams, and regulators over how to foster greater transparency in the reporting of threats and diversification associated with capital expenditures by extractive companies. And although the issues treated here apply to practically all extractive companies, the focus in this paper centres on international oil companies (IOCs) because, for them, the problems stemming from the capex-to-project disconnect in how threats get reported to investors are especially acute.

Furthermore, IOCs have recently garnered substantial public criticism from investors for excessive capital expenditures. In response, many IOCs have, in their public reports, expressed a commitment to pursuing more efficient capex policies. Yet there is often insufficient clarity for investors about how that goal is being pursued, or might best be pursued. The way in which capex information is presently conveyed to investors (as well as the wider public) simply does not provide the degree of transparency needed for determining whether IOCs – along with other extractive companies – are engaging in appropriate capex efficiency or diversification practices or not.

The inadequate transparency in reporting capex makes it much harder to determine responsible pathways to capex reductions. Many investors have expressed the desire for the total levels of capex undertaken by IOCs to be scaled down in order to focus on returning capital to shareholders (e.g., sustaining, or even increasing, dividend payments, which are a primary motivator for many investors to own IOC shares). But judging which paths to achieving capex reduction (as well as monitoring whether IOCs are straying from these paths or not) is a daunting task if investors possess insufficient information. Finding new tools – especially in the form of easily-interpretable metrics to be included in public disclosures – must become a priority to empower asset owners to make better-informed judgments.

This paper begins by spelling out the problems surrounding capex transparency in greater detail, and examines some barriers to their resolution. It then introduces two novel, and straightforward, metrics – *capex density* and *capex evenness* – that are capable of providing greater transparency on whether or not the degree of diversification in capex by an extractive company is at a responsible level. A few simple examples are provided to serve as a 'starter manual' for proper application of these metrics, and to illustrate how their use may benefit investors and management teams alike (as well as other interested stakeholders). The paper concludes with some suggestions for further refinement of these metrics, as well as how such metrics might be broadly implemented. To facilitate broad implementation of capex-balance metrics (i.e., evenness and density), an online calculator has been made freely available at: http://www.smithschool.ox.ac.uk/research-programmes/stranded-assets/publications.php.

2. Responsibly balancing capex

There exists a simple truth concerning capex in most industries: it requires balance. In essence, capex is a necessary evil: it provides the investment needed to sustain an enterprise's operations into the future, and potentially expand them; but it also represents costs to the enterprise that reduce current profits and tie up capital that could be used for other purposes (like paying shareholder dividends).

And the necessity of balanced capex in the oil & gas (O&G) industry is evident in how capex is discussed in the annual reports of international oil companies (IOCs). Companies such as BP, Chevron, ConocoPhillips, ExxonMobil, Royal Dutch Shell, and Total stress within their 2013 reports (the most recent available at the time of writing) a need for *capital discipline* to be traded off against *growth potential*. In their public disclosures, practically all IOCs prioritise being 'efficient' with capital expenditures by respecting such trade-offs.[1]

But the trade-off between 'future potential' and 'disciplined spending' is not the only dimension of balance that matters for capex by extractive companies. An equally-important consideration for most companies is how balanced capex is across the various projects in which the company itself invests (i.e., its *project portfolio*).

The importance of this *diversification* dimension is likewise evident in the reports of IOCs: most reports underscore how it is crucial for corporate strategy and performance to have adequately-diversified portfolios of projects in order to responsibly manage the risks which the IOC faces. And this emphasis seems correct, at least in principle, because diversification has stood as a cornerstone of sound risk-management strategies since it was first embedded into portfolio theory (Markowitz 1952; 1999) (which is itself both a ubiquitous model, and established tool for managing investment risks).

Apart from verbal insistences, however, IOCs' public reports and disclosures contain little – and, alarmingly often, no – quantified evidence that IOCs are pursuing responsible diversification strategies by balancing their capex across projects in order to reduce their exposures to correlated risk factors among those projects. But *absence of evidence* for responsible diversification does not automatically translate to *evidence of absence*. That is, just because IOCs' reports do not contain quantifications of how diversified their capex is does not necessarily mean that IOCs are not undertaking the appropriate forms of analysis at all. Indeed, many IOCs' reports do contain statements claiming that they are using sophisticated analytical tools to guide their diversification strategies. A main problem for investors, however, is that the inputs and assumptions embedded in those analyses (even if they are being responsibly undertaken) are generally too voluminous and intricate to be reasonably compressed into the space allowable for any annual report, or similar type of public disclosure. This problem short-changes not only investors, but also those IOCs who may actually be pursuing responsible diversification practices and strategies.

But just because including such analysis in its entirety is impractical should not excuse a general omission of useful information about diversification practices by IOCs. The information contained in a typical IOC's public reports and disclosures falls far short of being adequate for investors to make knowledgeable and prudent assessments of diversification strategies and practices being pursued. This inadequacy stems from the project-based nature of capex by extractive companies and their general failure to report project-level capex data. While it is common practice, for example, for IOCs to report company-wide capex information along with divisional (e.g., upstream, downstream) or regional (e.g., African, North American, European) disaggregation of capex, capex figures that are disaggregated at the project level are utterly non-existent in IOC reports. Moreover, in most reports it is difficult – if not impossible – for investors to construct for themselves even basic indicators of project-level diversification, because even the total number of capex projects currently being undertaken (and their respective stages of development) are not consistently available in many IOCs' public reports.

[1] Links to the aforementioned reports appear in the 'References' section of this paper.
[2] Although some opine that a shift from 'volume to value' may be underway (Handscomb, Lund, and Brunell 2014).

This lack of project-level data should disturb investors because, in general, many of the severest threats to IOCs' operations and businesses exist at the project level. Projects are the basic units of IOCs' production (and such production is the primary source of their revenues and profits). It is generally much more likely that an individual project will fail than will the entirety of an IOC's operations within a whole division or region. The infamous 'Deepwater Horizon' incident illustrates this principle cleanly: it involved a project-level disruption which caused significant difficulties for BP and its partners, despite no (lasting) wider disruption in the region or division of BP in which it was situated. Notably, however, a project-level disruption can be nearly as detrimental to an IOC as a divisional or regional disruption if such a project is *proportionally* large (i.e., it takes up a large fraction of the company's project portfolio in terms of revenues, profits, production, or capex). Thus, while it is undoubtedly important that IOCs and their investors consider how diversified is capex geographically (across regions and countries) and operationally (across divisions and products), it should also be incumbent upon IOCs to assess and convey to investors how diversified capex is across projects, because nearly all forms of meaningful risk faced by IOCs manifests ultimately at the project level.

2.1 Why project diversification matters

Additionally, the importance of project diversification by IOCs is amplified due to at least four distinct factors. Firstly, many of the risks that IOCs face are beyond the immediate control of individual IOCs themselves. Specifically, various hazards faced by IOCs due to changing economic, political, social, and environmental conditions are not controllable by the individual IOCs (and some may not even be collectively controllable). Nevertheless, many of the uncontrollable risks to which any IOC may be exposed do not equally impact all of their projects, even within a particular geography or division (or, for that matter, geology or technology). Indeed, a risk that may harm one project may improve the performance of another one. But this 'offsetting' of risk innately depends upon project diversification, and is generally vital for IOCs because many IOCs self-insure against many forms of hazard (i.e., many of their exposures are not covered by third-party insurance contracts, but are instead paid for from the IOC's own capital).

The usefulness of project diversification in terms of offsetting and self-insurance by IOCs may well only increase in the future due to a confluence of trends. Fundamentally, many of these trends relate to 'environmental hazards' faced by IOCs, whether physical, socio-political, or socio-economic. From a physical standpoint, one of the greatest threats involves the possibility of *stranded assets* due to present and future climate change. Specifically, future physical impacts from climate change are likely to manifest in very location-specific ways that in many instances may be sub-regional, and thus can be expected to vary most noticeably at a project level.

Project diversification strategies may prove to be one of the best bulwarks against asset stranding in another respect as well: mitigation of socio-political and socio-economic risks. That is, different projects have distinct pollution intensities (in terms of the types and volumes of greenhouse gases (GHGs) emitted per unit of fossil fuel extracted). Hence, even if all of the projects within a given segment (e.g., divisional or regional) of an IOC become subject to emissions regulation that imposes (e.g.) a tax or cost on GHG output, project variability may still help to protect a well-diversified IOC against not only the economic consequence of changing policies regarding GHG emissions, but also shifts in regulatory regimes and public action (e.g., boycotts) connected to environmental impact more generally. Specifically, sudden changes in political or social stance towards different forms of environmental impact (whether connected with climate change or not) can be disruptive at the local, regional, or even global levels for IOCs and other extractive companies. A well-diversified portfolio of projects can, however, help to mitigate the most disastrous consequences – economic, legal, and reputational – for such companies that stem from sudden regulatory or social changes.

Secondly, even those risk factors – such as the price of oil on the global marketplace – which tend to affect all projects of a given type (in this case, petroleum-related projects) in the same *direction* (i.e., higher oil prices tend to improve performance of all oil projects, whereas lower oil prices tend to harm them) need not impact all such projects to the same *extent*. Notably, unlike companies in many other industries, individual IOCs do not actually set oil prices themselves. They can only control the volume of product that they generate, and not prices directly.

This volume, however, carries different costs across different projects, and these costs can vary with oil price itself.

And the variability of these costs could become even more pronounced in a world that may have already surpassed 'peak oil': future difficulties in maintaining cheaply and easily-accessible supplies of fossil fuels make not only the idea of peak oil, but also the notion of *peak projects* a concern for IOCs. In general, most of the world's low-cost/high-volume projects are no longer available to IOCs. They have either been depleted (or nearly depleted), or else are controlled by national oil companies (NOCs). Most of the project opportunities accessible by IOCs are, as a result, low-cost/low-volume plays, or high-cost/high-volume ones (high-cost/low-volume plays are generally avoided by IOCs). In recent years, IOCs have exhibited a noticeable preference for high-cost/high-volume opportunities over low-cost/low-volume ones due to motives connected to a third reason why project-level diversification proves to be important: *reserve-replacement ratios*.

Reserve-replacement ratios (RRRs) are a metric used by many financial analysts to appraise the long-term viability of an IOC. RRRs are also commonly used by IOCs themselves to set strategic targets, and are inputs to many company, as well as project-level, decisions. RRRs account for the amount of 'proven' reserves (measured in the relevant standardised units) of oil and/or gas (usually reported separately) added by an IOC during a time period (e.g. a year) relative to those reserves extracted ('produced') during the same period. Intuitively, if these volumes are equal, then the RRR is 100%; but, if added reserves exceed extracted reserves, then the IOC is deemed to be 'growing'. RRRs less than 100% are generally conceived of as being undesirable by analysts, so IOCs strive to prove larger reserve volumes whenever doing so is feasible.[2] And this bias toward larger proven (or provable) reserves incentivises IOCs to undertake larger projects. This size-escalation in projects (and capex) seems evident in IOCs' activities over the past decade (and, in many cases, even longer).

Unfortunately, this preference for size (driven by RRRs) suffers from a statistical incongruity: proven reserves are not *actually-measured* reserves. Instead RRRs are only *statistically-estimated* reserves that are calculated by using engineering formulae which allow for a fixed threshold of error, although such estimates can oftentimes surpass the tolerated error level. Yet even when estimates are inside the 'tolerable' level of error, the fact that they are estimates results in actual reserve levels generally deviating from the reserve levels initially estimated for a project.

And this variability will tend to be characteristically larger for big projects than for small ones.[3] Hence, an IOC whose portfolio of projects is *imbalanced* (because it relies on a disproportionate number of large projects) may suffer from greater volatility in its RRRs than would another IOC that adopts a *balanced* approach to diversification across projects that are more similarly-sized (and thus more likely to offset one another to similar degrees).[4] It is well worth noticing that RRR calculations do not take diversification (of any form) into account. Even more problematic, however, is the fact that large projects which have a high per-unit cost of extraction (i.e., high-cost/high-volume projects) may become economically unviable with low marketplace prices for oil or gas, and production under those conditions may be suspended or discontinued for such projects, further harming RRRs.

Particularly in times when prices oscillate between historical highs and lows relatively quickly (as has occurred recently), an imbalanced portfolio of capex on projects that has many relatively large, high-cost projects may be especially vulnerable to such price volatility: large projects that were viable at high prices of oil and gas may suddenly become unviable when prices drop. Intensity of competition and managerial optimism, however, might bias IOCs towards taking on large, expensive projects whenever prices are sufficiently high, even if doing so jeopardises resilience to low-price conditions.[5] Sound project diversification strategies, however, can enable some price resilience.

[2] Although some opine that a shift from 'volume to value' may be underway (Handscomb, Lund, and Brunell 2014).
[3] Plainly, a 5% overestimation on a ten million-barrel field of oil exceeds the error of a 5% overestimation on a one million-barrel field by an order of magnitude.
[4] See CTI (2014).
[5] Further behavioural implications and drivers of improper capex diversification will be discussed within later sections.

Fourthly, the quality of project diversification can influence an IOC's access to capital. For many IOCs, a significant proportion of capex is drawn from the company's own operating surpluses, and thus is financed predominantly from internal capital. Nonetheless (and as highlighted variously in the risk disclosures of many IOCs in their public reports), failure of any major project could erode many IOCs' abilities to rely mainly on internal financing capabilities, and cause instabilities in their overall financial structures and budgets. Moreover, many IOCs do depend upon external financing for various elements of their operations. Leases are important instruments for the successful execution of many projects (as many IOCs might be reluctant to carry the land upon which they are conducting their extractive operations as a balance-sheet item; moreover, they may not wish to absorb the resale or legal risks associated with such ownership) and the availability of such leases may be determined by both project-specific collateral, alongside the cumulated history of project-level lease servicing by an IOC.

Furthermore, the base of assets against which an IOC's debt instruments might be collateralized is driven in part by the market value of such assets. Yet this value is set against impairments which are inherently project-based, given the generally limited resale/repurposing value of productive assets owned/operated by IOCs. It is thereby obvious that capital costs of IOCs are (at least predominantly) project-centric.

While there are certainly other reasons why an IOC should pursue project diversification strategies, readers might at this point be convinced that investors should be concerned by the fact that a disconnect exists between capex reporting and capex diversification.

2.2 Responsible limits

Synergies, economies of scale and scope, and learning effects (especially technical expertise in specific geologies) may accrue to some companies if the projects to which they allocate capex are similar in key ways. Most of these benefits (unlike many of the risk exposures faced by extractive projects) are directly under the control of the companies themselves.

Capex diversification is therefore a 'balancing act' that involves designing and maintaining a project portfolio that is neither too concentrated (and therefore exposed to risks and uncertainties which are too similar across the projects) nor too diversified (and thereby foregoing some benefits from having synergies, scale/scope economies, learning effects, etc. shared across projects). Yet knowing whether companies have properly judged these boundaries and kept their portfolios between them is difficult (if not impossible) for investors to discern from aggregated capex figures, even if project-level data are additionally and separately available in those same (or other) reports.

Many IOCs claim to generate a great many scenarios and explore possible contingencies in detail; yet these analyses are difficult to convey in a concise and comprehensible way within a document that must also contain plenty of other data and commentary. Moreover, some companies feel that these inputs and assumptions constitute a comparative resource over their competitors, and might be reluctant to release this information publicly (e.g. it may disadvantage them in auction or sale processes). For these reasons, a middle-ground solution seems required.[6] One such solution is proposed here.

[6] There exists a rich and vibrant academic literature surrounding how diversified companies should 'optimally' be. While there remain adherents to the view that diversification is not the responsibility of management teams, but of investors themselves, it should be apparent that investors should desire to know the true riskiness of a company in which they are investing, regardless of whether or not they believe that it is the company or themselves that should be primarily concerned with architecting proper diversification. The main point is: without sufficient information about how diversified the projects (and capex in them) of an extractive company are, investors have distorted views of risk.

3. New capex metrics

This section presents two heuristic metrics that can help indicate whether an extractive company is appropriately balancing its capital expenditures in a diversified way. These methods are described as 'heuristic' because, while they cannot guarantee that portfolios are diversified across all risk factors, they can efficiently identify when it is strongly likely that diversification is not being pursued responsibly. Hence these metrics can help mitigate the information-load problem in communicating diversification practices.

The first metric, called *capex density*, is a relatively naïve metric, although it is shown to improve upon the *status quo* of simple (aggregated) capex that is reported at present by IOCs. Nonetheless, capex density is flawed in a few key ways. The near impossibility of determining capex density for a typical IOC from information in its annual reports, however, indicates the degree of opacity faced by investors in properly appraising the capex activities of extractive companies. Capex density therefore serves as a stepping-stone for introducing the second metric: *capex evenness*. Whereas capex density can be roughly understood as the 'average' capex per project over a given time period, capex evenness represents a more comprehensive indicator of how much any one project contributes (either evenly or unevenly) to an 'exclusive average' (a novel albeit straightforward concept that is explained in detail shortly). Capex evenness has the potential to become a potent metric by which investors can analyse IOCs.

3.1 Capex density

When performed appropriately, diversification of investments (in the case of extractive companies, typically via project capex) makes the risks and uncertainties to which a portfolio is exposed less 'dense' by simultaneously: reducing the risks and uncertainties to which investments are jointly exposed; and reducing the sizes of exposure by any one investment to the risks and uncertainties unique to it within the portfolio. Simply, a diverse portfolio is one that has a low density of risk and uncertainty exposure.

One simple and heuristic way to measure such density is through dividing the total 'mass' of capital invested, denoted as X, by the 'volume' of investments, denoted by N. When applied to the capex on a portfolio of projects, this ratio becomes *capex density*, wherein X is the aggregate capex over a specified time t (and denominated in a common currency) and N is the relevant group of projects within such a portfolio:

$$(\mathbf{1}) \qquad \text{Capex Density: } D_t \equiv \frac{X_t}{N_t}$$

It should be noted that in the calculation of capex density, X_t and N_t might be allowed to vary with the type of capex and/or projects of interest. For example, they might apply only to maintenance or growth capex, or to new projects within the period. Regardless, it should be always clearly stated to what types of projects and capex X_t and N_t both apply in conveying capex-density ratios.

Capex density yields the 'average project cost' over some period. The interaction between aggregate capex X_t and number of capex projects N_t might show investors what a 'typical' project in the portfolio is costing in terms of capex for a time period. The benefits of using capex density to help evaluate capex can be compared to some measure of return (whether realised or forecasted) or compared against historical and peer performance.

This type of comparative analysis might aid in the heuristic evaluation of capex by revealing time-series or cross-sectional trends (or abrupt changes). It also naturally allows for straightforward comparisons among the portfolios of companies of different sizes (although in some circumstances some specific re-scaling may be desirable).[7] Furthermore, given that in some segments of the extractive industry (e.g., upstream oil and gas exploration and production) diversification of project portfolios has alternated in recent decades as being in and out of favour, comparative analyses of capex densities across companies and time might tease out 'outlier' companies, who were either leading or lagging relative to peers (or own prior performance) in governing exposures.

But capex density by itself is insufficient as a heuristic tool because of its lack of sensitivity to abnormally large or small outlying values. For example, an extractive company might have the vast majority (say, 95%) of its capex going to a single project, and the remaining capex spread equally among the remaining $N_t - 1$ projects in its portfolio during period t. While such a situation would be less 'dense' than if the same company were to allocate all of its capex to only a single project, it would nonetheless be indistinguishable from a situation wherein the same company allocated its capex equally across each of the N_t projects in its portfolio during period t.

The one project absorbing the majority of capex would be an outlier, and capex density cannot detect this. For that purpose another heuristic metric, *capex evenness*, is needed. Capex evenness can be seen as improving upon capex density.

3.2 Capex evenness

Capex evenness indicates how balanced capital expenditures are across projects, accounting for the number of projects that a responsibly-diversified portfolio should have. Capex evenness represents a more comprehensive indicator and has the potential to become a potent metric by which investors can analyse IOCs.

Within quantitative economics, Bordalo, Gennaioli, and Shleifer (2012) have recently developed an approach to salience detection that relies on distances of values from some 'exclusive average'. Their approach, in contrast with more parametric ones, is pleasingly straightforward, works well with relatively small samples (of sizes that typically characterise the project portfolios of extractive companies), and is not hampered by abnormal degrees of kurtosis or skew. The approach to salience taken by those authors extends readily to notions of capex evenness here.

Let x_t^n denote the capex (as a positive value) on project n (where $n \leq N_t \in \mathbb{Z}_+$ is an index of relevant capex projects in the company's portfolio P), such that $X_t = \sum_{n=1}^{N} x_t^n$. Then let π_t^n be the proportion of aggregate capex $x_t^n \,/\, X_t$ spent on project n during period t; that is, $0 < \pi_t^n \leq 1$ for each n, and:

$$(2) \qquad \pi_t^n \equiv \frac{x_t^n}{X_t}$$

Also let the vector of such proportions over all (relevant) projects upon which the company in question made capex during period t be denoted by $\boldsymbol{P}_t = (\pi_t^1, \dots, \pi_t^N)$. And let $\boldsymbol{P}_t^{-n} = \{\pi_t^m\}_{m \neq n}$ denote another vector of capex proportions that includes the proportional share of all capex on all relevant projects in P *excluding* project n. Furthermore, let there be a function $f(\boldsymbol{P}_t^{-n})$ such that:

$$(3) \qquad f(\boldsymbol{P}_t^{-n}) = \frac{1}{N_t - 1} \sum_{m=1}^{N_t} \pi_t^m, \qquad \forall m \neq n$$

[7] Conventional wisdom suggests that larger extractive companies will typically pursue larger projects (in terms of per-project capex) than smaller companies. But scale economies for larger extractive companies suggests that there should be some tendency to also engage in *more* projects than smaller companies as well. Determining whether X_t and N_t increases proportionately more rapidly with increases in company size (measured, e.g., by annual revenues) might therefore yield clues to how well a large company is performing on the basis of capex *intensity* relative to its smaller peers (and vice versa).

Following Bordalo, Gennaioli, and Shleifer (2012), a *capex evenness* function can then be defined:

$$(4) \qquad \sigma\left(\pi_t^n, f(\boldsymbol{P}_t^{-n})\right) \equiv \frac{|\pi_t^n - f(\boldsymbol{P}_t^{-n})|}{|\pi_t^n| + |f(\boldsymbol{P}_t^{-n})| + \theta}$$

In this evenness function, the parameter $\theta \in \mathbb{N}$ can be thought of as a *concentration threshold*; this value will be discussed shortly. Notice, however, that when applied to each project n in the portfolio P, the evenness function $\sigma\left(\pi_t^n, f(\boldsymbol{P}_t^{-n})\right)$ generates a value that indicates the relative extent to which the capex x_t^n in period t on each project n deviates from the average capex on all of the other projects besides project n in the portfolio P.[8] Thus, the value $\sigma\left(\pi_t^n, f(\boldsymbol{P}_t^{-n})\right)$ for each project might be thought of as a 'score' for how much of an outlier that project is in terms of its marginal contribution to capex density. Each of these evenness scores $\sigma\left(\pi_t^n, f(\boldsymbol{P}_t^{-n})\right)$ can be used in generating an *overall* capex-evenness score for aggregate capex in a portfolio over the period t.

To aid in building such a score, first reconsider the *concentration-threshold* parameter $\theta \in \mathbb{N}$. This threshold parameter dictates the 'minimum' number of discrete projects that it is acceptable for a company to engage in during the specified time period. It should be either stated by the company in its calculations (in which case it might signal management's perspective on the relative merits or demerits of diversified capex), or might be otherwise imposed by shareholders or regulators as a benchmark value (perhaps derived from historical averages, or operating as a policy mechanism).

Selection of the concentration-threshold parameter θ poses an important decision, and opportunity, for investors, as well as the companies in which they invest. And although both parties may share different perspectives on what the appropriate value for θ should be, being explicit about rationales for θ can be an important mechanism for communicating questions related to risk and risk management for both companies and their investors. In specifying a preferred value for θ, investors can signal to management teams the particular level of diversification-related risk that they may be willing to tolerate for their investments. Obviously it could prove difficult for management teams to accommodate the preferences of all investors if they express a wide range of θ values that they prefer or are willing to accept, but this dispersion in itself could be valuable information for management teams. Moreover, if several influential investors (e.g., large institutional investors, such as endowments, public pension funds, sovereign wealth funds, etc.) in a company were to arrive at a consensus value for θ and communicate this value explicitly to management, then such a communication may carry substantial weight.

Moreover (and perhaps more efficiently), management teams should wish to communicate their own preferred values for θ to investors because doing so can convey their expectations and strategies regarding risk governance. For example, a well-diversified company might make a case for a relatively high value of θ, as this could showcase its superior diversification strategy relative to its peers. Dissimilarly, however, some companies may wish to promote a smaller value for θ and justify doing so by demonstrating to investors that they are using suitable risk-management techniques to efficiently offset concerns associated with a dense portfolio of projects. Regardless, the essential message one must appreciate is that investors should demand that companies justify and explain their rationales for the particular threshold values θ which they may choose to advocate.

Returning to the subject of constructing the capex evenness metric, let the two values θ and N_t be used to define a company-specific *decay value* δ_t that equals:

$$(5) \qquad \delta_t \equiv 1 - \left(\frac{\theta}{N_t}\right)\left(\frac{\ln\,(N_t - \theta + 1)}{\ln\,(N_t - \theta + 1)}\right)$$

This decay value introduces a threshold-adjusted 'correction factor' that is used to alter the individual proportions π_t^n on the basis of relative evenness, as compared with the whole portfolio. (Note that with larger δ_t,

[8] Variants of the above may also be used that work with other measures of central tendency, such as mode or median.

the adjustment will be less severe, but with relatively small numbers of projects δ_t will approach or even equal zero as $N_t \to \theta$; $\delta_t < 0$ indicates that the company is making capex in too few projects relative to the concentration threshold θ). Let δ_t alter the individual proportions π_t^n through a project-specific weighting factor w^n, which will be equal to:

$$(6) \qquad w_n = \frac{\pi_t^n\left[\delta^{\sigma\left(\pi_t^n, f\left(\boldsymbol{P}_t^{-n}\right)\right)}\right]}{\sum_{k=1}^{N} \pi_t^k\left[\delta^{\sigma\left(\pi_t^k, f\left(\boldsymbol{P}_t^{-k}\right)\right)}\right]}$$

Each project-specific weighting factor w^n alters its associated capex proportion π_t^n according to:

$$(7) \qquad \tilde{\pi}_t^n = \pi_t^n \cdot w^n$$

These altered proportions $\tilde{\pi}_t^n$ are all then combined in order to formulate an overall evenness score:

$$(8) \qquad \text{Capex Evenness: } S_t \equiv \frac{1}{N_t \sum_{k=1}^{N_t} \tilde{\pi}_t^k}$$

Under this form, $\frac{1}{N_t} \leq S_t \leq 1$ (where $\frac{1}{N_t} \to 0$ as N_t becomes large), such that values of S_t close to or equal to one indicate capex distributions across portfolios which are considerably 'balanced' for being near (or actually) uniform; but, alternatively, values for S_t near to $\frac{1}{N_t}$ indicate extensive imbalance in capex patterns, such that the flows of capex to specific projects are especially dense.

3.2.1 Selecting and justifying concentration thresholds

An important question surrounding the above calculation of capex evenness involves the selection and justification of the particular concentration-threshold parameter value θ to be used. θ should be strictly-positive integer (i.e., a counting number), but other than this requirement there are no 'technical' restrictions on what θ can or should be. These restrictions should instead come from practical considerations about what might be the 'efficient' sizes of IOCs' project portfolios, and how these efficient sizes are impacted by investors' preferences regarding risk and uncertainty. Put differently, increasing the diversification of a project portfolio by adding additional projects to it that are only imperfectly correlated (and preferably largely uncorrelated) with those projects already in it has benefits only up to a certain point; beyond that point the incremental costs (especially those associated with governance, expertise, and loss of scale efficiencies) of further diversification begin to outweigh the benefits. Efficient diversification is a topic that has been extensively explored in financial economics regarding efficiently-diversified portfolios of securities, but much of that research cannot be directly applied to the issue of project diversification by IOCs, because securities are far more 'divisible' than are projects.

Hence, there is not at present much theoretical guidance about what an ideal and responsible value for θ should be. Consideration needs to be given to whether θ should vary across companies, or whether it should be set as an industry-wide 'norm'. These questions should be openly and carefully discussed by investors and management teams together, and this paper is hoped to help precipitate those discussions.

From an empirical and practical standpoint, it is unclear whether or not past precedent is necessarily relevant for determining suitable values for θ. As has been underscored repeatedly in this paper, IOCs have not historically adopted the practice of publicly disclosing how many capex projects their portfolios contain, so investors have to date not necessarily been able to properly scrutinise whether or not historical portfolios were indeed well-diversified or not. Hence, unless management teams are able to defend the case (with adequate evidence) that their past project portfolios were responsibly diversified, past project counts may not be a good guide to what θ should be going forward. But another, even more serious concern than the provability (or not) of past diversification practices may steer future values for θ: worries over 'peak projects'.

As remarked earlier in the paper, there is growing concern among experts that the number of potential projects remaining for economically-viable extraction of oil and gas may be diminishing. Of course, this hypothetical number of projects fluctuates with both: levels of technology; and the prices of oil and gas. Yet, one can reasonably assume that there are only a limited number of projects (for whatever price level and reasonable pace of technological development over coming decades) that remain for extraction. This number of remaining projects could be seen as some benchmark figure from which a responsible value for θ might then be reverse-engineered. That is, given some suitable assumptions about the number of IOCs that might reasonably coexist and compete for worldwide reserves, and some reasonable distribution of projects across those IOCs over time, then one might 'back-solve' for the number of projects that any one IOC should be undertaking at a given point in time in order to help determine what a theoretical value for θ could potentially be. Of course, such a benchmark calculation may well be (considerably) less than what the responsible value of θ should normatively be, because there may (now or at some point in the future) be too few remaining projects (and/or viable project opportunities) remaining among all IOCs to allow for responsible diversification of capex. These points accentuate the necessity that the chosen value for θ be backed by sound justification, and that the onus should be on management teams of IOCs to provide well-studied cases to investors for why specific values for θ are or are not suitable.

3.2.2 Buffers

It should be reiterated that capex evenness, S_t, as calculated according to the foregoing equations, can be at most equal to 1 (for very balanced distributions of capex across projects); and its minimum possible value is $1/N_t$ (for heavily imbalanced – and therefore badly diversified – concentrations of capex across projects). Nevertheless, investors may not feel totally comfortable with managers of IOCs maintaining portfolios of projects that operate exactly at these maximum or minimum limits. In particular, investors may prefer that managers distribute capex across projects in ways that are a specified threshold ψ_{min} above the minimum value of $1/N_t$ for S_t. For cases wherein $\theta < N_t$, a suitable value for ψ_{min} may simply be $1/\theta$. But some investors (perhaps out of a lack of surety as to what the appropriate value for θ should be), may prefer an even more conservative threshold. That is, some investors may prefer to have the minimum threshold ψ_{min} for capex evenness S_t be set at a certain percentage $y\%$ above the value $1/\theta$. This more conservative *lower buffer* for capex evenness can then be calculated according to:

$$\textbf{(9)} \qquad \text{Lower Capex-Evenness Buffer: } \psi_{min} = \frac{1}{\theta} + \left(1 - \frac{1}{\theta}\right) \cdot \left(\frac{y}{100}\right)$$

In Equation 9 above, $y \in [0,100] \subset \mathbb{R}$. This lower buffer can indicate the minimum amount of diversification that an investor is willing to accept by an IOC with respect to the smallest allowable value for S_t that the investor might be willing to tolerate.

Alternatively (but much less likely), an investor may wish that the portfolio of projects being pursued by an IOC (in terms of capex allocation) have no less than a certain degree of concentration. This preference then gives rise to the idea of an *upper buffer* ψ_{max} for capex evenness, which is straightforwardly calculated according to:

$$\textbf{(10)} \qquad \text{Upper Capex-Evenness Buffer: } \psi_{max} = 1 - \left(\frac{z}{100}\right)$$

In Equation 10 above, $z \in [0,100] \subset \mathbb{R}$. When both y and z are specified by an investor, then this should serve to range-bound the values of S_t that the investor is willing to accept from IOC management, according to the following: $\psi_{min} < S_t < \psi_{max}$.

3.3 Worked examples of capex balance: A starter manual

To bolster intuitions and help readers better understand the usefulness of capex-balance metrics (i.e., capex density and capex evenness), this subsection contains some indicative examples complete with values and discussion. The specific structure of examples highlights the aforementioned deficiencies within current practice. In essence, this section can be used as a 'starter manual' for readers in beginning to think about and implement capex evenness and capex density in analysing and monitoring the riskiness of IOCs. To help readers dive deeper into the examples here, as well as construct and test their own, we have made freely available a capex-balance calculator that may be downloaded by following the link below (instructions for its use are in the Appendix).

- *Link to capex-balance calculator*
  http://www.smithschool.ox.ac.uk/research-programmes/stranded-assets/publications.php

To make this section as straightforward as possible, all examples will be based upon a single 'template' case. This basic template considers the capital expenditures by a fictitious international oil company, OILCO, over the past fiscal year. Figures in all examples are considered in US dollars (USD$), and have been modelled at similar scales to those currently undertaken by many IOCs (based on 2013 annual reports). The examples vary in what information is and is not available to investors based on a close reading of the annual or quarterly reports of OILCO. A brief summary of the example cases considered in this section appears in the table below:

Listing and Summary of Example Cases

Scenario	Relevant information reported by OILCO	Capex Density	Capex Evenness
Case #1	- USD$ 24 billion in total capex over last fiscal year	Insufficient information	Insufficient information
Case #2	- USD$ 12 billion in aggregate 'Upstream' capex in last fiscal year - Upstream capex spread equally across 3 geographic regions	USD$ 4 billion in Upstream capex per geographic region	Insufficient information
Case #3	- USD$ 12 billion in aggregate 'Upstream' capex in last fiscal year - 12 Upstream projects received capex during last fiscal year	USD$ 1 billion per Upstream project	Insufficient information
Case #4	- USD$ 12 billion in aggregate 'Upstream' capex in last fiscal year - 12 total Upstream projects received capex during last fiscal year, distributed as follows: 2 Upstream projects received USD$ 2 billion each; 10 Upstream projects received USD$ 200 million each - θ is assumed to equal 10 projects	USD$ 1 billion per Upstream project	S_t = 0.240
Case #5	- USD$ 12 billion in aggregate 'Upstream' capex in last fiscal year - 12 total Upstream projects received capex during last fiscal year, distributed as follows: 2 Upstream projects received USD$ 1.5 billion each; 10 Upstream projects received USD$ 900 million each - θ is assumed to equal 10 projects	USD$ 1 billion per Upstream project	S_t = 0.953
Case #6	- USD$ 12 billion in aggregate 'Upstream' capex in last fiscal year - 12 total Upstream projects received capex during last fiscal year, distributed as follows: 2 Upstream projects received USD$ 1.5 billion each; 7 Upstream projects received USD$ 900 million each - θ is assumed to equal 10 projects	USD$ 1 billion per Upstream project	ERROR!

3.3.1 Example Case #1

Scenario: OILCO reports that it spent a total of USD$ 24 billion in companywide capex over the last fiscal year. Beyond this aggregate capex figure, however, OILCO provides no other relevant information regarding its capex activities: it does not disaggregate its capex more granularly, nor does it state the number of projects (or corporate costs) to which capex pertains.

Calculations: Neither capex density nor capex evenness can be calculated based on this information.

Implications: Investors should be very concerned with the lack of transparency about how capex is being spent.

Realism: In Case #1, OILCO provides only slightly less information than do actual IOCs, who typically provide some geographic or divisional disaggregation of reported capex.

3.3.2 Example Case #2

Scenario: Again assume that OILCO reports that in the last fiscal year it spent a total of USD$ 24 billion in companywide capex. This time, however, also assume that in its public reports OILCO further discloses that, of its total capex over the last fiscal year, USD$ 12 billion was spent on 'Upstream' projects. Furthermore, it reports that, of this Upstream capex, approximately USD$ 4 billion each was spent in North America, Middle East/North Africa, and Europe (i.e., its total capex on Upstream projects over the last fiscal year was approximately evenly divided across three geographical regions).

Calculations: From this information one can calculate only a 'regional' capex density, which is approximately USD$ 4 billion per geographic region in Upstream capex over the past fiscal year. Realise, however, that this capex density figure is not the same as the one described earlier in this section; that is, it is not a true capex density figure, because it gives no indication of how capex is being diversified across projects. There is not enough information to calculate capex evenness.

Implications: Investors should be very concerned with the inadequate capex transparency provided by OILCO. While a regional capex density figure can be calculated, this does not give any meaningful view about OILCO's diversification, because it says nothing about the project-level capex patterns being undertaken by OILCO. For example, OILCO could be pursuing several dozen projects in North America, but only one in Europe, which would make its project distribution heavily imbalanced and vulnerable to Europe-specific hazards and risk factors. The fact that not even the basic number of projects receiving capex over the fiscal year is not disclosed prevents any meaningful transparency.

Realism: In Case #2, OILCO provides almost exactly the same level of information as do nearly all IOCs in their public reports and disclosures. That is, while IOCs often provide capex figures disaggregated at the divisional (e.g., 'upstream') or regional (e.g., 'Europe') levels, the failure to report any data on the number of projects receiving capex prevents investors from being able to calculate any value of capex density or evenness at the project level. It must be emphasised that Case #2 will be the most realistic of all cases studied in this section.

3.3.3 Example Case #3

Scenario: Assume that OILCO reports the same information as in Example Case #2, but that it now additionally reports that it invested capex in 12 Upstream projects worldwide over the last fiscal year. OILCO does not, however, report how much capex was spent on each project, nor the geographic region to which any of the 12 upstream projects belongs.

Calculations: This information suffices to calculate project-based capex density, which, based on the information disclosed, is USD$ 1 billion per upstream project, which indicates to the reader how large is the 'average' upstream project that received capex over the last fiscal year. Nevertheless, there is not enough information disclosed to calculate capex evenness.

Implications: Investors should be seriously concerned that, although there is enough information to calculate the average size of upstream project in OILCO's portfolio that received capex over the last year, they still possess no information about how balanced the $SUD 12 billion spent across all of the 12 Upstream projects was.

Realism: In Case #3, OILCO provides more information to investors regarding capex diversification than does any IOC in its most recent annual reports (at least based on 2013 public filings). That is, no IOC provides information on the total number of projects receiving capex during a given reporting period.

3.3.4 Example Case #4

Scenario: Assume now that OILCO discloses, in addition to the information in Example Case #3, the additional information: among the 12 upstream projects in which OILCO invested capex in the past fiscal year, it spent the following per project: USD$ 5 billion each on two projects; and USD$ 200 million each on ten projects. The company also issues guidance (which it claims that investors support), of a concentration-threshold parameter value set at $\theta = 10$.

Calculations: The capex-density value can be calculated at USD$ 1 billion per upstream project, which is unchanged from Case #3. Yet, capex evenness can now finally be calculated as well. This value is S_t = 0.240, which is much nearer to the minimum possible value of $\frac{1}{N_t} \approx 0.083$ than it is to the maximum value of 1. In fact, if investors desired a 20% lower buffer above the value $\frac{1}{\theta}$ (i.e., $y = 20$) according to Equation 9, then OILCO would fail to be above this threshold (which would be ψ_{min} = 0.280).

Implications: From the information provided by OILCO in Case #4, investors finally have a clearer picture of how capex is being allocated across projects. For many investors, the state of OILCO's diversification of capex across projects may be troubling (due to its indication of a high degree of concentration risk), but at least investors are now aware that OILCO may not be diversifying its capex responsibly, and may be able to encourage OILCO's management to take corrective action.

Realism/Alternatives: In Case #4, the amount of information disclosed regarding capex is far more than any IOC discloses today in its public reports. And while it may not be practicable for the amount of capex spent on each project to be disclosed (as it is in this example), investors can gain a much more intuitive and succinct understanding of an IOC's diversification practices if only capex evenness and capex density figures are disclosed (i.e., as opposed to reporting the capex allocated to each project, an IOC might convey comparable information to its investors by simply reporting capex evenness and density figures, along with the value of θ used in such calculations).

3.3.5 Example Case #5

Scenario: For this example, assume that OILCO discloses the same amount of information as in Example Case #4, except that the values that it reports for capex spent on each of the 12 Upstream projects over the past year are as follows: USD$ 1.5 billion each on 2 projects; and USD$ 900 million each on the remaining ten projects. As before, OILCO issues guidance that its concentration-threshold parameter value should be set at $\theta = 10$.

Calculations: In this altered version of Example Case #4, project-based capex density remains the same as before at USD$ 1 billion per upstream project. Now, however, capex evenness can be calculated to be S_t = 0.953, which lies much nearer to the maximum-possible value of 1 than the minimum-possible value of $\frac{1}{N_t} \approx 0.083$. Moreover, even with a 90% lower buffer (which, when calculated using Equation 9 would yield a value of $\psi_{min} = 0.910$), the measured capex evenness value is still comfortably within the 'tolerable' level.

Implications: In this setup, investors should be far more comfortable that OILCO's management team is engaging in responsibly-balanced capex across projects than in previous examples. While investors should still obviously seek other assurances from OILCO's management team that diversification is being responsibly undertaken, the values of capex unevenness undertaken here indicate that investors might take significant comfort.

Realism/Alternatives: Same as in Case Example #4.

3.3.6 Example Case #6

Scenario: For this final example, assume that OILCO discloses the same amount of information as in Example Case #5. In this situation, however, assume that OILCO reports that it only has in its Upstream portfolio 9 projects, on which it spent USD$ 9.3 billion in total during the last fiscal year. Assume also that OILCO reports the following breakdown of its capex: over the last fiscal year, USD$ 1.5 billion was spent on each of 2 projects, and the remaining 7 Upstream projects each received USD$ 900 million. Furthermore, the company still issues guidance that its concentration-threshold parameter value should be set at $\theta = 10$.

Calculations: In this altered version of Example Case #5, OILCO's project-based capex increases negligibly, to approximately USD$ 1.03 per Upstream project. Now, however, its capex evenness produces an 'ERROR' value because of division by zero, which is caused by its portfolio of $N_t = 9$ projects being smaller than the concentration-threshold parameter of $\theta = 10$.

Implications: The 'blowup' of capex evenness should be a red-flag to investors that OILCO is not balancing its project portfolio across a responsible number of projects.

Realism: Same as in Case Examples #4 and #5.

3.3.7 Synopsis of case examples

The preceding case examples should make clear to readers the present gap between what little information is reported by IOCs regarding capex, and the greater transparency needed for investors to make judgments about the diversification practices of IOCs that are more accurately and fully informed of the actual levels of risk involved. As underscored by Case Examples #4, #5, and #6 (which provide more information – despite their brevity – than IOCs' public reports do about capex patterns), IOCs need not report capex for every project; but even by disclosing slightly more information than they do now (in the form of capex evenness statistics and number of projects receiving capex), management teams may easily go much further in informing their investors.

3.4 Added benefits

Metrics such as capex evenness can give more visibility on the project-based diversification practices of extractive companies than do current reporting practices. And, when properly calibrated (i.e., when suitable values of θ are chosen for the type of capex being disclosed), these more advanced metrics can serve as behavioural controls on management. Consider, for instance, the 'sunk-cost fallacy': a cognitive bias wherein those committing the bias continue to spend significant volumes of capital on projects simply because significant volumes have already been spent on ('sunk into') the project.[9] Logically (and empirically, as has been demonstrated experimentally), the sunk-cost fallacy worsens for larger projects. Metrics like capex evenness may help to better discipline management teams by helping to mitigate the sunk-cost fallacy.

To see this possibility, realise that the evenness metric motivates management teams to spread capex as evenly across projects as is feasible. Project managers who compete with one another and are incentivised to rally more capex to their projects will have to justify why their project deserves a different level of capital from the average, which dissuades putting disproportionate amounts of capital towards underperforming projects just because such projects already have substantial past capital committed to them. Likewise, competition between project management teams may cause rival managers to question why an underperforming project may be receiving the average amount of capex, and encourage the project's abandonment, which may further discipline and discourage the negative effects of the sunk-cost fallacy by IOCs.

And note furthermore that by using and publicising metrics such as capex evenness, IOC management teams may be better insulated from some downsides of other psychological missteps, such as the *planning fallacy*. The planning fallacy describes a systematic bias by people to underestimate the time needed to complete projects (see especially: Buehler, Griffin, and Ross (1994)). Quite simply, with more diversified capex and project portfolios, even if management teams experience time-overruns on projects due to the planning fallacy, the consequences of doing so will be spread across a greater number of projects, and should reduce the deleterious effects of doing so.

Furthermore, an assessment of the managerial and governance capacities of an extractive company to engage in the sort of capex intensity implied by capex density and evenness scores. Some extractive companies might be 'spread too thin' in terms of their relative governance capacities, and be undertaking more projects than they can safely monitor and manage.

In terms of management's attention, those projects which consume a disproportionately large fraction of capex may garner a disproportionately large quotient of management's time and energy (as well as that of, e.g., boards of directors). Such disproportionate attention on large projects may cause neglect of smaller ones, which plausibly might create further incentives for managers to 'focus' on the larger projects if smaller ones underperform due to such neglect. And such circularities may cause adverse, self-reinforcing impacts on the intensity profile of an extractive company's capex. Possibilities such as this one pose important topics for future research.

Finally, IOCs, like other very large companies, may face problems in the 'efficiency' of internal capital markets (that is, in how efficiently management is able to allocate capital within the company itself to various divisions, geographies, projects, and project managers). The problem of inefficient internal capital markets has been studied extensively in management science and organisational psychology; a recurrent finding is that 'winning' managers who are in charge of projects that are either (or both) 1) large relative to other projects, or 2) are currently (or recently) more profitable than other projects, tend to continue to be allocated disproportionately large amounts of a firm's capital. The problem with such rich-get-richer effects in internal capital allocations is that they can make the organisation as a whole less stable (even if it entrenches and reinforces 'favoured' projects and managers) and induce myopic decision-making (which can can worsen when inefficient internal capital markets combine with the sunk-cost fallacy in managerial decision-making). And while these sorts of problems are serious threats to the wellbeing of IOCs and other large companies, they are very difficult for investors to observe directly. Hence, having in place metrics – such as capex evenness – that might discourage some projects or managers from becoming disproportionately large and posing outsized risks and/or drains on organisational resources, is innately desirable from a governance standpoint.

[9] On sunk costs and other cognitive biases, see especially: Kahneman, Slovic, and Tversky (1982); Gilovich, Griffin, and Kahneman (2002); Kahneman (2011).

4. Bringing responsible capex diversification into action

A pragmatic question now arises: how might capex evenness (or similar metrics) be introduced into reporting practices by extractive companies? A realistic answer is that introduction of such metrics for exposure evaluation may be driven by both investors and leading extractive companies. Specifically, shareholders concerned with transparency over capex activities by extractive companies might lobby the management of companies they own to introduce capex evenness as voluntarily disclosed figures. Alternatively, they might take a more binding approach, and encourage regulators to issue guidance on disclosing such figures, or else make them required. On the company side, leading extractive companies that pursue effective and efficient levels of diversification in their capex activities might wish to showcase this dimension of outperformance (relative to peers) to investors by voluntarily reporting capex evenness figures (and other information). Such change over time may cause laggard companies to likewise disclose such figures and take action in order to remedy any deficiencies in responsible capex conveyed by them.

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Glossary

Capex density: an indicative metric that gauges the 'average' or 'typical' size of a capex project in a time period

Capital expenditure (capex): financial capital spent by a company to acquire or improve a long-term asset

Capex evenness: an indicative metric that gauges how balanced a company's capital expenditures are across projects, accounting for the number of projects that a responsibly-diversified portfolio should have (see p. 12)

Capex intensity: a summary judgment of a company's pattern of capital expenditures that takes into account factors such as: the total volume of capital expenditures relative to the company's size; the density of capital expenditures being undertaken; and evenness with which capital expenditures are distributed across projects

Capex project: a discrete, single-location project that receives capital expenditure from a company

Concentration threshold: the minimum number of capex projects that it is acceptable for a company to engage in during the specified time period (p. 13)

Diversification: a risk-management procedure for reducing non-systematic risk in a portfolio of assets by distributing capital across multiple assets that have exposures to specific risk factors that differ across the assets

Downstream: a component of the oil and gas production chain that usually refers to the refining, processing, and purifying of petroleum crude oil and/or natural gas, as well as the marketing and distribution of these commodities

Heuristic: any pragmatic or 'practical' problem-solving technique that does not necessarily guarantee an optimal outcome, but is instead generally sufficient to achieve immediate objectives

Internal capital markets: any method (whether part of a formal process or not) that a company uses to allocate financial capital within the organisation itself (i.e., between divisions or regions of operation)

International oil company (IOC): a large corporate entity that specialises in upstream and/or downstream oil and natural gas activities; generally understood as publically-traded companies (also colloquially called 'Big Oil') that include the following entities: BP; Chevron; ConocoPhillips; ExxonMobil; Royal Dutch Shell; Total

Lower buffer: the minimum degree of concentration allowable for a portfolio of capex projects (see p. 15)

Peak oil: an event (based on original research by M. King Hubbert) that is the point in time which corresponds with the maximum global rate of petroleum extraction

Planning fallacy: a psychological phenomenon under which forecasts about the time (or, less commonly, capital) required to complete a project involve an optimistic bias, whereby projected completion times are systematically less than actual completion times

Reserve-replacement ratio (RRR): a metric in the oil and gas industry that measures the volume of 'proved' oil/gas reserves added to a specific company's reserve over a period of time relative to the amount of 'produced' oil/gas reserves extracted during that same period

Salience: a psychological phenomenon whereby an individual's attention is disproportionately attracted to some particular feature or stimulus relative to other features or stimuli that are also present

Sunk-cost fallacy: a psychological phenomenon (bias) that involves costs that have already been incurred and cannot be recovered; those who commit the sunk-cost fallacy justify continued expenditures in the present or future on the basis of sunk costs (which should not be part of the cost-benefit analyses for typical projects)

Upper buffer: the maximum degree of concentration allowable for a portfolio of capex projects (see p. 15)

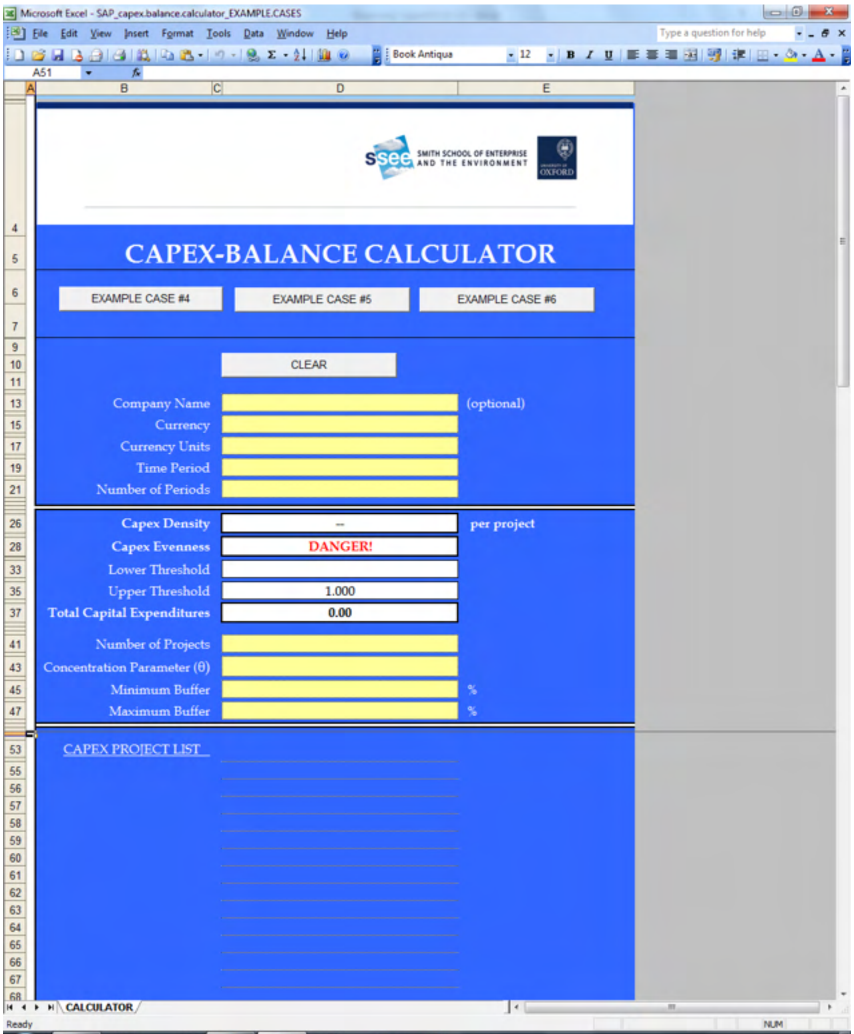
Upstream: a component of the oil and gas production chain that usually refers to the exploration and production activities associated with finding and extraction of underground or underwater crude oil and/or natural gas fields

Appendix: Overview of the capex-balance calculator

This section provides an overview for readers on how to operate the freely-available capex-balance calculator that was designed specifically to accompany this paper. That calculator may be downloaded at:
http://www.smithschool.ox.ac.uk/research-programmes/stranded-assets/publications.php

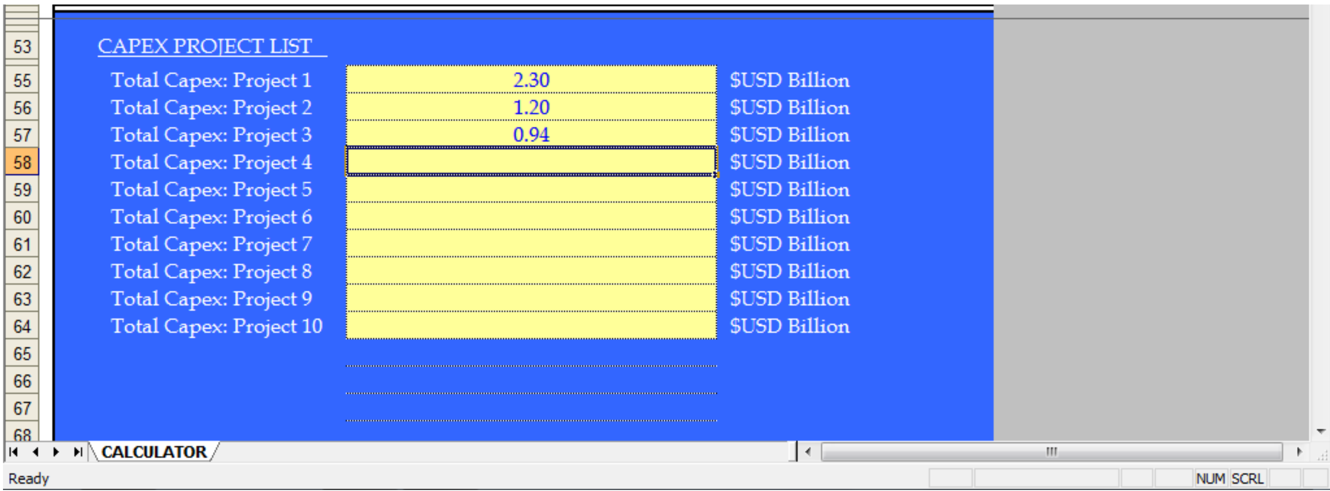
The capex-balance calculator was built in Microsoft Excel 2003, and can generally be used with any version of Microsoft Excel that is backward-compatible with that edition of the Microsoft Excel software. The calculator relies on several 'macros', and therefore users should have that feature enabled in order to use the calculator. No part of the calculator is locked or protected, so users may freely modify or combine the calculator with their existing analytical packages.

The calculator consist of a single, self-contained worksheet with input and output fields (see the figure below for an image of the layout of the calculator).



Within the calculator, yellow cells constitute input fields, whereas white cells are output fields. Some input fields require specific units of input (e.g., whole numbers); when users input inappropriate units an error message will be immediately generated to instruct the user about how to correct the value to the appropriate units.

Upon specifying the number of projects (in the sixth input field from the top of the screen: "Number of Projects"), the calculator automatically generates the appropriate number of input fields for each capex project. Users should input the capital expenditure allocated to each such project into its corresponding input field (see image below).



The input fields "Company Name", "Minimum Buffer", and "Maximum Buffer" are all optional fields. Note, however, that a "Danger!" message (in red font) will appear in the "Capex Evenness" output field whenever capex evenness is below a suitable value (which is set according to the "Concentration Parameter" value, as well as a combination of the "Minimum Buffer" and "Maximum Buffer" values, when the user enters values in those fields.

An inbuilt functionality resets the calculator whenever the "CLEAR" button is pressed. Users should realize that pressing the "CLEAR" button is an operation that cannot be undone, and any inputted data will be lost after pressing "CLEAR".

To assist users in becoming familiar with the calculator, three of the Example Cases appearing in the main text of this paper (in Section 3.3) have been pre-programmed into the calculator (these are: Example Case #4; Example Case #5; and Example Case #6). Pressing the correspondingly-labeled buttons at the top of the calculator will automatically populate the values from these cases in Section 3.3 into the calculator.

Specific questions regarding the use and functionality of the calculator can be directed to the following address:
dane.rook@smithschool.ox.ac.uk

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