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Technology Frames: The Art of Perspective and Interpretation in Strategy

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The Art of Perspective and Interpretation in Strategy

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Abstract

In this paper, I bring together the literatures of the economics of innovation, corporate strategy and managerial and organizational cognition to explore how and why companies come to different conclusions and strategies for technology when presented with essentially very similar situations and information. Building on the work of Orlikowski and Gash (1994) on technological frames, I seek to explore the role of the technology frame of key senior managers in defining corporate strategy with respect to technology. To provide an empirical basis for the study, I take the case of the 6 leading US vertically integrated oil companies involved in the exploration and production of petroleum during the period 1984 to 1997. The analysis considers two key salients for the technology frame which are operationalised for the six companies based on their R&D expenditures, patents, publications and contrasted with their operational performance measures. These salients reflect respectively *adaptational mapping* (whereby signals in the environment prompt adaptation) and *formational mapping* (whereby experience and path-dependency influence interpretation) within the technology frame. The findings indicate support for the proposed approach to proxying technology frames on the two key points of salience for the upstream petroleum industry, and the paper concludes with a short discussion of future lines of research.

Keywords technology frames, upstream petroleum, technology strategy, adaptational mapping, formational mapping

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1 Introduction

In this paper, I bring together the literatures of the economics of innovation, corporate strategy and managerial and organizational cognition to explore how and why companies come to different conclusions and strategies for technology when presented with essentially very similar situations and information. Drawing on the past work on mental constructs or 'frames' (Walsh (1995), Spender (1989), Tversky and Kahneman (1981), Weick (1977, 1986, 1993), and building on the work of Orlikowski and Gash (1994) on technological frames, I propose that the technology frame is the interpretative system of managers to understand the firm's technological position and opportunities as well as the expectations of the dynamics of their relevant innovation system(s). In other words, I seek to explore the role of the technology frame of key senior managers in defining corporate strategy with respect to technology. In this sense, the firm's technology frame itself becomes a competitive factor.

The importance of technologies to the operational success of the firm has always been critical, and therefore the technology frame is a useful place from which to explore the role of frames in the choices and success of firms. To provide an empirical basis for the study, I take the case of the 6 leading US vertically integrated oil companies involved in the exploration and production of petroleum during the period 1984 to 1997. I operationalise the technology frame for analysis by identifying two salients of the frame: the nature of the role of technology and the upstream business strategy. The nature of the role of technology for this industry can be defined as either an explicit role, whereby the firm positions itself purposefully as a 'technology company', or an implicit role, whereby the firm interprets R&D and technology as part of the infrastructure that allows exploration and production activities to be carried out rather than as ends in and of themselves. The upstream business strategy is generally characterised as a strategy of growth or efficiency, whereby growth indicates a relatively extensive exploration programme with a primary objective of securing more reserves and efficiency reflects a more cautious longer-term approach. Indicators for these salients are drawn from

analysis of annual reports and financial statements, and they are described for each of the ten firms. These data are also confirmed by fieldwork interviews and industry press research.

Through this empirical case, I explore the dynamics by which individual technology frames co-evolve with firm level and ultimately industry level "recipes" as described by Spender (1989). The role of the technology frame in structuring strategy is considered through a more detailed analysis of the case histories of Exxon, Mobil, Chevron, Amoco, Texaco and Arco. Through these case histories, I consider how technology frames impact on corporate strategy and thereby take on a competitive dimension, and propose how this research can be taken forward.

The paper is structured as follows. In the next section, I set out more fully the concept of technology frame as I intend to use it here as well as its established use in other scholarly work in the literatures of strategy and cognition. Section three comprises the empirical case to be tested and the methodological approach that I have chosen to use. The findings from this study are presented in Section four, together with some comparative assessments of the strategic value of frames across these companies. I conclude with some preliminary conclusions about the role of technology frames in strategy and outline some subsequent steps in this wider programme of research.

2 Technology frames and interpretation

> Knowledge is proportionate to being. ...You know in virtue of what you are.
> ***Aldous Huxley (Time Must Have a Stop, Ch. 26)***

Veterans of fieldwork in companies throughout the world will recognise the argument that companies see the world differently to one another and, in fact, senior managers perceive their 'reading of the game' as a competitive domain. We should expect the role of these interpretative frameworks, or frames, to influence (and be influenced by) how the firm evolves (intentionally and unintentionally) and how it seeks to act. Far from being

an interesting aside in the topic of firm evolution, the frame provides the link between its inheritance (established and path dependent cognitive maps, capabilities, routines and preferences), its sense making efforts (Teece, 1998, 2000; Weick, 2001) (justification, development and documentation [Weick op.cit. pp 20-23] of the most fit-for-purpose strategies) and its future (the boundaries for the firm of choice and action in light of inheritance and capabilities to translate strategy into action, and in light of the firm's environment).

The concept of framing and interpretation has been appreciably - though not exclusively - advanced in psychology, political economy and information sciences, which treat the matter of problem specification and process mapping squarely as a function of human behaviour and experience. Clinical psychologist Edward Tolman (1948) first discussed cognitive maps as a 'field map' developed in the course of learning and experience with the environment. Axelrod (1976) applied the concept more specifically to political decision-making. He argued that decision-making was largely dependent on the existing set of beliefs and previous knowledge of the individual, because these maps determined how the problems, decisions and options were perceived. In the case of Tolman's findings, we can describe this process as 'adaptational mapping', whereby signals in the environment prompt the agent to adapt their interpretative frameworks of their condition of being (in other words, their 'reading of the game'). Axelrod emphasises another vector of influence related to path-dependency, that which we can term 'formational mapping'.

Organisational theorists, notably Weick (1977, 1986, 1993), Fiol and Huff (1992), Lyles and Schwenk (1992) and Starbuck and Mezias (2003), have extended this discussion of cognitive maps and the process of sensemaking to the firm and highlighted their role in organisational success or failure. There have been only preliminary efforts in the economics literature to draw in the role of interpretative frameworks at the level of the firm with respect to its own evolution. A notable exception to this is the work of Fransman (1994 a,b) who defines the 'vision' of the firm as "...the dominant set of beliefs

in the firm regarding the firm's internal and external circumstances, the shape of things to come in the future and, in the light of these factors, the way the firm should 'play its cards'."(1994a, p. 755) This contribution was presaged by Edith Penrose in her seminal discussion of 'the theory of the growth of the firm'(1959, p. 5), where she spoke of firm-specific 'images' that relate closely to notions of interpretative frameworks.

The role of interpretation is more often recognised at more isolated levels of analysis and choice. In a recent paper on investment decision-making in the oil and gas sector, the authors state that,

> Variation in approaches to appraising the value of exploration and production opportunities is based in part on the scope for different interpretations of the different types of variables. And this scope allows for interpretations to be influenced by shared assumptions, interpretative frameworks and operating procedures, which emerge within organisations, and exist prior to the onset of any particular episodes of appraisal and decision-making. (Finch, Macmillan and Simpson, 2002)

Decision theory provides another approach to an agent's perception of the choice landscape and strategy. Two key works in this literature, Schelling's (1960) book, *The Strategy of Conflict*, and Tversky and Kahneman's (1981) seminal article, "The framing of decisions and the psychology of choice", consider how decisions are made under conditions of bounded rationality and different frames of thought. In Schelling's work, co-ordination between two separated agents was achieved through the selection of 'salient' combinations. For example, when asked to choose a letter of the alphabet to match that chosen by the other agent, the respondent chose "a" or "z". Salience denotes a matter of marked value of importance to the individual and which 'stands out'. This meaning is not intrinsic to the matter, but rather is attributed by the individual. Points of salience are labels that are recognised by agents because they are analogous or associated with ideas from *common experience*, culture or mindset. (Mehta, Starmer and Sugden, 1984) In effects, points of salience are points of significance in the evolved cognitive maps reflecting experiences and belief systems comprising an individual or organisation.

Building on the concepts of sensemaking and salience, the concept of 'frame' in this paper provides the organisational construct through which the firm assesses its current position through sensemaking and explores its choice landscape (the environment, the competitors, the opportunities and the like) using points of salience held by senior management, in particular. The frames can be described as the perspective from, or a lens through which, the firm considers its commercial past, present and future. The frame comprises the firm's appraisal of the competitive value of its resources and capabilities and its ability to obtain and/or contain these. As such, it is critically linked to the process of strategy development and implementation. March and Simon (1958) described this role of the mental "model" of the agent; "...choice is always exercised with respect to a limited, approximate simplified 'model' of the real situation. . . We call the chooser's model his 'definition of the situation'." (1958, p. 12) Several authors have considered the strategic value of interpretative capabilities at the firm level (Lippman and Rumelt, 1982; Barney, 1991; Barr et al, 1992) and have emphasised the biases that are introduced through experience as decision makers misremember and search for analogues. However, there has been less focus on the process by which interpretative frameworks are mediated at the organisational level (how does strategy emerge from the frames of many senior managers and technical staff?). Moreover, relatively less attention has been paid to the impacts of these frameworks on the innovation and technology strategies of firms, where novelty and uncertainty greatly frustrate easy analogue mapping; recent exceptions to this discuss technology disruptions in photographic equipment (Tripsas and Gavetti, 2000) and pharmaceuticals (Kaplan, Murray and Henderson, 2003). In these cases, the authors are referring, explicitly or not, to the technology frames of the firms in question.

The concept of 'technology frame' as developed in this paper thus has overlaps with similar sounding notions scattered around some of the relevant literatures. Because most of the work to date has however been couched very much in qualitative terms, the precise meanings of those scattered notions are generally difficult to apply in practice. Still less do we have much quantitative information about their impacts. The present paper takes one of the first steps in this direction, while recognising its contiguity with other work.

3 Technology frames in upstream petroleum

The concept of technology frame was first presented by Orlikowski and Gash (1994) who argue that the individual's interpretation of technology was fundamental to understanding their interaction with it. (1994: 175) They define the technology frame as "...that subset of members' organizational frames that concern the assumptions, expectation, and knowledge that they use to understand technology in organizations." (op.cit: 178)
In their discussion of the technology frame for information systems, the authors focus "...on those aspects of shared cognitive structures that concern technology." (op.cit: 175) In other words, Orlikowski and Gash are also exploring the salience of technology frames and the means by which these salients co-ordinate (or frustrate) the interaction with the technology. Through detailed field study work with a professional services firm, they reveal the influence that technology frames have on the individual's interaction with technology and, moreover, that congruence (and incongruence) of frames across groups affects the organisational use and change of technology.

This work by Orlikowski and Gash (and indeed subsequent work by Orlikowski (2000) and others) addresses key issues related to organisational change and adaptation to technology and provides deep insights to the workings of frames within the firm. My purpose in this paper is to consider a different level of technology frame effects at the firm level: that of technology strategy choice. Because strategy determines resource choices and co-ordination for the firm, the management leadership of the firm must have a principal role to play in creating and implementing strategy, thereby committing the firm to the planned investment and collaboration (and this is quite in keeping with views from both Penrose (1959) and Chandler(1977)). My question is whether it is possible to identify from management words and choices the underlying technology frame that is holding sway in the firm at that time, and to consider this with respect to operational outcomes.

Testing frames in upstream petroleum

I have chosen to test these concepts in the case of the leading 6 US integrated companies (the US 'majors') in the upstream petroleum industry. The upstream petroleum industry is the sector of the wider hydrocarbons industry that comprises the exploration and production of crude oil and natural gas. What characteristics distinguish this industry from others are its scale (in capital and operations), its long investment horizons, its geopolitical importance, the interdependencies of its actors, and the sophistication of its capital and organisational structures. The US-based oil operators alone accounted for 17% of the Standard & Poor Industrials Net Income in 2000, or $53.2 billion.

For an industry which often labours under the illusion of being technologically mature or for which "technology is played out"[1], the oil majors continue to spend hundreds of millions of dollars annually on R&D investment and to seek new means of improving the development and application of new technology in the industry through innovative organisational approaches. This mistaken understanding of the technological intensity of the industry owes much to a poor public representation of the knowledge and technology involved in upstream petroleum, to a limited view of the benefits of technology (as only reducing costs) and to an assumption that outsourcing activities strictly implies outsourcing knowledge.

Intense technological activity and profound industry restructuring have typified the upstream petroleum industry over the past two decades, and competitiveness in upstream performance has gained in importance. Whilst the 1970s was a period of unprecedented generalised oil price rises (in nominal terms), the situation reversed sharply in the early 1980s when the prices plummeted back to historical levels. The period 1984 to 1997 makes an appropriate period of study for two reasons. Firstly, it is a period within which these oil majors undertook no significant mergers or acquisitions, so the six companies we are considering are as consistent as possible. Moreover, 1984 was the marker for

change in oil prices, a disruption which prompted strategic reaction. As such, the analysis in this paper addresses these six US majors over the period 1984 to 1997.

Technology frame and salients

The technology frame and its composite salients also determine how firms assign worth to knowledge and technology assets with respect to its past and future development and performance. In order to compare these frames across the six peer group companies, we must first identify key commonly shared salience for the period of study. For the upstream petroleum sector, two key salients of the technology frame are likely to have affected strategy with respect to technology investment and outcomes and thereby to have affected operational outcomes. These are: the upstream business strategy and the nature of the role of technology.

The upstream business strategy defines the nature of exploration and production of hydrocarbons to be undertaken by the company. There is no single best model for petroleum exploration and production that suits all times, companies and environments. The company choice at BP in the 1990s to 'hunt for elephant fields'[2] requires different technological capabilities from a strategy to 'concentrate on proven areas'.[3] Because this salient is activated primarily by changes in the external environment, I argue that this is a process of *adaptational mapping* in the technology frame.

Upstream business strategic objectives can be summarised as either Growth or Efficiency with targeted growth. A Growth strategy indicates a relatively extensive exploration

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[1] At the 2002 Annual Conference of the Institute of Petroleum, this comment was offered by Dr Rob Arnott of the Oxford Institute of Energy Studies. London, February 19, 2002.

[2] Elephant fields are conventionally defined as fields with more than 500 billion barrels of oil equivalent in situ.

[3] This was a theme found in both the international and US exploration and production strategy at Chevron, the philosophy was termed 'Frontiers on familiar ground'. "Increasingly, the outer limits of known producing regions are viewed as the new frontiers. There are good reasons for this: Familiarity with nearby geology increases the chance of successful new discoveries, and an existing infrastructure greatly enhances the economics of new production." (Chevron, 1994, p. 8)

programme with a primary objective of securing more reserves. This is a longer view strategy that is more tolerant of high-risk and high-cost initiatives in the effort to identify new reserves. An Efficiency strategy reflects a more cautious longer-term approach taken under conditions of persistently low oil prices and natural gas. The strategy is targeted towards efficient (effective and low-cost) exploration and production methods on generally 'high quality and low risk' reservoirs. It is essential to pursue some programme of growth (exploration of new reservoirs) in order to counteract the depletion of existing reserves. Therefore, in practice, efficiency strategies are combined with a programme of targeted growth. This programme has typically been dedicated principally (but not exclusively) to the capture of very large fields in known oil provinces. It is important to emphasise that these strategies are cyclical in nature, reflecting the market conditions and broader socio-economic trends. Therefore, it is likely that there will be some concordance between firms with respect to this salient of the technology frame.

Three strands of influence converge on the interpretation of the role of technology: company history, the perceived characteristics of markets and wider trends in technology management. Because of this path-dependency, I argue that this is a process of *formational mapping* in the technology frame. At an abstract level, companies will give either an Explicit or an Implicit recognised role to technology. The Implicit role of technology signifies a determination by the firm that R&D and technology are part of the infrastructure that allows exploration and production activities to be carried out. Typical signals of a firm pursuing an implicit role regime include the following:

- R&D and technology are not identified as a strategic advantage in the E&P business;
- there will be no mention of R&D and technology in the Chairman's Letter to Stockholders;
- there will be no dedicated discussion of R&D and technology in the review of operations;
- there will be no representation of R&D and technology at the executive level.

Firms that maintain an implicit role of R&D and technology do not necessarily have lesser technological capabilities, but there is an inherent bias that technological development is conducted for a specific purpose, i.e. for the specific needs of a given field development programme. The role is therefore one of problem-solving, rather than opportunity-making.

The Explicit role for technology is found in firms that position themselves purposefully as a 'technology company'. Signals that firms hold an Explicit role include a list that is roughly the reverse of that for an implicit role:

- technology and the strategic role of R&D will be described in the Chairman's Letter to Stock holders;
- there will be a (at least one) senior Executive Officer with responsibility for technology and R&D;
- there will be a dedicated discussion of the development, application and commercialisation of technology in the review of operations.

These firms will generally describe themselves as firms at the frontier of technology development of the industry. R&D and technology are strategically important to E&P activities, but instead of being subsumed within these activities, there is an acknowledgement that the R&D programme and technology is both informed by these activities but sufficiently apart to look longer term. The balance of effort will include a greater share for the longer view (even 'blue sky' projects).

In the next section, I set out how these salients were proxied and the outcomes of comparing company frames (measured by these two salients) and their technological and operational outcomes.

4 Findings

In order to test the impact of the technology frame empirically, I define here proxies for each of the salients presented. For the upstream business strategy proxy, I define a firm as pursuing “G” (growth) or “E” (efficiency) by assessing the trends in the gearing ratios of the six US majors. The data are drawn from the Financial Statements of the Annual Reports of these companies, in accordance with GAAP guidelines.

For this article, the nature of the role of technology is proxied by the placement of technology in the Annual Report. The Annual Report acts not only as an autobiography of the firm for that year but also - and perhaps most importantly - as a message for investors, staff, industry partners and clients as to the firm’s strategic interests. Previous studies of management mental models have attempted to quantify these through personnel proxies and through survey response (Kaplan, Murray and Henderson, 2003) This study follows a similar strategy to that used in Kaplan, Murray and Henderson (op.cit), capturing the recognition and response by senior management of dynamic, discontinuous events (in their case, the emergence of biotechnology and the pharmaceutical firms) through an analysis of the Letters to Stockholders. I would agree with the authors in their assertion that, “Moreover, substantial qualitative evidence suggests that the Letter is written or closely reviewed by the Chairman and/or the CEO, that it is distributed to the executive team for comments and revisions.” Much the same could be attributed to the Annual Report in general, in particular with respect to the discussion of technology within the report.

Where technology was given a separate section, the firm was marked as “Annual Report 1". Frequently, technology would receive a subheading within the wider section on the production areas of upstream, downstream and chemicals. In these years, the firms were marked as “Annual Report 2". Finally, some firms did not address technology specifically anywhere in the report. These cases were noted as “Annual Report 3". Where firms included technology as part of operations or not at all in detail, I would

argue that these firms are holding an Implicit role for technology. Firms that report on technology separately in the Annual Report are considered to hold an explicit role for technology.

These proxies are then used to test the predicted relationships to technology inputs, outputs and operating performance. Technology inputs are represented by the annual upstream R&D expenditures for these companies. The upstream R&D figures are part of the U.S. Department of Energy Financial Reporting System, and are the most accurate available for these companies.[4] In terms of technology outputs, I am using the global patents of these six companies (by year) which are applicable to upstream petroleum. These data are from the Derwent Scientific and Patent Database. Using a similar approach, an annual count of publications relevant to upstream petroleum for these six companies was provided by the TULSA database of the University of Tulsa. Typically, there is a lag before strategy affects outcome in terms of patents and publications, and I have used a lag of two years here. Lag structures are always contestable, and the choice of two years is made in line with comments from industry participants during the field study.

Three operating outcomes are considered: two physical measures and one financial. Well success ratios are the number of productive to total wells drilled (exploratory and development). The farther away the ratio is from 1, the greater implied loss in costs for the firm. These data are compiled from company data prepared according to the Statement of Financial Accounting Standards No. 69, indicated as 'Supplemental Oil and Gas Information'.[5] The final measure is that of the upstream margin, which is essentially the net profit margin on upstream petroleum activities. These figures are compiled from the Annual Financial statements.

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[4] I gratefully acknowledge the help and support of Jon Rasmussen and Neal Davis of the Energy Information Administration of the US Department of Energy in using the Financial Reporting System database.

[5] I gratefully acknowledge the support of Nick Cacchione of John S. Herold, Inc in compiling these figures.

Taking each of these input, output and operating performance measures as the dependent variable in turn, I used a fixed-effects panel regression to test whether the relationships would meet the expected patterns. The findings are presented in Table 1 for both the upstream business strategy and the role for technology salients.

Table 1 Proxied relationships between Frames, Technological Investment Outcomes and Operational Effectiveness

	Strategy (Growth, Efficiency)				Annual Report (Explicit, Implicit)			
	Expected	**Actual**	T	Coeff.	*Expected*	**Actual**	T	Coeff.
Upstream R&D	***G* +**	**G + ****	2.52	13341	***E* +**	**E +**	1.45	7724
Upstream Patents (lag 2)	***?***	**G +**	1.22	4.23	***E* +**	**E + ****	3.27	11.55
Upstream Publications (lag 2)	***?***	**E -**	-0.3	-3.8	***E* +**	**E - ****	-2.25	-29.2
Exploratory Well Success Ratio	***G* -**	**G - ****	-2.88	0	***?***	**E -**	-0.61	-0.1
Development Well Success Ratio	***G* -**	**G - ***	-1.62	0	***?***	**E +**	1.21	0.01
Upstream Margin	***G* -**	**G - ****	-2.47	-1.3	***?***	**E +**	0.91	0.48

As Table 1 shows, upstream R&D investment was expected to be positively correlated with a Growth approach to upstream business strategy and an Explicit role for technology. We would expect that as a company becomes more expansionary in its upstream business, it would also increase R&D investment to account for new circumstances and opportunities encountered. The relationship for the upstream business strategy proxy is shown to be positive as expected and statistically significant; although

the relationship with the role for technology proxy is of the expected sign, it falls below statistical significance at the 5% level.

The technology output relationships have more mixed results. A priori, there is no reason identified why a company taking a Growth or Efficiency approach should patent more or not. In the analysis, patents appear to have a positive (though statistically insignificant) relationship. However, the relationship for the role of technology salient is clearer and supportive of expectations. Companies holding an Explicit role for technology patent more. Publications, however, do not have the pattern expected. Companies holding an Explicit role for technology tend to publish less. Of course, this could be explained differently; publications allow no appropriation or control of technology, and this may bias against publication amongst those firms who see their technology as of strategic importance. Further field study is needed to explore this relationship of publications to the technology frame and the strategies that result from the frame.

A priori, we did not define how companies with different approaches to the role of technology would perform in terms of well success ratios and the upstream margin. The results were not statistically significant, implying a more indirect relationship with operating performance. However, the signs raise interesting issues that need further research. A company with an Explicit approach to technology would appear to be as a Growth company, willing to take greater technical risks in exploration (according to the exploratory well success ratio). Perhaps more controversially, the signs also indicate that Explicit technology companies have higher upstream margins.

Expectations could be made about the upstream business strategy on the basis of field interviews and trade literature. We would expect companies taking a Growth approach to take greater risks in well development as part of an expansionary process. Therefore, we would expect the well ratio to decline in a growth period. Given the extra costs of expansion, we would also expect the net margin to decline as the balance of new investment to earnings tilts towards investment. In all three cases, these expectations are

borne out, although the development well ratio is not as statistically significant. This is likely to be due to the fact that development wells are drilled in known reservoirs and therefore the risk is almost entirely technical; most company pundits would expect development well ratios to be somewhat unresponsive to upstream business strategy as they reflect technological capabilities rather than strategic choice.

The dynamics in the two proxies, upstream strategy and the role for technology, are also interesting to compare for these six companies. It is clear that whilst there seems at times to be a coincidence between a Growth strategy and an Explicit role for technology, comparing the proxies across the six companies over time reveals that the proxies are not really correlated at all. We should expect this given our assertion that upstream strategy salients are driven by adaptational mapping (taking cues from the environment and experience) whilst salients concerning the role for technology are driven more by formational mapping (path dependency in company approaches to technology.

Over the period, Exxon's approach to the upstream business appears to have followed largely an efficiency model but with a period of growth in the late 1980s and early 1990s. However, positioning of technology in the Exxon Annual Report was much lower in two periods, 1984-1986 and 1992-1994, when the industry was in visible recession and companies were undergoing significant changes and downsizing. For Exxon, though, the early 1990s was an investment period. One explanation for this is that Exxon was managing shareholder's opinions by appearing to focus more on the business of producing oil rather than research. Overall, the proxies for Exxon indicate an explicit role for technology, and we recognise that Exxon has always maintained one of the largest R&D budgets for upstream in the industry, which whilst declining in value over the period still remained three times higher than its nearest US competitor.

From its patents, publications and R&D expenditures over the period, Mobil would appear to be holding an explicit role for technology, and this was evident in the positioning of technology in the Annual Report for the period up to 1992. In 1992, the

approach demonstrably changed in the Annual Report, and this year coincided with the high water mark for Mobil's upstream R&D expenditure (patents steadily declined over the period). This was an important period in Mobil's management, as this coincided with the placement in senior management of exploration and production of a senior manager from Mobil's downstream activities. The focus at Mobil became much more one of short term results and efficiency[6], and this is also evident in the change in the upstream business strategy.

Similar analyses of Chevron, Amoco, Texaco and Arco reveal similar dynamics in the proxies and indeed in the underlying salients for their technology frames. The approach to upstream business and the interpretation of the value and role for technology are not divorced from one another, but they have their own internal dynamics and they are also more generally related to the broader technology frame of the firm. For example, Arco demonstrated in terms of its investment behaviour a much more aggressive growth strategy than the other five US oil companies over this period. This strategy was closely tied to two issues key for Arco: (1) the Alaskan North Slope province was largely in Arco's hands and it required significant investment (with very good prospects for profits) and (2) Arco had recently pushed its way into this top tier group of oil majors and still was relatively small. However, despite the significant R&D investments and numbers of new technologies and techniques developed by Arco, the company held an implicit role for technology, considering its value as one important tool in the toolbox of oil company management, but certainly not the most important.[7]

5 Taking things forward

These findings indicate support for the proposed approach to proxying technology frames on two key points of salience for the upstream petroleum industry: upstream business strategy and the role of technology. Upstream strategy, as a process of adaptational

[6] Interview with former senior manager at Mobil Research and Technology Centre, Mr J Carter, ExxonMobil offices, Houston, March 2000.

mapping, is simply proxied in this study, and the expectations are largely supported. The role for technology, as a process of formational mapping, is proxied using company expressions of importance as revealed through positioning in the Annual Report. Although the evidence in this analysis is more mixed for this salient with respect to final operational outcomes, the relationship between the frame (as proxied by this salient) and upstream patents does reflect a significant correlation, which is missing in the case of relating patents to upstream R&D expenditure or publications (Acha and von Tunzelmann, 2001). The correlation between the frame salient and upstream publications is significant, but negative and against expectations. These findings may indicate that patents and public positioning of technology (as through an Annual Report) are drawing from the same corporate strategy to position themselves as a technology leader or as a technology user; whereas, the publication data may be driven by the personal ambitions and interests of the individual staff writing these articles for industry conferences and journals.

The next step in this research will be to combine further proxy measures to better reflect the adaptional process, namely oil price trends and rig counts (which reflects exploration activity across the industry). A more complex proxy for the role of technology would include some historical patterns of investment in technology. This is most effectively done by addressing company approaches to specific technological methodologies, such as deepwater exploration. We can expect that companies with experience in difficult offshore environments will have been predisposed to switching to deepwater methodologies first; certainly, we can recognise this in the current leadership in deepwater which is represented by two North Sea veterans, BP and Royal Dutch Shell. Of course, this requires a wider panel of companies to allow for a more robust testing of the proxies and the expected relationships.

Furthermore, I plan to extend this study to consider more directly the processes by which senior management brings congruence in frames for technology or at least mediates the

[7] This viewpoint was confirmed in interviews with senior management of Arco's E&P Technology Centre

decision-making process across different interpretations. This will need more detailed field study with firms, and it will building on the established evidence on decision-making in oil companies by Finch, Macmillan and Simpson (2002). A similar extension needs to consider how congruence can develop across firms, as points of salience may also help to co-ordinate activity across companies in a peer group. With respect to deepwater and 3D seismic, we are currently exploring how methodologies developed and disseminated across the peer group companies and the conditions that made this possible. Within this, the role of the technology frame must be given importance.

In this paper, I hope to have shown that there is evidence that individual framing (via senior managers) can be traced in the strategic choices made by firms about technology. The next steps of this area of research must be to consider what strategic competitive advantages can be provided to firms for differentiated technology frames and how these advantages can be mitigated by other factors of importance. In other words, how far does 'reading the game' better than any of your competitors get you?

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