

Energy, uncertainty, and entrepreneurship

*John D Rockefeller's sequential approach to transaction costs
management in the early oil industry*

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Abstract

This article delves into the challenge of successful entrepreneurship in the energy industry under conditions of uncertainty by examining the case of John D Rockefeller's Standard Oil Company, which rapidly seized control of an initially-uncertain industry. It finds that Rockefeller cemented control through a willingness to internalise contextual uncertainty (related to the nature of the energy business) as a stepping stone to managing contractual uncertainty (related to transactions with other parties). This finding suggests that thinking sequentially about the management of contextual and contractual uncertainty aids entrepreneurial success in the field of energy. This suggestion accords with standing calls in the transaction costs literature, which means that findings may generalise to some extent. However, the exploratory nature of the analysis implies the need for further research about the argument's compatibility with modern energy practices and its generalisability. **Word count:** 7977.

Keywords

Uncertainty; Rockefeller; Standard Oil; Entrepreneurship; Transaction costs.

1. Introduction

A renowned investment manager recently stated that “the only certain thing about oil's price is its uncertainty” [1]. The World Bank expressed concern about the challenge that regulatory, technological, and climate uncertainty means for clean energy technologies [2]. A prominent forum noted that “future regulatory uncertainty makes it difficult for investors to formulate risk and return expectations, causing hesitation and preventing capital inflows” [3].

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In sum: in the energy industry, uncertainty is a hurdle to entrepreneurship, defined here as the agent-led “process of creating new value (an innovation and/or a new organization)” [4]. In the context of a world that aspires for a more sustainable energy system, uncertainty is troubling. It can have a “paralysing effect on decision-making within institutions that are accustomed to dealing with challenges under a ‘predict-then-act’ paradigm [5]. There is, therefore, a need to study how to overcome uncertainty in the field of energy.

The author means ‘uncertainty’, not ‘risk’. An analogy that helps differentiate the concepts is the game of Russian roulette. Russian roulette entails a $1/n - \varepsilon$ possibility of death, where ‘ n ’ is the number of chambers in the gun and ‘ ε ’ the unknown possibility of a malfunction. The original game, thus, is more about risk than about uncertainty but, if players cannot count the chambers in the gun or work out the chances of a malfunction, the game becomes one of uncertainty. Energy entrepreneurs, who are key to the possibility of an energy transition, do not play Russian roulette. However, in the field of energy, much uncertainty escapes elimination. So, the rationale applies: gauging risk without information is impossible, and energy entrepreneurs often act in such daunting circumstances. In the context of the need for a sustainable energy transition, it is therefore vital to study ‘uncertainty’ as a challenge in and of itself.

This article dives into ‘uncertainty’, as such, by recalling that while it poses a challenge, uncertainty is also *the* source of entrepreneurial possibility [6]:

In a well-organized society, if business men know either (1) what actual changes are impending or (2) the "risks" they run... the effect in the long run is the same; the only result of such changes will be a certain redistribution of productive energy which will take place continuously and without any disturbance of perfect competitive conditions.

This view is valid in the field of energy, where authors know that “uncertainty can both create opportunities for entrepreneurs to engage in emerging technologies, as well as hamper entrepreneurs in undertaking action” [7]. Unfortunately, while much has been written about the dynamic between uncertainty and *aggregate* realities such as oil prices [e.g., 8,9], new energy technologies [e.g., 10–12], and politics [e.g., 13,14], little has been written about how energy entrepreneurs can manage uncertainty *individually*. This focus is worrying because, being both a challenge and opportunity, at the aggregate level uncertainty will undoubtedly cause many failures. Focusing on uncertainty’s potential to cause failures may lead to a pessimistic view of uncertainty, which would lead to it being misrepresented.

The puzzle concealed in the fact that entrepreneurs need to overcome uncertainty is the question of whether some strategies are better than others at managing uncertainty (the alternative being that entrepreneurs need sheer luck to overcome it). This puzzle is too large to address at once, so this paper focuses on a related but much more specific research question: how did John D Rockefeller's Standard Oil Company manage uncertainty? As seen later, the case is fitting for an article about energy entrepreneurship amidst uncertainty. Moreover, Standard was pivotal to one of the greatest transitions in the history of energy: the 1860-1910 ramp up of the oil industry [15].

Section 2 presents the theory. Section 3 introduces the method of analysis. Section 4 and Section 5 analyse and discuss Standard's case. Conclusions, in Section 6, summarise and call for further research.

2. Theory

The property-rights approach to transaction costs (TCs) can account for uncertainty being both a challenge and an opportunity for entrepreneurs. This approach is traceable to Coase's explanation of the emergence of firms [16,17]:

The entrepreneur has to carry out his function at less cost, taking into account the fact that he may get factors of production at a lower price than the market transactions he supersedes, because it is always possible to revert to the open market if he fails to do this.

When two or more parties agree (the contract) that the entrepreneur will deliver tangible wealth (the property) to users for a given price (the mechanism), entrepreneurs must cover costs for raw ingredients *plus* all other costs arising from the need to *transact* with others, and they must do so more efficiently than competitors. Uncertainty is variously present in the entrepreneurial process, so it stands to reason that entrepreneurs who deal with uncertainty efficiently will likely deliver their products or services at a lower cost than competitors (or a higher benefit at a comparable cost). The challenge, but also the opportunity, is managing uncertainty better than competitors.

TCs matter in the energy industry. The industry is fertile ground for integration [18], and both vertical and horizontal types of integration can reduce TCs [19–21]. Vertical integration brings external operations under the entrepreneur's control: the equilibrium is where the entrepreneur becomes more efficient than the collective firms that would otherwise play a part in the process. Horizontal integration widens the pool of options available to an entrepreneur: the equilibrium is where the gains from diversification outweigh the costs of

doing so. For both, however, the existence of an equilibrium implies the need for information. It is impossible to know how much to integrate, or in what direction, or when, or how, without information.

Information challenges notwithstanding, energy entrepreneurs can look into the idea of energy security as a broad guide to what the market desires. Despite the ambiguities that surround energy security, commentators agree that “large, flexible, and well-functioning energy markets provide security by absorbing shocks and allowing supply and demand to respond more quickly and with greater ingenuity than a controlled system could” [22]. So, the world sees energy markets as a way to achieve energy security. Energy entrepreneurs are central to the functioning of energy markets, even if failures are always possible and non-market mechanisms may be necessary complements [23]. It stands to reason, then, that much of the uncertainty of the energy business is tightly linked to the uncertainty associated with prominent energy security challenges.

The most notable energy security challenges are the ‘availability’, ‘accessibility’, and ‘affordability’ concerns that came to prominence in the 1970s, and the various considerations of social, political, and environmental ‘acceptability’ highlighted afterwards [23–25]. The Asia Pacific Energy Research Centre (APERC) [26] recently brought these factors together to produce the ‘4A’ model. This article uses APERC’s model, with two minor modifications: firstly, the addition of ‘adaptability’ due to the need for the alignment of energy technologies and production platforms, and, secondly, the treatment of ‘affordability’ as a ‘+A’ factor to highlight that affordability can be affected by other ‘As’ and by exogenous factors [27]. The result is a functional view of energy security with five variables: availability, accessibility, acceptability, adaptability, and affordability (4A+A).²

For this article, these 4A+A factors also point to an expectation: entrepreneurial strategies that absorb or internalise uncertainty related to energy availability (E_1) / accessibility (E_2) / acceptability (E_3) / adaptability (E_4) / affordability (E_5) will contribute to success amidst uncertainty. While straightforward, this expectation is daring in the context of modern energy because many in the field try to avoid uncertainty through collective [neoclassical] efforts aimed at gathering better information and improving governance [e.g.,

² APERC’s model can be criticised for not explicitly establishing links with higher-level security theory [28], as can the 4A+A model. Since there are no complete models of energy security, however, the 4A+A can be seen as a satisfactory expression of the functional side of the energy security challenge.

29–33]. By confirming or rejecting this expectation, this paper helps to establish if Standard’s strategies support modern practices in the field of energy.

It is worth mentioning before moving to the methods section that models similar to the 4A+A exist outside of energy. Cherp and Jewell [28], for example, mention a model by Penchansky and Thomas that examines the “degree of ‘fit’ between the clients and the system” in the health services industry [34]. Their model looks into the availability, accessibility, accommodation, affordability, and acceptability of health services. Another example is the field of food security. Here, the United Nations Food and Agriculture Organization defines food security through availability, access, utilisation and stability, where utilisation is a nutritional measure of how adaptable food is to the human body and stability refers to adequate continuous intake [35,36]. There is, also, a model of food security based on considerations of availability, accessibility, adequacy, acceptability, and agency [37]. This article cannot claim direct relevance to these fields because it focuses on energy. Similarly, as elaborated below, the method limits the generalisability of the argument. However, the fact that the 4A+A has non-energy parallels opens room to contemplate the argument’s applicability beyond energy.

3. Method

Rockefeller’s Standard faced significant uncertainty. Political uncertainty, due to the recently concluded American Civil War and other conflicts at the international level such as the Franco-Prussian War [38]. Market uncertainty, because the energy industry at the time was fertile terrain for speculators [38].³ Technological uncertainty, because the industry featured new and competing technologies, namely the coal-based kerosene recently discovered by Canadian geologist Abraham Gesner [39]. In addition, the period saw not one but two oil gluts, the first precipitated by a production rush following George Bissel and associates’ discovery in 1859 [38,40,41] and a subsequent swing after the Civil War [41]. It is hard to pin down the exact level of uncertainty of the combined challenges. Uncertainty may well be as difficult to conceptualise as the number ‘zero’, so the very idea that it can be measured, ranked, or compared, needs exploration. However, the challenge was great, particularly for an entrepreneur who, despite being remembered as a rich man, came into the business as a humble merchant of daily produce. Standard, nonetheless, “brought ‘order out of chaos—

³ Speculation is not necessarily negative, as it can drive financial incentives up. The subjectivity of speculation, however, makes it hard to find certainty in it.

Rockefeller euphemism for monopoly” [42]. If there is such a thing as a *successful approach* to entrepreneurship amidst uncertainty, Standard is an outstanding place to start exploring.

There is room for tension about how to approach single cases in the context of energy research and the social sciences. On the one hand, single case analyses lack the robustness (the extent to which findings are stable) and generalisability (the extent to which findings inform our understanding of other cases) associated with other methods. Likewise, trying to automatically compare a case as old as Rockefeller’s Standard with modern cases of energy entrepreneurship risks falling into the ‘apples and oranges’ fallacy [cf. 43]. This consideration does not mean the comparison is impossible, but it does mean that additional research is needed to determine the extent to which comparability exists. Limitations notwithstanding, authors agree that there is value in using single cases for exploratory analysis. They “are useful for exploration and for generating hypotheses – for creating new conjectures in a sort of ‘light bulb’ moment” [44] and, if well chosen, a single case can go as far as to enable the testing of expectations/hypotheses [45]. It is too early to speak of general theories about energy entrepreneurship amidst uncertainty. So, this article starts by grounding debate in an exploration of what seems to be an uncontroversial instance of significant entrepreneurial success amidst uncertainty.

On the other hand, even single cases are implicitly comparative, because selection follows considerations relevant to a broader set of cases [46]. Qualitative studies can claim ‘analytical generalisation’ when driven by a logic applicable elsewhere, and when the cases are comparable to those elsewhere [47]. This article builds on theory applicable across the world of energy. Moreover, Rockefeller shared the foundational challenge faced by all energy entrepreneurs: the existence of a threshold at which activities must cease due to what Taleb [48] refers to as an “absorbing barrier” from which there is no recovery, i.e., ruin. The plight of entrepreneurship amidst uncertainty is that the more uncertain a situation is, the harder it is for an entrepreneur to trust its ability to avoid ruin. In this sense, Standard’s case is comparable, to a degree deserving further research, to that of all energy entrepreneurs (perhaps even to all entrepreneurs). So, while the findings here speak directly only of the Standard, there is room for some generalisability.

In sum, then, a single case exploration can help to confirm primitive expectations that may or may not apply to other cases, but that can, in itself, advance research. This is, indeed, the goal here: to confirm the expectations given earlier and identify room for further research.

4. Analysis

Rockefeller entered the oil industry in the early-1860s and, by 1870 he held some 4% of the refining market [49,50]. He then created the Standard Oil Company in Cleveland, which grew rapidly. Standard's share of the market by the end of the 1970s was somewhere between 80% and 95% [42,51]. Standard saw increased competition from the late-1880s, but its dominion only ended when the US Supreme Court broke the company apart in 1911. Even then, the resulting companies became some of the biggest energy conglomerates that exist to date. Guided by the 4A+A, this section explores how Standard approached uncertainty.

Before entering specifics, however, it is essential to recall that there was a single guiding rationale underneath all of Rockefeller's actions: control. Rockefeller was aware of there being an opportunity in uncertainty. For example, in his autobiography, Rockefeller tells the story of a partner to whom he lent money for an uncertain investment on the condition that the partner would only need to repay the money if the investment turned profitable [52]. That said, his actions sought uncertainty only instrumentally, as his goal was invariably 'control' (and had been since he was young, when, "to ensure that he won, he submitted to games only where he could dictate the rules" [53]). So, the sections below analyse how Rockefeller approached the uncertainty associated with the 4A+A challenges in pursuit of control, but they do not suggest that Rockefeller himself thought in 4A+A terms.

4.1. Availability (via location)

Early oil entrepreneurs had three options regarding location: next to production centres, next to markets, or somewhere in between. While refiners located next to production centres had more insight into, and influence over, local dynamics, oil availability was scattered across states [54]. Cleveland is somewhat in between production centres in Pennsylvania, West Virginia, Indiana and Kentucky. The opportunity to aggregate oil from different suppliers grew as the size of the industry increased. Location enabled supply diversification. However, Rockefeller could not have known this for certain when he chose Cleveland. Production concentrated initially in Pennsylvania and West Virginia, which are next to each other. Indiana and Kentucky only became significant supply regions by the mid-1870s and early-1880s. Unsurprisingly, at the outset, those close to production centres felt safe, even boasting of the future with certainty [38]. In turn, concerning supply, Rockefeller bore more initial uncertainty than many competitors.

The other half of Rockefeller's location strategy relates to demand. Centralised refiners near big markets were able to exploit economies of scale too. By 1872, for example, New York's refining capacity was only ~20% lower than Cleveland's [38]. New York also had an advantage over Cleveland regarding the initial level of uncertainty. New York was a massive market, so it was not unwarranted for local refiners to see their proximity to consumers as a source of certainty. It was easier to ship oil to New York to refine and sell locally than to ship the oil to Cleveland, refine it in Cleveland, send the kerosene to New York, and then trade in New York. However, in pursuit of certainty, entrepreneurs can corner themselves into a situation where they block the possibilities that come with uncertainty. In this particular case, that corner was New York, which was as far away as possible from emerging city markets such as St. Louis and Chicago. So, from a demand perspective, Rockefeller initially bore more uncertainty than refiners in New York, but when markets developed westwards Standard's location enabled more horizontal integration, this time at the demand level.

Standard never stopped organising operations according to this 'middle-point' rationale. Standard's expansion, which took place between the late-1880s and the 1910s, went as far as to create the Vacuum Oil Company AG in 1904, a Vienna-based subsidiary that invested ~\$3 million by 1910 despite fierce opposition by the local government [55]. Having a foothold in Vienna was important because the region was a major producing centre with favourable access to all European submarkets. The rate of oil discoveries in the United States limited the 'middle-point' strategy, but it followed a similar pattern. A good example is an interplay between Standard's approach to California and Texas. California's oil production only ignited after output in the region went from 2.6 million barrels in 1889 to 24.3 million in 1903 [56]. Standard had already set up shop in California in 1900 with the objective of enlarging market presence [56]. When the boom came, Standard acted rapidly by repeating the middle-point recipe, which led it to holding ~75% of the refining market by the turn of the century [56]. However, Standard did not show much interest in Texas due to geological miscalculations by staff, animosity with the local elites, a mismatch between the type of oil in Texas and Standard's traditional supply and, importantly, thinking that its California operations were sufficiently close to service the region [54,57,58]. Texas turned out to be essential to accessing foreign markets, however, so not setting operations there was a mistake. A mistake that shows how much Standard believed in its 'middle-point' rationale.

4.2. Accessibility (via transportation)

Some see Rockefeller's management of accessibility to/from oil/markets via the control of transportation as *the* reason Standard succeeded [e.g., 38,49]. This article shows that all other 4A+A factors also played a role, but there is no denying that transportation was vital.

Much uncertainty existed in transportation. The infrastructure was in development, and secret rebates and the intentional misclassification of freight by railroad companies were common [59]. 'Secret', however, refers not to a situation where nobody knew about the practice. What nobody knew was 'who' got exactly 'what'. In such a situation, the natural response is for each entrepreneur to aim for as many and as large rebates as possible. Accordingly, Rockefeller was amongst the first to pursue rebates [38], but he was not the sole beneficiary [60]. So, the rebates were a source of uncertainty because although they were common knowledge, actionable information about relative transportation costs did not exist.

The turning point was the South Improvement Company, a cartel initiative that sought to lower uncertainty for both railroads and refiners [61]:

Competition among the railroads led to price wars... [which] led Scott [from the Pennsylvania Railroad Company] to try to limit competition among the railroads by creating the South Improvement Company, a railroad cartel consisting of the Erie, New York Central, and Pennsylvania railroads, which set prices and freight volumes to prevent rate wars and establish advantageous shipping prices for the railroads.

The matter of who brought who into the scheme is debatable. Some believe that the railroads included the region's largest refiners [49, cf. 60]. Others claim that Rockefeller got the idea from other refiners [40]. Initially, though, Rockefeller did not seem enamoured with the scheme and may have only joined after considerable persuasion [40]. What did happen after, however, is that Rockefeller manoeuvred his and his partners' shares so that Standard would have formal control of the initiative [40]. In other words, he took over the initiative before the cartel materialised and then designed it to his advantage, to the point that the result included means to gain information about competitors' shipments [40].

Investing in taking control of a cartel is similar to buying a different organisation to bring it under control, i.e., vertical integration, so the strategy itself is about managing contractual TCs. However, Rockefeller acted before knowing if the South Improvement Company was viable. In doing so, he effectively broke the process of integration into a two-step sequence. Firstly, he invested in internalising all the uncertainty of the cartel, then, secondly, he designed rules to lower his contractual TCs. Proof of his willingness to take on

significant uncertainty is that, this time, Rockefeller failed as public outcry led to the collapse of the South Improvement Company initiative and a blockade against Standard [38,62]. In other words, Rockefeller invested when the cartel's future was still uncertain, but the cartel did not come to fruition, to Rockefeller's disappointment [40].

Rockefeller still profited from the South Improvement Company. Once again, however, the key was seeing possibility in uncertainty, or at least to fear it less than competitors. While the South Improvement Company was still a possibility, he capitalised on the fear of an uncertain future by getting others to sell their operations to him at unfavourable prices [40]. Integration, once again. Sequential integration, though. At the time of bidding, Standard was still a similar size to other refiners. Placing so many independent bids put Rockefeller in the dark about what the outcome would be, and costs would have been incurred regardless. He was an outstanding deal-maker, however. So, by the time he finished, Standard had the scale needed to control the railroads. Then, finally at that point, "what did he [Rockefeller] do? ... He got a rebate" [40]. That is, he used his newly-privileged position to reduce his contractual TCs. He allowed participation by other "large shippers, who could guarantee large and regular shipments and could threaten to ship by other routes, [who] were granted rebates by the railroads" [62]. However, Standard cared for relative advantages [61] and its newly enlarged size sufficed to ensure an advantage vis-à-vis all other refiners.

4.3. Adaptability (via innovation)

Refining was an attractive business at the time [40]. It also made sense for Rockefeller to give refining a try because he was a merchant of daily produce which, at that time, meant that he traded some oil as part of his previous activities [63]. However, Rockefeller entered the business only after internalising technological uncertainty by convincing the British inventor Samuel Andrews to be a partner. The partnership mattered. Rockefeller could have avoided giving shares by hiring average technologists. Instead, he parted with a significant share of his company to acquire Andrews, who proved to be nothing short of a genius and was able to transform bitumen into kerosene much more efficiently than others [40]. Without Andrews, Standard would have been dependent on the market for innovation. With Andrews, Standard had someone under its roof tasked with continuously dealing with the technological uncertainty imposed on energy entrepreneurs by the need to adapt raw resources into usable fuels.

The size of the resulting advantage is a matter of debate. Some believe that Standard's pre-1870 success was "solely on account of its superior efficiency" [50]. Others claim that refiners in the region were not that far behind [40]. Regardless, the advantage existed. Multiplied by scale, it would have made a difference. Once again, however, the strategy was sequential. The first step was to incur the cost of bringing someone on to tackle adaptability. Efficiencies only came as a result of that move. Now, Andrews grew increasingly unhappy with Rockefeller's aggressiveness during the 1870s and sold his shares to Rockefeller in 1880 [64], but he left behind a culture of innovation [65]. In doing so, he ensured that Standard would not have to rely on the market to overcome technological uncertainty.

Inevitably, Standard would miss an innovation or two. When this happened, however, the company flexed its financial muscle. Crucial to the argument here is the fact that rather than merely paying to get access to market technologies, Rockefeller pursued external innovation with the goal of internalising it. An excellent example was the late-1880s purchase of patents related to an invention by Hermann Frasch, which enabled the purification of sulphur-rich oils. Frasch initially worked for Standard but was underappreciated, so he developed and patented his method independently. Rather than just getting access to the process, however, "Rockefeller paid a handsome price to acquire the Frasch properties *and* bring Frasch back into the Standard fold" [66]. Standard internalised both the technology and the innovator. The investment worked. Standard became able to use sulphur-rich oil, cheaper than other oils, without a loss in quality. Having exclusive access to the best techniques equates to some degree of control over competitors. This final control, however, does not change the fact that Rockefeller sunk the cost on the *possibility* of a satisfactory outcome, rather than the *certainty* of it.

Refining saw substantial improvements during the 1870s [50], and the 1880s saw an explosion of genius elsewhere. At least one competitor, a company called Branobel, short for 'Nobel brothers' in Russian, rivalled Standard's in-house innovation capacity [67]. Alongside the increase in expertise under other roofs came an erosion of Standard's market share, which shows that being par to the market in adaptability is not enough for control. Being comparatively superior, though, may require investing in little more than hope and trust in the capacities of innovators, as did Rockefeller with Andrews.

4.4. Acceptability (via quality)

Frasch's assistant, William Burton, reportedly got his surname appended to Frasch's invention for helping to convince large customers of the quality of the output [66]. Burton might well have been an outstanding assistant that deserved credit nonetheless, but the fact that he has a place in history due to having helped to spread acceptance for Frasch's invention shows the importance of the matter.

The fact that Standard cared about acceptance is not a surprise. The entire region of Cleveland marketed itself as having an "immovable reputation for the quantity and quality of this most important product" [40]. To the extent that Standard was part of Cleveland, the company must have benefited from certainty collectively derived from the region's reputation. Rockefeller, however, was not content with just being part of the region's prestige. His desire to stand out even amongst Cleveland's refiners was such that the name of the company, 'Standard Oil', was chosen a symbolic statement amidst concerns for the safety of other oils [43]. This willingness to be a direct point of reference was bold, given that people were not fond of Rockefeller or his company. On the contrary, as noted earlier, the Standard was publicly vilified in the context of the South Improvement Company.

Retailers would still prefer to buy from Standard because of confidence in the quality of his product [64], because "even the most anti-Rockefeller muckrakers conceded the high quality of operations at the Standard" [63]. Acceptance, thus, was built on a twofold strategy. Part of this strategy related to the considerations in the previous section. In a nutshell, better technology results in a better product. The full formula, however, also involved an additional, and rather daring, element. Rockefeller embraced the idea of oil as a dangerous product. Effectively, then, he invested in making oil uncertain in the eyes of consumers. Only, he exempted his company from the resulting fears by also investing in marketing that highlighted the quality of Standard's oil.

It is easy to see how this strategy led to control when looking at events retrospectively. At the time, however, heightening doubts about the nature of the product while also placing his brand in direct contact with audiences was courageous, particularly considering how poorly Rockefeller did at managing audiences during the South Improvement Company episode. Nonetheless, the strategy worked. The savings are impossible to calculate, but the implementation was so fantastic that the very usage of the word 'standard' became a branding fashion after *the* Standard Oil Company [68].

Eventually, Standard moved to reduce other non-fixed costs by removing the middlemen from the logistical equation [20]. The move represented an act of integration, this time into the distribution level. At the time, normal distribution channels were so inefficient that “all Rockefeller's laboriously wrought economies were thrown away when the oil passed into the hands of the jobber” [64]. Standard, instead, operated with religious efficiency at all levels.

Standard did not expand geographically until the late-1880s, which makes it hard to argue that there was a rush to integrate into retailing elsewhere. However, geographical expansion was catalysed at least partially by the desire for acceptance, as evidenced by the fact that Standard only started to discuss expansion around 1885, when existing price advantages and bad-mouthing of competitors proved insufficient to counter market penetration by other companies [43].

4.5. [+] Affordability (via corporate governance)

There are visible links between considerations related to all factors noted thus far and the final affordability (+A) of Rockefeller's enterprise. Standard became more affordable to run every time non-fixed costs fell following actions related to any 'A'. Rockefeller was then able to choose if he wanted to keep the savings for the benefit of Standard or pass them onto customers, a normative question that falls outside the scope of this article. The interlinkages are part of the reason why affordability is separate from other 'A' factors. As noted earlier, however, the other part of the reason why affordability is separated into a '+A' factor is that it can also be affected by efforts exogenous to the other 'A' factors. In Standard's case, the most significant such effort was Rockefeller's interest in efficient management.

Another of Standard's founding partners, Henry M. Flagler, was vital in this regard. Flagler came into the picture before the incorporation of the company, around the same time as Rockefeller and his original partner, Maurice Clark, had a falling-out. Flagler was behind both the decision to turn the company public in 1870 [69] and the decision to turn the company into a trust in 1882 [70]. The incorporation in 1870 was in line with the best management practices of the time [64]. Not necessarily in the oil industry, where lousy management abounded [65], but on par with practices elsewhere. The re-organisation into a Trust in 1882, however, was nothing short of an innovation in management [71]. The change sought to bring efficiency into the administration of what had become a gigantic system of interlocked entrepreneurial efforts by integrating the management of it [51]:

... "for convenience of control and management the Standard Oil Trust was formed... an agreement, placing all the stock of these various companies in the hands of trustees, declaring the terms on which they were held, and providing for the issuance of a certificate showing the amount of each owner's interest in the stock so held in trust... [that] did not in any essential manner change the character of the association previously existing... [but] was simply a common ownership of stock in various corporations... [because] it seemed preferable, instead of organizing one corporation in New York, to organize a corporation in each State where business was being carried on, so that the business transacted in each State might be conducted by a home corporation..."

Regardless of intentions, though, the idea of the Trust was novel. By going through with it, Standard went beyond internalising uncertainty. Instead, it directly created uncertainty for itself by locking its future into a change for which no precedent existed.

The result was satisfactory. The reorganisation created “an extensive system of reporting by the individual companies and of personal consultation [that] contributed to making centralized coordination and control of decentralized management of operations reasonably effective” [71]. The new system was not perfect. Distances and external management of some operations weakened the effort [71]. However, the system sufficed to support the subsequent process of further vertical and horizontal integration that followed, and one that led to Standard becoming fully-integrated by the 1890s [54,70,71].

5. Discussion

Rockefeller saw possibility in his decisions. Perhaps he even self-confidently believed in his capacity to produce a particular outcome. Entrepreneurs engage in prospective thinking as part of the normal entrepreneurial experience. So, Rockefeller could have perhaps gone as far as to specifically consider how to best organise uncertainty [72]. This argument does not deny that uncertainty can be reduced into measurable, or at least categorisable, bits. Retrospectively, in fact, almost everything is measurable. The point here, however, is to inquire into what good entrepreneurship amidst uncertainty is, which requires examining how entrepreneurs choose between one or another organising strategy. In this sense, the analysis indicates that when Rockefeller made the investments needed to have/build proprietary solutions for each 4A+A challenge, he did so on account of little more than entrepreneurial instinct. Moreover, the analysis also shows that Standard’s strategies diverged from those by competitors and were, for the most part, untested; daring, even. Therefore, the analysis confirms that, for Rockefeller’s Standard, the willingness to invest in strategies bearing more

uncertainty than those of competitors contributed to success amidst uncertainty, which confirms all expectations.

The key to understanding how the strategy worked is the exact sequence of steps that underpin Standard's strategies, namely, an initial act of internalising contextual challenges, proxied here by the 4A+A factors and devising proprietary solutions to them, and then, the subsequent use of these solutions to reduce the costs of transacting with others. The sequence is evident concerning availability and accessibility, for example, where Rockefeller set up shop in a supply/demand middle-point before oil discoveries had been finalised and before markets developed westwards, which then enabled diversification of both supply and demand. The sequence is also noticeable concerning adaptability, where Rockefeller even parted with a share of his company to bring Andrews under his roof, solely in the hope that Andrews would provide efficient solutions across the entire technological dimension. Actual gains in efficiency, however, only materialised after Andrews joined the company. It is not as easy to appreciate the sequence concerning acceptability and affordability because actions on these fronts were fuzzier than in other areas. However, the linking of Standard's brand with the fears associated with the safety of oil logically precedes customers' discrimination against other brands due to safety concerns. Had only the first part of the strategy worked, namely Standard's implied acceptance of oil as inherently dangerous, Rockefeller would have been discriminated against, along with other competitors. Similarly, the willingness to re-organise an entire company into a new untested managerial model is tantamount to diving 'head-first' into a completely uncertain way of doing business, with managerial efficiencies only coming after the reorganisation.

Of course, it is easy to justify all of Rockefeller's strategies in hindsight; perhaps even call them obvious. However, no entrepreneur, not even Rockefeller, can predict the future. On all fronts, Rockefeller invested in unique, independent strategies in the domains of the 4A+A factors without knowing what the future would bring. In a way, he trusted his ability to mould the future in his favour. Invariably, however, the proprietary solutions for the 4A+A challenges improved Rockefeller's bargaining position, which *then* led to controlling suppliers, competitors, and consumers. And so, we get the sequence of steps by which Rockefeller approached the uncertainty of his business: first, devise proprietary solutions to the 4A+A challenges, then, second, use these solutions to reduce the costs of transacting with other actors in the market.

The sequence behind Standard's strategies is fascinating from the perspective of the literature about TCs. As noted earlier, market transactions happen, always, in the context of one or another form of contract. Saying that Standard's actions toward the 4A+A factors equated to the ability to minimise the costs of transacting with others is the same as saying that Standard's actions toward the 4A+A factors equated to the ability to minimise contractual costs. In turn, this analysis highlights the need to differentiate between the costs associated with overcoming contextual uncertainty (related to the nature of the energy business, proxied here by the 4A+A challenges) and contractual uncertainty (related to interactions with other parties). As such, the findings here can be rephrased as follows: Standard's proprietary mastery of contextual uncertainty enabled it to control contractual uncertainty.

The author is unaware of a view of uncertainty management as a sequential approach to the management of TCs that is as succinct as that in the previous paragraph's last sentence. However, the property rights approach to TCs does acknowledge the benefit of understanding contextual and contractual uncertainty as logically distinct. Initially, distinction emerged from concern about overstressing the TCs concept by using it indiscriminately for all costs of operating as a firm [73]. Later, the distinction was cemented as authors chose to focus on the management of contractual uncertainty. For example, Munger's [74] recent explanation of the sharing economy as a vehicle for economy-wide TC reductions focuses on contracts by formally externalising the management of contextual uncertainty as a matter of "natural selection". Lately, the field has even seen the emergence of writings about environmental [contextual] uncertainty that acknowledge the need for understanding contextual and contractual uncertainty as sequential [75].

The paragraph above shows that the TC literature converged into a sequential view in a fairly organic manner, and very slowly. Even today, despite acknowledgement and interest, the literature still struggles slightly when it comes to explaining the management of uncertainty [76]. A fascinating aspect of Standard's case is that it already operated with a sequential approach to managing contextual and contractual uncertainty a full half-century before Coase even suggested the TCs concept. This fact should not be taken lightly, as it speaks of the value of having a good entrepreneurial instinct. That said, fascination aside, the TC literature's organic move into acknowledging the need for a sequential view of contextual and contractual uncertainty does mean that the findings here are fully compatible with said literature. The cost of overcoming uncertainty is one of the most important TCs faced by

energy entrepreneurs. Success is more likely for entrepreneurs who, like Rockefeller, excel at managing uncertainty. And, a way to manage uncertainty excellently is to first invest in mastering contextual challenges such as the 4A+A and, *then*, to use this proprietary mastery to minimise contractual costs.

Note, however, that Rockefeller's strategies began by investing in proprietary solutions despite not knowing with certainty if these would deliver better or less costly solutions than competitors. This is an act of internalisation of contextual uncertainty. Before the investment, the uncertainty comes down to the question of whether an energy entrepreneur is or is not able to overcome the 4A+A challenges. After the investment, the uncertainty comes solely down to whether the energy entrepreneur can recuperate the cost of overcoming the 4A+A challenges. Contextual uncertainty is brought inwards by the act of investing in proprietary solutions. Clearly, the key is figuring out a way to ensure that said solutions are, indeed, better or less costly than those of competitors. Just hoping for it is unlikely to deliver this objective, though. So, there are two possibilities in this regard. Either Rockefeller was an incomparably lucky person, or he was an entrepreneurial genius because he internalised contextual uncertainty in a manner that maximised his ability to deliver better or less costly solutions than competitors.

A plausible way to explain how Rockefeller made the most of his internalising of contextual uncertainty is to recall the multi-dimensionality of Standard's strategies. Standard's location addressed both availability and accesibility in parallel. Standard then used the subsequent reduction in contractual uncertainty (achieved by integrating supply and demand) to increase investment in transportation infrastructure that then led to even less uncertainty concerning accessibility. Likewise, Standard understood that Andrews' role was not only to adapt bitumen into distilled product efficiently, but to do it in a way that led to a safe product that then enabled the company to tie its brand to considerations of acceptability, which creates a similar dynamic between adaptability, acceptability, and affordability. Finally, Standard's continued pursuit of organisational efficiency bridged efforts across all 4A+A factors by, firstly, bringing the company up to management benchmarks through its incorporation and, secondly, creating an original management structure that delivered even further efficiencies across the entire spectrum of operations. All of Standard's strategies crossed over the 4A+A factors, back and forth, many times.

The message that the multi-dimensional approach to the 4A+A factors sends is that, when it comes to uncertainty, more can be better. This statement may sound counterintuitive

if uncertainty is viewed pessimistically, as a total hindrance. However, it makes sense if uncertainty is viewed from a Knightian perspective as, also, opportunity. If uncertainty is a source of possibility, the absence of uncertainty limits manoeuvrability. Entrepreneurs willing to accept uncertainty along various dimensions have a degree of manoeuvrability that is not logically possible for entrepreneurs that avoid uncertainty.⁴ An equilibrium is implied, of course, but the exact point of equilibrium likely varies depending on conditions, so a single case analysis is not the place to enter the matter further.

Despite the straightforwardness of the mechanisms covered thus far, and despite their compatibility with the property rights approach to TCs, there is much room for controversy in the above. To begin with, many of the practices in the field of energy are not so easy to reconcile with this argument. Consider, for example, the contradictions between Standard's strategies and modern practices such as supply cuts and subsidies. These practices each emanate from an interest in a specific 4A+A factor, availability and affordability, respectively, while the analysis here suggests that multi-dimensional energy practices are superior. Moreover, while the fact that these practices seek to collectively manage contextual uncertainty implies an acceptance of the fact that contextual and contractual uncertainty are not one and the same, these efforts lump contextual and contractual uncertainty into a single initiative, contrary to the sequential approach that this analysis highlights. Furthermore, both supply cuts and subsidies are used to try to avoid some of the uncertainty around the 4A+A factors, while Standard's case suggests that the individual entrepreneur should internalise uncertainty.

There is, also, no denying that there are modern techniques that may render the modern energy entrepreneurship challenge different to that faced by Rockefeller. Consider, for instance, the increasing inclusion of qualitative considerations into the analysis of uncertainty. This trend seeks to move beyond the field's emphasis on technical sources of uncertainty at the expense of social, political, and economic ones [5]. Authors associated with it have even criticised standing toolsets for their tendency to try and reduce what is either irreducible or not yet reduced at the time of necessary action [77]. As a result, they move away from an interest in the prediction of uncertainty and toward an interest in adapting to contingencies [77]. The type of analysis highlighted by these authors is one where human foresight combines with computational analysis to obtain a guide of the pathways open at any

⁴ The former also spend less in analytics and contracting than the latter, but this is obvious.

given point in time [78]. This trend is not entirely inimical to the findings here. Most of the actions taken by Standard after internalising uncertainty opened pathways amicable to the company's objectives. The idea of adapting to contingencies is compatible with a view of entrepreneurs as acting to open their preferred pathways. However, it may be a stretch to compare modern computer-assisted qualitative modelling with Rockefeller's imagination.

Consider, also, the 'real options' approach to investment under uncertainty, which gained traction in energy [e.g., 79–82] in the 1990s [83,84]. This approach acknowledges that investments have an irreversible component, but it also emphasises *options* as a mechanism to avoid some of the uncertainty by avoiding fully closed contracts during early stages [85]. In other words, today, entrepreneurs faced with uncertainty do not irrevocably sink investments. Instead, they can opt for investing in, say, stock associated with infrastructure, but also buy an *option* to have the right to sell this stock in the future. If the business goes awry, the entrepreneur sells and transfers the impact onto others. Implied in this chain of events is some degree of sequentiality, as the option defers part of the challenge posed by uncertainty, but the entrepreneur does internalise some uncertainty. Moreover, options, themselves a type of derivative (which implies this paragraph applies to derivatives, too), are private contracts, so the above-noted conundrum with collective contracts is not applicable. As a result, there is room for dialogue between the findings here and those in this literature, but also for controversy concerning the extent to which an entrepreneur should rely on this type of modern instruments.

In summary, modern practices in energy mesh the Rockefeller-like management of uncertainty 'upon action' with its management through foresight and contracts. Two divergent arguments are possible from here. The first is that modern energy entrepreneurs can offset the need for directly managing certain aspects of the 4A+A factors by relying on modern information- or contract-driven initiatives. The second is that modern energy entrepreneurs who succeed in individually managing the 4A+A factors can more successfully profit from subsequent activities, whatever these may be. This argument is exploratory, so it is impossible to go beyond stating these two possibilities. Further research is necessary. Regardless, additional ideas, mechanisms, and hypotheses emerge from this analysis.

It may be, for example, that Standard's case is best interpreted as a warning rather than advice, given that Rockefeller was a monopolist and this type of entrepreneurial approach is discouraged nowadays. The question of compatibility with modern normative preferences can help ideating new research and hypotheses at the normative level. It may also be that

Standard is a good case to gain insight into a strategy that works amidst uncertainty, but that additional successful approaches exist too. This rationale is, at its core, a patronymic hypothesis of plurality, which calls for specifying different mechanisms that may also be sound approaches to managing uncertainty and engaging in empirical research upon them. Additionally, as usual, omissions and gaps necessarily exist, particularly given the single-case nature of the analysis, so further room for research exists in the inherently limited scope of the argument. Finally, as discussed before, while the findings here may be generalisable, the empirical evidence does not speak of the degree to which generalisation is possible.

The need for further research notwithstanding, no amount of additional research can deny the facts. Rockefeller's Standard succeeded amidst uncertainty. Axiomatically, there are lessons in it.

6. Conclusions

This article began by noting the concern for uncertainty that exists in the field of energy, which invites thinking about sound approaches to entrepreneurship amidst uncertainty. A single article cannot address the totality of this puzzle, but an exploratory analysis is possible through the case of John D. Rockefeller's Standard Oil Company, which faced significant uncertainty. Since uncertainty is an important cost of operating in a market, the article grounds itself in the TCs literature, which says that entrepreneurs able to manage uncertainty are likely to have more success than those that struggle with it. The article then specifies expectations by noting that energy entrepreneurs are bound to be challenged by uncertainty associated with five prominent energy security challenges: availability, accessibility, adaptability, acceptability, and affordability (4A+A).

The analysis reveals that Standard succeeded with a sequential approach whereby it internalised the contextual uncertainty associated with all 4A+A factors and *then* used this to manage contractual uncertainty. The limitations of a single case analysis forbid claims of completeness or generalisation. Limitations notwithstanding, however, the analysis casts doubt on the view of uncertainty as inherently harmful, showing that there is opportunity in uncertainty. Additionally, the case holds referential value and signals room for further research in various ways such as, for example, the possibility of Standard's strategies being *the* or *a* robust way to manage uncertainty.

Acknowledgements

The author received no specific funding for this article. However, the author is grateful for funding as 2015/16 Konrad Adenauer Stiftung (KAS) Fellow at the European Centre for Energy and Resource Security (EUCERS), King's College London (KCL), where exploration of the 4A+A started, and for feedback by Prof Dr Friedbert Pflüger, Dr Frank Umbach, and Arash Duero in the context of the fellowship. Special thanks, too, to Dr Christel Koop and Dr Tomas Maltby for feedback throughout the author's short academic career and on this project. The responsibility for the use of feedback remains, of course, with the author.

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