**Political risk and technology strategy: An empirical investigation**

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## ABSTRACT

Political risk has been recognized in the management literature as an important external threat for firm activities, but it has played no role in the debate on entry decisions of firms with regard to new markets or technological subfields. This paper analyzes the impact of political risk on firm entry into new technological subfields. We test this relation using longitudinal data from 15 upstream oil companies. We construct political risk measures for various operational performance areas and link these to patents and publications as proxy measures of R&D activities and entry into various technology areas. Our analysis reveals directly opposed results for patenting and publishing behavior in response to external threats. Contrary to patenting behavior, companies publish less when they are confronted with political risk and publish more when they are active in politically stable countries. This research also shows that previous findings of Mitchell (1989) concerning firm entry into new technologies and technological subfields hold with regard to short-term activities and assets, but they may lose explanatory power for medium- and long-term activities.

**Keywords**: external threats, political risk, firm entry, technological subfields

## Political risk and technology strategy: An empirical investigation

INTRODUCTION

Firms frequently face decisions of whether and when to enter a new market or technological subfield. Research on entry decisions of firms examines entry timing (Lieberman and Montgomery 1988; Aghion, Blundell et al. 2009) and entry strategies with regard to organizational factors such as previous experience (Henderson 1993; Klepper and Simons 2000; King and Tucci 2002), firm size (Schumpeter 1934), resources and capabilities (Helfat and Lieberman 2002), and complementary assets (Teece 1986; Tripsas 1997), among others.

The scholarly literature in the strategy field takes environmental opportunities and threats as important correlates with firm entry and success. Some of this literature is related to technology and marketplace conditions (Freeman and Soete 1997) such as the rate of technological change (Tushman and Anderson 1986), demand uncertainty, and market instability (Kerin, Varadarajan et al. 1992; Szymanski, Troy et al. 1995). In this context, researchers find that the probability of entry increases with the degree to which a firm's core products are threatened by substitution, replacement, or obsolescence (Mitchell 1989).

Other fundamental non-market-related business threats exist, however, and little is known about their impact on firm entry. One such threat is political risk, which has been recognized in the management literature as an important external challenge (Fagre and Wells 1982; Frynas 1998; Henisz 2003), but it has played little role in the debate on decisions to enter new markets or technological subfields. This paper extends previous research on firm entry and examines if political risk affects firm strategies beyond mitigating risk and bargaining approaches (Lohrke, Simpson et al. 2007). We ask if and how political risk affects firm entry into new technological subfields (Mitchell 1989) and innovation strategies.

Political risk has largely been defined as risk that involves all non-business risks that have the potential to change the prospects of the profitability of a given investment (Cosset and Suret 1995), and it is a highly relevant issue for companies that are active in numerous countries with different market and non-market environments—especially countries with unstable and nontransparent economic and regulatory regimes.

As a context, we use the example of primary sector firms, notably firms active in the upstream oil industry, which are forced to source natural oil and gas from particular geographical areas because natural resources are fixed in certain locations and are not available in abundance all over the planet. For these companies, political instabilities constitute a serious threat to their core products (i.e., exploitation of finite natural resources), but they are constrained in their response to instability and therefore often stay and operate even in unstable producer countries to preserve access to resource deposits. Despite the particularities of firms that exploit natural resources, their situation serves as an interesting example of several industries that voluntarily or involuntary source from single or politically risky locations (e.g., the dependence of certain sectors on Chinese manufacturers).

## THEORETICAL BACKGROUND

This research focuses on entry into new technological subfields. This category of entry is created by technological change and is based on new knowledge that often is difficult to incorporate into existing product lines or core production of established firms (Tushman and Anderson 1986; Mitchell 1989). As mentioned above, the literature on entry has taken into consideration various environmental opportunities and threats that influence entry timing and success. Most of these relate to technological or market conditions (Kerin, Varadarajan et al. 1992; Szymanski, Troy et al. 1995). Instead, this paper focuses on a non-market-related external threat—political risk—that may encompass negative consequences of government interventions, the occurrence of political events or constraints imposed on a specific industry and/or company, or discontinuities in the general business environment resulting from political change (Cosset and Suret 1995). Consequently, political risk can interfere with ownership, operations, and transfers (Lohrke, Simpson et al. 2007).

The international management literature proposes as solutions to such problems the development of non-market strategies (e.g., bargaining with host countries) to counteract political risk (Henisz 2003), which requires the development of non-market capabilities as an important component of the capability portfolio (Holburn and Zelner 2010). Research on foreign direct investment (FDI) (Errunza and Losq 1987) and financial portfolio management (Cosset and Suret 1995) proposes the redirection of funds to other host countries (Brunetti and Weder 1998). Critical for successful bargaining or investment solutions is whether political risk is of a non-systematic or systematic nature (Butler and Joaquin 1998). If risk is non-systematic, it affects only certain assets, and firms may be more able to mitigate such problems through bargaining approaches. They also can improve the level of return relative to risk by diversifying their portfolios. An example of diversifiable risk for oil companies is the exhaustion of certain resource deposits (little or no oil is produced from them in a certain year). In this case, they could mitigate this risk by exploring and exploiting new and more diverse geological resource deposits.

On the other hand, political risk that is systematic in nature is shared by all corporate assets or by the entire industry sector, and bargaining approaches may be successful only in the short term, at best. Moreover, this political risk tends to be undiversifiable (Cosset and Suret 1995). This is partly the situation for the upstream oil and gas sector: Conventional hydrocarbons are declining globally and near their resource limits, except for the Middle East region; thus, the global conventional oil supply is at political risk (Bentley 2002). Concretely, all companies in the sector must deal with countries with elevated risk levels in order to meet increasing demand for oil and to secure resource reserves, especially because government-controlled oil companies account for the vast majority (more than 80%) of current oil reserves (Davis 2006a).

Research suggests that firms will be more innovative and open to explore new product development and business fields in order to offset negative consequences from environmental threats (Damanpour and Gopalakrishnan 1998). Scholars also argue that exogenous threats may trigger risk-taking strategies because they bear the potential to render performance objectives of organizations obsolete, as they may erode strategically important firm positions (Bromiley, Miller et al. 2005). Managers hold certain expectations with regard to their firms' performance (Greve 2003), and when their envisaged organizational performance objectives are threatened by external events, these decision makers increasingly will assume greater risk in attempts to ensure that performance objectives are met (Fiegenbaum and Thomas 1988; Lehner 2000). Different expectations in the upstream oil industry may influence the evolution of corporate financial performance based on petroleum prices (Weston, Johnson et al. 1999). Different managerial expectations refer to the ability of firms to preserve the level of their overall natural resource endowment in order to stay competitive (Parry 1997) as well as to their capacity to exploit investment opportunities based on the prospects of their assets (Weston, Johnson et al. 1999). Preserving their resource base and effectively and efficiently exploiting opportunities requires access to acreage with the lowest unit costs which refers to proven petroleum resources as opposed to access to deposits with potential (Stabell 2006).

Firms can efficiently increase their resource base and access to acreage through structural changes in the industry, notably through mergers and acquisitions (M&A). This often has been the case in the oil industry, with an accelerating rate of M&A activity since the 1990s in the industry, the most visible result of which was creation of some of the largest global corporations, the so-called super-majors: ExxonMobil, Chevron (Chevron Texaco), BP (BP Amoco Arco), Conoco Phillips, and Total (Total Fina Elf). The gains from this strategy are bound to level off because all oil companies face the same challenges stemming from political risk in the area of conventional resource deposits. In order to stay competitive in the long run, firms must efficiently exploit current business opportunities and simultaneously explore innovative alternatives (Abernathy 1978) based on the development of fundamentally new capabilities (Teece, Pisano et al. 1997). This allows for timely responsiveness to environmental challenges in order to readjust their strategies and to create a better fit between organizational decisions and the environment (Greve and Taylor 2000). This change in strategic emphasis (Siggelkow and Levinthal 2003) is reflected in the deployment of resources in activities that aim to promote exploratory firm activities (March 1991), such as technological exploration of radically new business areas and the development of new technological capabilities (Katila and Ahuja 2002), such as renewable energy technologies that would render oil and gas producers less dependent on hydrocarbon-rich host countries. From this follows:

*Hypothesis 1: When political risk increases, firms are likely to invest in new technological subfields.*

To understand entry decisions with regard to technological subfields, one can also draw on theories of investment behavior that focus on external threats stemming from innovation and technology changes and that base their understanding of incumbent responses on the degree of newness (incremental vs. radical) of innovation and the role of market power as central variables (Gilbert and Newberry 1982; Reinganum 1983; Blundell, Griffith et al. 1999; Aghion, et al. 2005).

Arrow (1962) suggests that firms in competitive markets have significantly greater incentive to invest in innovation than do firms that are active in markets characterized by a certain degree of monopoly power. Gilbert and Newberry (1982) develop a model in which, under certain monopoly conditions, firms have an incentive to maintain their monopoly power by patenting new technologies ahead of potential competitors in order to extend their existing market power to a new generation of technology. Necessary conditions for these results to hold are that innovation is of incremental nature and that the older technologies remain viable substitutes for the new one (Gilbert and Newberry 1982). On the other hand, Reinganum (1983) shows that under conditions where the innovation is incremental, incumbents will rationally invest less in innovations than new entrants, for fear of cannibalizing profits from their existing product lines. Mitchell (1989) finds that incumbents were more likely to enter new subfields if there was a threat to their core product, they possessed specialized supporting assets, and they had few potential rivals. For the analysis, Mitchell examined the diagnostic imaging industry and considered threats as fundamental to a firm's core product when the underlying technology of current products was challenged by the emergence of a new technology. Mitchell found that of all three factors mentioned above, only "threat to core products and business" both increased the probability of entry and made firms enter earlier.

> An industry incumbent will be likely to enter a new subfield if the firm possesses a broad base of assets required for successful commercialization of the new goods or if its core products are threatened. An incumbent will generally be less likely to enter if there are many potential rivals, but a firm facing threats to its core product will enter sooner when there are many potential rivals. (Mitchell 1989: 208)

We assume that the logic of Mitchell, which was developed for technology-based manufacturing companies, can be extended to the natural resource sector, and we claim that fundamental threats to a firm's core business lead the firm to the exploration of new business and technological subfields, which have their basis in knowledge that resides mostly outside the firm and which would involve major reorganization and technological changes of the firm. Technological subfields involve high technical and market uncertainties. The former refer to questions about the validity of the underlying scientific knowledge and whether the technology will be sufficient and reliable in the future; the latter include uncertainties with regard to customer needs and wants as well as methods of sales and distribution (Leifer et al. 2000). Examples of uncertainties include issues related to greenhouse gases and oil companies' investments into renewable technologies, which emit no carbon dioxide in their generation of power (solar, photovoltaics, windmills, fuel cells, geothermal energy). Investing into these so-called renewables confronts firms with constraints raised by existing corporate R&D in a vertically integrated and mature industry, as well as the need to coordinate those technologies so that they become complementary and so that their development also increases marginal returns of other firm activities (Armour and Teece 1980; Davis 2006b).

Within oil companies' upstream business are technological subfields that go beyond conventional exploration and production and that demand the development and employment of radically new technologies. Examples of these subfields include those aimed at taking the potential offered by shale oil sources or ultra-deep offshore heavy crude oil deposits and turning that potential into commercial reserves.

To conclude, fundamental threats to firms' core business may have led firms to the exploration of unconventional activities and technological subfields in order to defend their competitive position. From this follows:

*Hypothesis 2: Incumbents whose core business is threatened by political risk are more likely to enter radical technological subfields.*

## INDUSTRY CONTEXT

### Overview

The core business of upstream oil companies in our sample is petroleum and gas manufacturing, and their business model is petroleum sales (Stabell 2006). Upstream petroleum manufacturers produce oil and gas, and for them natural resources are not a simple resource advantage (Hitt and Ireland 1985) but instead represent their core resource, in the sense that their endowment with natural resources presents a key factor of strategic importance (Amit and Schoemaker 1993). The continuous acquisition, exploration, and development of oil and gas assets are therefore necessary in order to replace resource reserves. Operating companies are competing on their systems for identifying and understanding hydrocarbon reservoirs and managing their effective exploitation in a commercially timely manner. These systems bundle a range of techniques, technologies, and complementary assets. (Acha 2003: 78)

In this context, access to natural resource deposits, both current and future, is vital to a firm's sustained competitive advantage in the industry. This is reflected in the importance of resources and reserves as a critical input into the determination of financial results and as an important measure for company performance: the value of a firm is driven by how many resources it can pull from the ground now and in the future. Access to complementary assets (Helfat 1997), such as transportation and distribution facilities, and access to resource deposits are among the most important vectors of competitive advantage for petroleum and gas manufacturers. For political risk to have an effect on the core business of these natural resource exploiting firms, it must interfere with access to, ownership of, and operations of resources and/or complementary facilities that can prove to be bottlenecks when there are rapid demand shifts for their goods and services (Stabell 2006).

### Evolution of Oil Industry Political Risk

Prior to 1970, the largest oil multinationals, notably Exxon, Royal Dutch Shell, British Petroleum (BP), Chevron, Texaco, Gulf Oil, and Mobil (also termed the "Seven Sisters"), as well as the Compagnie Française des Petroles (CFP, later TotalFinaElf), dominated the oil industry. These companies either owned or controlled under contract the rights to the major share of global reserves. Together they accounted for 81% of all crude oils produced in the world. Nowadays these super-majors produce less than 12% of the total (Davis 2006a).

Of the original Seven Sisters (and CFP), only four of the companies remain in business, with Gulf Oil disappearing completely after Chevron acquired it during the mid-1980s. All the others, with the exception of Shell, have either merged and/or acquired smaller "independent" oil companies, such as BP, which acquired the American companies Amoco and Arco in the 1990s. In addition, CFP has undergone various mergers and become TotalFinaElf (today named Total). Official explanations of these merger activities put forward financial necessities resulting from heavy capital investments and high-risk projects concerning the development of new oil provinces. The merger waves also, however, reflect profound industry transformations in response to other various causes. Political nationalizations were the original threat to the Seven Sisters' oil-producing assets. In 1938, the future Arabian American Oil Company (Aramco) discovered large oil deposits in Saudi Arabia, and throughout the following decades, the Saudis took over control from the Americans.

Iran nationalized its oil assets in 1951 for the first time, after the Shah was deposed for a short time by Parliament (until 1953, when the government was replaced after a coup orchestrated by the United States). This turned the Anglo-Iranian Oil Company (later BP) into a company without portfolio (Yetiv 2004). Nevertheless, the control of the global oil market remained in the hands of the Seven Sisters until it gradually eroded in the 1960s, when power began to shift to the oil-producing countries, also in the course of decolonization and nation-building, which enticed many of these countries to assert rights over their own resources.

In the aftermath, many national governments of oil-producing countries sought larger shares in ownership and control over their national oil industries. The Organization of Petroleum Exporting Countries (OPEC) was founded in 1960, and until 1973, the institution managed to wrest away the price-setting role of international oil companies (IOCs). OPEC member countries quadrupled the price of oil in a one-sided decision that severely weakened the strong occidental IOCs (Yetiv 2004).

Nationalizations triggered major industry changes by breaking the links between company production of crude oil, on one hand, and company refining and marketing of crude and derived products, on the other. For a start, major oil companies lost ownership over reserves and production assets, with the result that today IOCs have equity access to only 24% of the world's oil and gas reserves, whereas about 60% are presently held by national oil companies (NOCs), which leaves IOCs with limited involvement through service contracts or technical agreements. Oil multinationals at present continue to face increasing political risks. Various countries, for example Venezuela and Uzbekistan, hold potentially high risks with regard to issues such as confiscation of assets, sovereign non-payment, and political interference.

## METHOD

### Sample

Our data collection efforts produced a sample of 15 international oil companies continuously active in the upstream petroleum sector from 1990 to 2006. The analysis focuses on the relationship between firms' exposure to political risk and their R&D investment and technological capability building. Our main sources of data are IHS Databank's "Petroleum Economics and Policy Solutions" (PEPS) and "Energy Data Information Navigator" (EDIN). IHS is a provider of economic and financial information on countries, regions, and industries. The company also is a leading global data and information provider in the energy sector, and it delivers data and expertise especially about the oil and gas industry. Its PEPS database is the most exhaustive independent database for information on worldwide exploration of liquids and gas, as well as for production statistics (exploration and production, or E&P), covering information about exploration activities, performance, reserves, licenses, production, and other such data, breaking down information by country and companies. Another IHS data source used in this research, EDIN, is a query and reporting tool on all activities concerning E&P and midstream data on the oil and gas industry.

The 15 international oil companies studied are Shell, Exxon Mobil, BP, Chevron Texaco, Total, ConocoPhillips, ENI, Hess, Kerr McGee, Marathon, Norsk Hydro, Occidental, Repsol, Statoil, and Anadarko; together, they represent 80% of all recoverable oil found in offshore fields containing between 50M and 250M barrels, worldwide. We have data for these firms for the years 1990-2006.

## Measurement

*Independent Variable: Political Risk*

Political Risk is measured in terms of political stability. For each country in which oil companies of our sample have had operations, a risk value was calculated for each year (1988-2008). This value is based on a political risk measure derived from the International Country Risk Guide (ICRG) data set of the Political Risk Services group (PRS). PRS focuses on political risk analysis and provides data on political risk rating. Among various suppliers of political risk data and ranking, PRS is the only one that opens the "black box" and provides detailed and transparent information concerning their methodology to calculate, construct, and interpret political risk rankings (Guessoum 2004). The ICRG data cover 12 political, socioeconomic, and commercial risk components (see Table 1). The aim of the political risk rating is to provide a means of assessing the political stability of concerned countries on a comparable basis. ICRG weighs the risks by assigning risk points to each risk. The minimum number of points that can be assigned is zero, while the maximum number of points depends on the fixed weight each component is given in the overall political risk assessment. ICRG measures risk in terms of degree of political stability, and it depicts risk on a scale of 0 to 100, where 100 represents the most stable and least risky political situation (PRSGroup 2009).

--- Table 1 about here ---

A data set was constructed that linked each country's political stability value in each year to the various operational performance values of each individual oil company (production, reserves, exploration success, oil rights at the end of the year. and oil rights for new field wildcats). Linking those variables allows us to tell, for example, how much oil a company has produced in a given year and in which countries, with which political risk ratings (see Table 2).

---Table 2 about here ---

For each of these measures for each firm in every year, we create a political risk measure, which is the maximum political risk that the company had exposure to in that particular year, based on the group of countries where the firm operated during that year. This political risk measure is an absolute value that does not reflect the partition of investments and operations in different host countries but instead concentrates on the worst case. For example, for a firm that has three production sites, of which two are in Norway and one is in Nigeria, the maximum value would correspond to the political risk value for Nigeria, which is the politically more unstable country of the two in which the company operated that year. If the company sells all its assets in Nigeria a year later and buys a third one in Norway, then Norway's value would be the relevant (and only) maximum value for that year.

The reason to use the maximum value is related to the systematic nature of political risk within the entire upstream oil sector. As mentioned above, the overall exposure to political risk is higher in the oil industry than in many other industry sectors, which means that companies cannot diversify away a basic risk as easily as can companies in other industries. Within their asset portfolio, however, they encounter different degrees of political risk and to a certain extent they can control and reduce the overall level of non-diversifiability of their portfolio by operating in differing countries and situations, thus hedging against the worst cases.

*Entry into Technological Subfields*

We use patents and publications as proxies to measure R&D activities and development of technological capabilities. Patents and publications are widely accepted proxy metrics for firm capabilities. Even though there are some weaknesses to patent and publication data as proxy measures for technological capabilities (Archibugi 1992; Debackere et al. 2002), these measures frequently are used in the literature to determine the scope of capabilities and firms' R&D preferences within a larger scope of technology areas.

*Publications.* This paper uses GeoRef as publications database. GeoRef is the database of the American Geological Institute (AGI) and contains more than 2.5 million entries (as of November 2003). It covers worldwide technical literature on geology, geophysics, geochemistry, mining, reservoir engineering, technology in exploration and production (drilling, well completions, etc.), offshore production, unconventional production, ecology linked to mining and oil activities, and renewable energies. Altogether, 27,500 entries of publications by companies were analyzed for the time period covered; 25,384 accounted for publications from companies of our sample. We coded the publications in line with the Petroleum Abstracts Tulsa database (see Table 3). These categories cover various alternatives for upstream oil companies with regard to technology fields and business activity. We refer to four large categories. First, we refer to technologies important for the existing upstream core business, which create value based on existing or incrementally modified competencies and technologies exploitation in March's (1991) sense. This sector comprises six large technology areas: geophysics, drilling, well completions, reservoir engineering, offshore, and improved/enhanced oil recovery (IOR/EOR).

---Table 3 about here ---

Second, we refer to technologies that are radical within their core business, for example, important technologies for "unconventional" oil and gas search and exploitation (e.g. tar sand, retort). The third category corresponds to renewable energies technologies. The fourth category relates to ecological issues with respect to oil-and gas production. Categories 2 to 4 refer to exploration activities that demand novel competencies that enable ongoing innovation and generally aim at superior and long-term returns (March 1991).

*Patents.* We used the same technology categories identified for the publications and based on the Petroleum Abstracts classifications. Moreover, we have classified the categories according to the strategic orientation of companies (more toward exploration or exploitation). Finally, three independent oil engineers and industry experts from the petroleum industry validated these categorizations and classifications. Patent data were drawn from the European Patent Office Worldwide Patent Database (EPO Patstat, version of October 2007). We use patent families (according to the International Patent Documentation Center definition), which assemble and standardize equivalent patent documents for multiple countries into one group.

*Modeling.* To test our direct effect hypotheses, we use fixed- and random-effects panel data models. Random-effects present an alternative approach that takes into consideration the panel nature of our data. This is useful because we have multiple observations from the same firms over a period of up to 17 years, and thus the error terms for each firm are not independent from year to year. On the other hand, we also use fixed effects panel data models to control for unobserved heterogeneity. We run regressions on patents and publications in different technological areas and the maximum political risk, which is expressed as the lowest political stability value a company encounters in its portfolio with regard to the various operations areas: production, reserves, exploration, and areas where oil firms recently acquired oil rights.

## RESULTS

The tables 4 and 5 show the descriptive statistics and correlation matrix for our sample, respectively. Tables 6 and 7 present the results of the regression models. Table 6 covers the fixed effects models, and Table 7 the random effects models.

---Tables 4, 5, 6 and 7 about here ---

Our analysis focused on two aspects. First, we asked if political instabilities and risks are positively related to firm entry into new technological subfields. Second, we asked whether firms are more likely to enter new technological subfields when they are threatened in their core business. We defined threat to core business for natural resource–based companies as a persistent menace that has a sustained and long-lasting impact on long-duration assets, such as newly and successfully explored oil prospects and oil and gas reserves that firms will tap in the middle or long run. Note that the random effects and fixed effects models show consistent overall results.

We find that at high levels of political risk and/or low political stability, companies increasingly patent, both in radically new technological subfields and in conventional technology areas related to their current activities (incremental). The highest levels of statistical significance are found in terms of patenting activities with regard to renewable technologies as well as unconventional technologies related to the existing core business (see Models 4 and 5 in Table 6 and Models 17 and 18 in Table 7). Generally, at low levels of political risk and/or high political stability, companies' patenting activities decreased (compare models 2-6, 9, and 10 in Table 6 and Models 13-18 in Table

7). The only exceptions concern positive correlations political stability and patenting with regard to drilling and offshore technologies (see Models 10 and 11 in Table 6).

These results are consistent with what theorists would expect with regard to technology and innovation strategies of firms under external threats: in unstable environments, firms tend to be innovative and open to exploring new technological subfields. With respect to patenting activities, we can confirm these assumptions based on a non-market external threat, that of political risk. On the other hand, we find that publications are almost always positively correlated with political stability. When companies are active in politically unstable environments, they publish less than when they are active in stable environments (compare Models 7 and 8 in Table 6 and Models 19-23 in Table 7). This primarily concerns publications in the fields of offshore, unconventional, and radically new technology. Our results concerning publications cannot confirm previous theory that claims that firms under external threats will be more risk seeking and innovative.

This contradiction between patenting and publishing behavior is interesting, considering that patents and publications are often used simultaneously as proxies for innovativeness and technological capabilities with regard to input and output (Argyres 1996; Deng, Lev et al. 1999). Interestingly, we also find that companies exhibit different patenting and publishing behavior depending on whether political risk affects production sites (short-term assets) or regions in which firms hold oil and gas reserves (long-term assets). The most striking "reaction" with regard to patenting is observable when political risk and instability have an impact on current production. Firms confronted with unstable countries that host production facilities patent in unconventional technology areas within their core business, as well as within new business fields, such as renewable energy technologies (see Models 4, 5, 15, 17, and 18). Furthermore, there is also an increase in patenting activities observable with regard to traditional core business technology, such as reservoir engineering and drilling (see Models 2, 3, 14, and 16), even though statistical significance levels are lower than for unconventional and radical technology fields.

The second upstream performance area that showed statistical significance was "reserves"—areas where firms possess resource deposits that will be exploited sometime in the future. Here, publication activities are also positively related to political stability (compare Models 20-23). Firms publish less when they are confronted with political risk in their reserve areas, whereas when reserves are not threatened, they publish significantly more in all radical technology fields as well as with regard to topics related to ecology and sustainable development. With the exception of a variable called "patents all" that comprises all technology areas and is negatively related to political stability, patenting plays nearly no role when reserves are affected by political risk.

Thus, our hypotheses are not rejected when the results are based only on organizational patenting activities. The results show that entry into new technological subfields is related to political risk; clearly firms patented more in radically new technology areas when their short-term assets—notably production facilities—were threatened. On the other hand, we cannot fully confirm the hypotheses when we analyze the situation of long-duration assets, such as reserves. We can see that patents all are significantly related, but we cannot isolate the different technology sectors.

## DISCUSSION

Our findings support previous research that claims that incumbent firms are likely to enter new subfields if they are confronted with fundamental threats to their current business, due to technological discontinuities (Tushman and Anderson 1986), or because they cannot defend their market power position (Arrow 1962; Gilbert and Newberry 1982; Porter 1985).

Political risk with regard to current production activities may have the consequence that industry power shifts to host governments and that oil companies become less able to influence the terms of operations. Moreover, firms' financial returns from oil exploitation may be pushed to minimal margins, or they may even lose access to resources completely. Consequently, in situations of political risk, oil companies endure considerable uncertainty about their future revenues. If firms are to survive these challenges, they must develop strategies to master them.

Strategies could consist of creating and maintaining a stable work environment that allows the firm to pursue its commercial operations by means of investments through corporate social responsibility engagement (CSR). Dependent on the underlying theoretical paradigms, research in favor of a broader CSR strategy sees in it a potential success factor for competitive advantage for the pursuit of strategic economic goals (Porter and Kramer 2002), or as a general obligation of internationally active firms, beyond their role as economic actors, to fill the governance vacuum left by globalization (Scherrer and Palazzo 2008). Research has questioned CSR practices, however, especially with regard to the oil and gas industry (Frynas 2005). CSR projects should be long-term solutions to create a sustainable and positive impact on the firm's larger environment and to mitigate political risk. Instead, social engagement often is reduced to opportunistic, short-term actions, most often because of the incompatibility of corporate objectives with social developmental objectives (Frynas 2005). Examples are the frequent rotation of asset managers among subsidiaries. Furthermore, managers in those companies usually are trained in business or engineering and are perfectly able to manage complex technical and managerial challenges, but they often are unprepared for CSR projects. Under these circumstances, the development of new technological capabilities and investment into new technological subfields might prove to give firms more liberties in dealing with political risk challenges and to render their future business less vulnerable to political threats.

Our research shows that the assumptions of Mitchell (1989) hold with regard to short-term activities and assets, but they seem to lose explanatory power for medium- and long-term activities. This is surprising, especially with regard to the oil and gas sector, as in this case the core business consists of exploiting and delivering primary resources. Natural resources, in this context, do not constitute a simple input that is employed to produce other goods and services. Natural resources and the derived processed raw materials (e.g., refinery products) are the output and the core product of these companies. Companies compete in this industry on their processes of exploring, exploiting, and delivering oil and gas. If current and future access to resource deposits is disturbed or entirely interrupted, companies will not be able to pursue these activities, with serious consequences for the mid- and long-term prospects of their core business and competitiveness.

Moreover, the firm's current market value is based on its potential to generate value in the future. Again, this depends on a firm's endowment with natural resources in the future (today's reserves). Reserves serve as important information for the financial sector concerning prospective operational performance of companies. Political risk that has potentially negative impact on these mid- to long-term assets has the capacity to erode a firm's future resource base and thus to erode its mid- to long-term competitive advantage.

The results on publications in alternative energy sources may have some explanation in the psychological literature on the relationship between time pressure and organizational efforts. Research claims that managers will be more "risk-alert" under a threat that has an immediate or short-term effect, such as bankruptcy, and they will develop quick and effective responses because of time constraints (Maule, Hockey, and Bdzola 2000). Our analysis reveals conflicting results for the patenting and publishing behavior of oil and gas firms exposed to political threats. This raises the question whether these two forms of innovation activity signify different things; if they do, it may be unwise to use them concurrently as proxies for capability development and organizational R&D preferences.

Oil companies employ publications to signal technological strengths to potential partners, as well as for other reasons. In the context of resource exploration and exploitation, it helps a company to improve its technological reputation with government licensing award bodies, as these authorities expect companies to which they grant licenses to be able to deal with exploration and exploitation of fields in the most effective, profitable, and environmentally sound manner (Acha 2002). Publishing behavior acts more to reveal the areas in which companies believe they have knowledge or lessons to share with a wider community than to secure and protect innovation efforts in new technologies and technological subfields. It gives some ideas about their overall innovation activities (Narin 1994), but it does not reflect efforts to preempt territory in unconventional or radically new areas. The positive correlation of publications with political stability makes sense, as publications do not reflect any effort to anticipate or counteract consequences from business threats.

On the other hand, patents are among the strongest means of protecting innovative efforts in new technology areas. The value of patents is often overestimated by researchers, however, especially when patents are considered isolated from other R&D stocks (Scotchmer 2004), and moreover, firms have other tools (e.g., trade secrets) at their disposal to protect their intellectual property efficiently (Scotchmer 2004). Patents may indicate that much research has been invested by R&D departments, as stated by Trajtenberg (2002: 43): "[T]he simple patent count could be regarded as a more refined input measure (vis-à-vis R&D), in the sense that it incorporates part of the differences in effort and nets out the influence of luck in the first round of the innovative process."

Furthermore, the upstream oil and gas sector relies substantially on complex technology applications through new combinations of new and old techniques, methods and equipment, materials, and software. For firms, it is therefore very difficult to properly circumscribe processes and methodologies within one patent that covers all intellectual property interests. Nonetheless, given the costs and efforts to produce patents, patent count may be considered a strong indicator of organizational sensitivity to threat, as it allows study of the activities the organization takes in response to political risk, among them the emergence of new products (Trajtenberg 2002), as well as entry into new technological subfields.

## LIMITATIONS AND FUTURE RESEARCH

Political risk has been recognized in the economics and managerial literatures as being an important external threat and an important factor in investment decisions. This study has examined how firms' innovation strategies change in the light of this threat. We draw on the entry literature that, among other aspects, claims that the strongest driver increasing the likelihood of firms entering new technological subfields is a threat to core business (Mitchell 1989). Our research shows that this assertion also holds in contexts where firms are threatened by menaces other than typical industry threats (Porter 1985) or threats leading to creative destruction (Schumpeter 1934).

We concentrate on technology and innovation strategies of firms in a single primary industry, the upstream oil and gas sector, and show how the political environment affects them. Estimates concerning the influence of political risk on technology and innovation strategies are robust. Control variables for oil price and firm size show statistical significance but do not eliminate the effects. However, other factors affect technology choices of oil companies into radically new fields that this research has not taken into consideration. For example, uncertainties as to which renewable energy technology is going to prevail in the future play an important role, as shown by recent efforts to develop different fuels for motor vehicles. Various possibilities already exist that conform to stricter environmental regulations (e.g., compressed natural gas, hybrid vehicles, fuels cells, efficient diesel). Each of these solutions requires a particularly large (and expensive) infrastructure in order to serve users. If oil companies invest in these infrastructures, they would find themselves in a potential holdup situation if one automobile producer withdrew its vehicle type from the market, and they would face large difficulties in recovering their investments. In addition to competition between technologies, the situation is complicated by the establishment of industry standards for a given technology. For example, the emergence of a particular renewable standard could be worth billions of dollars for the firm holding property rights to technology that meets that particular standard (Davis 2006b).

Other research has found that variables related to corporate home countries, such as the nature of national regulatory systems and the environmental orientations of those home countries, have influenced corporate greenhouse gas policies and their commitment to renewable energies (Levy and Kolk 2002). Moreover, oil companies experience intensive public scrutiny and criticism with regard to their business activities and the effects on natural environment and societies. In this context, they are often faced with social risk (Yaziji 2003) which refers to processes by which firms are challenged by non-governmental organizations (NGOs) in order to adhere to certain values and norms. NGO campaigns target company reputation and legitimacy as they try to influence public perception against the firm. Maybe the most famous example is the case of Brent Spar where Greenpeace opposed Shell's plans to sink a decommissioned offshore oil structure in the sea. The campaign was accompanied by huge media coverage and resulted in consumer boycotts and violent vandalism against Shell service stations all over Europe (Sluyterman 2010). Even though it was demonstrated that Shell's plans were the most responsible option with regard to environmental effects, Shell gave in to public pressure. The company learned that " Based on the uproar over what they had initially viewed as a purely technical decision, the company's managers concluded that public perception mattered. They came to see that emotions and beliefs could ultimately have as much influence on Shell's "licence to operate" as hard facts and demonstrated performance." (Sluyterman 2010: 218). It also teaches about the importance of external stakeholders for technology and innovation choices of firms.

Industrial change is a complex system in which organizational, economic, and political actions and reactions are seen in response to numerous threats and opportunities. Industries and organizations correspond to the definition of adaptive systems (Holland 1992). As Mitchell (1989: 227) states, "the analysis of industrial change (therefore) requires audacity—the audacity to treat some factors as independent in what we recognize is really a non-linear multi-equation system and probably a chaotic one at that. Nonetheless, the inferences that we draw from investigation of inter-temporal strategic actions are important to our understanding of organizational and social forces." Our research is intended to further the effort to understand that system and resolve its chaos through better understanding of the relation between political risk and industrial change in general and strategy development in particular.

REFERENCES


Abernathy, W.J., J. M. Utterback . 1978. Patterns of Industrial Innovation. *Technol. Rev*. **80** (7) 40-47

Acha, V. L. 2002. Framing the Past and Future: The Development and Deployment of Technological Capabilities by the Oil Majors in the Upstream Petroleum Industry. Unpublished doctoral dissertation. SPRU, University of Sussex at Brighton, UK.

Aghion, P., N. Bloom, R. Blundell, R. Griffith, P. Howitt. 2005. Competition and Innovation: An Inverted-U Relationship, *Q J. Bus. Econ*. **120** (2) 701-728

Aghion, P., R. Blundell, R. Griffith, P. Howitt, S. Prantl. 2009. The effects of entry on incumbent innovation and productivity. *Rev. Econ .Stat.* **91**(1) 20-32.

Amit, R., P.J.H. Schoemaker. 1993. Strategic assets and organizational rent. *Strategic Manage. J.* **14**(1) 33-46.

Archibugi, D. 1992. Patenting as an indicator of technological innovation: A review. *Sci. Public Pol*. **19**(6) 357-368.

Argyres, N. 1996. Capabilities, technological diversification and divisionalization. *Strategic Manage. J.* **17**(5) 395-410.

Armour, H.O., D.J. Teece. 1980. Vertical integration and technological innovation. *Rev. Econ. Stat.* **62**(3) 470-474.

Arrow, K. 1962. Economic welfare and the allocation of resources for inventions. T. Nelson, ed. *The Rate and Direction of Inventive Activity: Economic and Social Factors*. Princeton University Press, Princeton, NJ, 609-625.

Atsegbua, L. 1993. Acquisition of oil rights under contractual joint ventures in Nigeria. *J. Afr. Law* **37**(10) 10-29.

Bentley, R.W. 2002. Global oil & gas depletion: An overview. *Energ. Policy* **30**(3) 189-205.

Blundell, R., R. Griffith, et al. 1999. Market share, market value and innovation in a panel of British manufacturing firms. *Rev. Econ. Stud.* **66**(3) 529-554.

Bromiley, P., K.D. Miller, D. Rau. 2005. Risk in strategic management research. M.A. Hitt, R. Edward Freeman, Jeffrey S. Harrison, eds. *The Blackwell Handbook of Strategic Management.* Blackwell Publishing, Oxford, U.K., 259-288.

Brunetti, A., B. Weder. 1998. Investment and institutional uncertainty: A comparative study of different uncertainty measures. *Rev.World. Econ.* **134**(3) 513-533.

Butler, K., D. Joaquin. 1998. A note on political risk and required return on foreign direct investment. *J Int. Bus .Stud*. **29**(3) 599–608

Colitti, M., C. Simeoni. 1996. Perspectives of Oil and Gas: The Road to Interdependence. *J Energy* **2**(2) 88-90

Cormier, D., M. Magnan. 2002. Performance reporting by oil and gas firms: Contractual and value implications. *J. of Int. Accounting, Auditing & Taxation* **11**(2) 131-153.

Cosset, J.-C., J.-M. Suret. 1995. Political risk and the benefits of international portfolio diversification. *J. Int. Bus. Stud.* **26**(2) 301-318.

Damanpour, F., S. Gopalakrishnan. 1998. Theories of organizational structure and innovation adoption: The role of environmental change. *J. Eng. and Tech. Man*. **15**(1) 1-24.

Davis, J. 2006a. And then there were four . A thumbnail history of oil industry restructuring, 1971-2005. J. Davis, ed. *The Changing World of Oil: An Analysis of Corporate Change and Adaptation*. Ashgate, Aldershot, England, 1-12

Davis, J. 2006b. Why don't oil companies commit to renewables? A corporate constraints perspective. J. Davis, ed., *The changing world of oil: An analysis of corporate change and adaptation.* Ashgate, Aldershot, England, 169-189

Debackere, K., A. Verbeek, M. Luwel, E. Zimmermann. 2002. Measuring progress and evolution in science and technology—II: The multiple uses of technometric indicators. *Int. J. Manag. Rev.* **4**(3) 213-231

Deng, Z., B. Lev, et al. 1999. Science and technology as predictors of stock performance. *Financ. Anal. J.* **55**(3) 20-32.

Fagre, N., L. J. Wells. 1982. Bargaining power of multinationals and host governments. *J. Int. Bus. Stud.* **13**(2) 9-23.

Fiegenbaum, A., H. Thomas. 1988. Attitudes toward risk and the risk-return paradox: Prospect theory explanations. *Acad. Manage. J.* **31**(1) 85-106.

Freeman, C., L. Soete, 1997. The Economics of Industrial Innovation. MIT Press, Cambridge, MA.

Frynas, J. G. 1998. Political instability and business: Focus on Shell in Nigeria. *Third World Q.* **19**(3) 457-478.

Frynas, J. G. 2005. The false developmental promise of Corporate Social Responsibility : eveidence from multinational oil companies. *Int. Aff.* **81**(3) 581-598

Gilbert, R. J., H. M. Newberry. 1982. Preemptive patenting and the persistence of monopoly. *Am. Econ. Rev.* **72**(3) 514-526.

Greve, H. R. 2003. A behavioral theory of R&D expenditures and innovations: Evidence from shipbuilding. *Acad. Manage J*. **46**(6) 685-702.

Greve, H. R., A. Taylor. 2000. Innovations as catalysts for organizational change: shifts in organizational cognition and search. *Admin. Sci. Q.* **45**(1) 54-80.

Guessoum, Y. 2004. Evaluation du risque pays par les agences de rating : Transparence et convergence des méthodes. Working paper, CNRS Université de la Méditerranée (Aix-Marseille II).

Helfat, C. E. 1997. Know-how and asset complementarity and dynamic capability accumulation: The case of R&D. *Strateg. Manage. J.* **18**(5) 339-360.

Helfat, C. E., M. E. Lieberman. 2002. The birth of capabilities: Market entry and the importance of pre-history. *Ind. Corp. Change* **11**(4) 725-760.

Henderson, R. 1993. Underinvestment and incompetence as responses to radical innovation. *RAND J. Econ.* **24**(2) 248-269.

Henisz, W. 2003. Politics and international investment. *J. Int. Bus. Stud.* **34**(2) 223-225.

Hitt, M. A., R. D. Ireland. 1985. Strategy, contextual factors, and performance. *Hum. Relat.* **38**(8) 793-812.

Holburn G.L.F., B. A. Zelner 2010. Political Capabilities, Policy Risk and International Investment Strategy: Evidence from the Global Electric Power Industry. Strateg. Manage. J. **31**(12) 1290-1315

Holland, J. H. 1992. Adaptation in Natural and Artificial Systems. MIT Press, Cambridge, MA.

Katila, R., G. Ahuja. 2002. Something old, something new: A longitudinal study of search behavior and new product introduction. *Acad. Manage. Rev.* **45**(6) 1183-1194.

Kerin, R. A., P. R. Varadarajan, R.A. Peterson. 1992. First-mover advantage: A synthesis, conceptual framework, and research propositions. *J. Marketing* **56**(4) 33-52.

King, A. A., C. L. Tucci. 2002. Incumbent entry into new market niches: The role of experience and managerial choice in the creation of dynamic capabilities. *Manage. Sci.* **48**(2) 171-186.

Klepper, S., K. L. Simons. 2000. Dominance by birthright: Entry of prior radio producers and competitive ramifications in the U.S. television receiver industry. *Strateg. Manage. J.* **21**(10-11) 997-1016.

Lehner, J. M. 2000. Shifts of reference points for framing of strategic decisions and changing risk-return associations. *Manage. Sci.* **46**(1) 63-76.

Leifer, R., McDermott, C., O'Connor, G. C., L. Peters, M. R., R. W.Veryzer. 2000. Radical Innovation: How Mature Companies Can Outsmart Upstarts. Boston, MA.: Harvard Business School Press.

Levy, D. L., A. Kolk. 2002. Strategic responses to global climate change: Conflicting pressures on multinationals in the oil industry. *Bus. and Politics* **4**(3) 275-300.

Lieberman, M., Montgomery, D. 1988. First mover advantages. *Strateg. Manage. J.* **9**(S1) 41-58.

Lohrke, F. T., G. W. Simpson, D. Hunt. 2007. Extending the bargaining power model : Eighteenth century lessons from Panton, Leslie and Company in managing political risk. J. *Manage. Hist.* **13**(2) 153-171.

March, J. G. 1991. Exploration and exploitation in organizational learning. *Organ. Sci.* **2**(1) 71-87.

Maule, J., R. Hockey, L. Bdzola. 2000. Effects of time-pressure on decision-making under uncertainty: Changes in affective state and information processing strategy. *Acta Psychol.* **104**( 3) 283-301.

Mitchell, W. 1989. Whether and when? Probability and timing of incumbents' entry into emerging industrial subfields. *Admin. Sci. Quart*. **34**(2) 208-230.

Murray, T. H. J. 1990. North American drilling activity in 1989. *AAPG Bull.* **74**(10B) 7-36.

Narin, F. 1994. Patent bibliometrics. *Scientometrics* **30**(1) 147-155.

Parry, I. W. H. 1997. Productivity trends in the natural resource industries 1970-1994. *RFF Discussion paper* 97-39, Washington D.C.: Resources for the Future.

Porter, M. E. 1985. *Competitive Advantage: Creating and Sustaining Superior Performance*. Free Press, New York.

Porter, M.E., M.R. Kramer. 2002. The competitive advantage of corporate philanthropy. *Havard Bus. Rev*. **80**(12), 56–69.

PRSGroup. 2009. *ICRG Methodology*. Available at http://www.prsgroup.com/ICRG_Methodology.aspx#PolRiskRating.

Reinganum, J. 1983. Uncertain innovation and the persistence of monopoly. *The Am.Econ. Rev.* **73**(4) 741-748.

Scherer, A.G. , G.Palazzo. 2008. Globalization and Corporate Social Responsibility. A. Crane, A. McWilliams, D. Matten, J. Moon, D. Siegel, eds. *The Oxford Handbook of Corporate Social Responsibility.* Oxford University Press , 413-431.

Schumpeter, J. A. 1934. *The Theory of Economic Development*. Harvard University Press, Cambridge, MA.

Scotchmer, S. 2004. *Innovation and Incentives*. MIT Press, Cambridge, MA.
Siggelkow, N., D. A. Levinthal. 2003. Temporarily divide to conquer: Centralized, decentralized, and reintegrated organizational approaches to exploration and adaptation. *Organ. Sci.* **14**(6) 650-669.

Sluyterman, K. 2010. Royal Dutch Shell: company strategies for dealing with environmental issues. Bus. His. Rev. **84** (Summer 2010) 203-226

Stabell, C. 2006. Competitive strategy and industry structure. J. Davis, ed., *The Changing World of Oil: An Analysis of Corporate Change and Adaptation*. Ashgate, Aldershot, England, 89-104.

Stevens, P. 2008. *A methodology for assessing the performance of national oil companies. Background paper for a study on national oil companies and value creation*,World Bank, Washington, D.C.

Szymanski, D. M., L. C. Troy, S. Bharadway. 1995. Order of entry and business performance: An empirical synthesis and reexamination. *J. Marketing* **59**(4) 17-33.

Teece, D. J. 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Res. Policy* **15**(6) 285-305.

Teece, D., G. Pisano, et al. 1997. Dynamic capabilities and strategic management. *Strateg. Manage. J.* **18**(7) 509-533.

Trajtenberg, M. 2002. A penny for your quotes: Patent citations and the value of innovations. A. B. Jaffe, M. Trajtenberg, eds., *Patents, Citations and Innovations : A Window on the Knowledge Economy.* MIT Press, Cambridge, MA, 25-49.

Tripsas, M. 1997. Surviving radical technological change through dynamic capability. *Ind. Corp. Change* **6**(2) 341-377.

Tushman, M. L., P. Anderson. 1986. Technological discontinuities and organizational environments. *Admin. Sci. Quart*. **31**(3) 439-465.

University of Tulsa (1995), *Analysis of research and development trends among major petroleum corporations in the United States*, conducted for BDM Oklahoma Inc, Subcontract 93-0001, contract DE-AC22-94PC91008, University of Tulsa, Tulsa 8-9.

Weston, J. F., B. A. Johnson, J.A. Siu. 1999. Mergers and restructuring in the world oil industry. J. Energy Fin. Devel. **4**(2) 149-183.

Yaziji, M. 2003. Toward a theory of social risk. *Int. Stud. Manage. Organiz.* **34**(4) 87-107

Yetiv, S. 2004. *Crude Awakenings : Global Oil Security and American Foreign Policy*. Cornell University Press, Ithaca, NY.

**Table 1: Political Risk Components**

| *POLITICAL RISK COMPONENTS* | | |
|---|---|---|
| **Sequence** | **Component** | **Points *(max.)*** |
| **A** | Government Stability | **12** |
| **B** | Socioeconomic Conditions | **12** |
| **C** | Investment Profile | **12** |
| **D** | Internal Conflict | **12** |
| **E** | External Conflict | **12** |
| **F** | Corruption | **6** |
| **G** | Military in Politics | **6** |
| **H** | Religious Tensions | **6** |
| **I** | Law and Order | **6** |
| **J** | Ethnic Tensions | **6** |
| **K** | Democratic Accountability | **6** |
| **L** | Bureaucracy Quality | **4** |
| **Total** | | **100** |

*Source.* PRS Group (2009)

**Table 2: Performance Measures**

| Measure | Meaning |
| --- | --- |
| Production | Gives an indication of how long oil companies effectively and consistently can maintain production. It is an indicator for the current situation (Stevens 2008). |
| Reserves | Reserve estimates rely on assumptions about the size of the reservoir, recoverability of reserves, extraction costs, selling prices, and other factors. They give an indication about the mid- and long-term perspectives concerning the organizational endowment with natural resources (Cormier and Magnan 2002). |
| Exploration Success | Exploration success is pivotal to upstream companies because they need to replace the reserves that they generate through production. Exploration success is a prerequisite for sustainable growth in production. It is an indicator of the mid- and long-term perspective concerning how long and how well a company will be able to sustain production. |
| Oil Rights (year end) | They are contractual agreements between producing host countries and firms that fix the conditions under which the parties plan to explore and exploit natural resources. Oil rights are a performance measure that also gives an indication of the ability of the firm to renew its activities, especially with regard to the exploitation of further reserves (Atsegbua 1993). Oil Rights (year end) refer to all rights the company holds at the end of a certain year. They are an indicator of the company’s access to resource deposits. |
| Oil Rights (new awards) | Oil rights concerning new awards refer to rights on wells that have not been previously exploited by the oil company. These can refer to new oil discoveries, as well as already developed areas that companies take over from other firms. Oil Rights (new awards) indicate short- to mid-term exploitation prospects (Colitti and Simeoni 1996). |

**Table 3: Publication Classification**

**Geo (Tulsa 1.0-3.0)**
**Geology/ Geochemistry/ Geophysics**
*seismic processing*: data processing, velocity computation, amplitude vs. offset, migration, recording, stacking, interpretation
*seismic surveys*: reflection method, common depth point method, wave source, equipment, transmission, shear wave source, streamer, 3 component geophone, stratigraphy, vertical profiling

**Drilling (Tulsa 4.0)**
*Drilling fluids*: clay stabilization, fluid, fluid loss additive, oil base mud, fluid testing, mud thinner, formation damage
*Horizontal well technology*: drilling, well, well completion

**Well Logging (Tulsa 5.0)**

**Well Completion (Tulsa 6.0)**
*Well stimulation/fracturing*: acidizing, fluid loss additive, hydraulic fracturing, blender, fracturing fluid, foam fracturing, fracturing pressure, acid fracturing, fracturing fluid additive, fracture geometry, formation damage

*Well workover*: sand control, well tool, milling, recompletion, inhibitor squeeze, scale removal, sand consolidation, corrosion testing, corrosion inhibitor, cathodic protection
*Cementing*: bond strength, coiled tubing, cementing, cementing head, cement mixer, cementing collar, lightweight cement, cement composition, cement slurry, cement testing, cement rheology, portland cement, cementing plug, retarded cement
*Other well completion*: inflatable packer, setting tool, retrievable packer, perforator, centralizer, electric well pump, slim hole completion, tubing conveyed operation, bridge plug, shaped charge perforator, casing perforating, gravel packing

**Reservoir Engineering (Tulsa 8.0)**
*Formation evaluation:* core analysis, relative permeability, core barrel, wettability, fluid sampler, formation tester, formation evaluation, pressure transient analysis / pressure build-up analysis, formation damage
*Reservoir predictive methods:* reservoir model, reservoir study, reservoir fluid flow, vapor liquid equilibrium/phase behavior, compositional model
*Improved oil recovery:* carbon dioxide flooding, carbon dioxide injection, reservoir heating, steam flooding, steam injection, miscible displacement, surfactant waterflooding, combination flooding, polymer waterflooding, microemulsion, profile control, enriched gas drive, emulsion flooding, caustic waterflooding, viscous oil recovery, thermal recovery, in situ combustion, waterflooding

**Supplemental Technology (Tulsa 12.0)**
*Offshore*: tension leg platform, riser pipe, production platform, semisubmersible drilling barge, floating production platform, drilling platform, tethering, platform jacket

*Source.* University of Tulsa (1995)

**Table 4: Descriptive Statistics**

| Variable | Obs. | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|---|
| Publications in all Technology Areas | 315 | 20.6 | 29.6 | 0 | 146 |
| Publications Well Completion | 315 | 1.3 | 5 | 0 | 62 |
| Publications Reservoir Engineering | 315 | 9 | 31.5 | 0 | 399 |
| Publications Offshore | 315 | 8.2 | 11.9 | 0 | 79 |
| Publications Improved Oil Recovery | 315 | 2.6 | 9.8 | 0 | 122 |
| Publications Geophysics | 315 | 9.9 | 39 | 0 | 588 |
| Publications Drilling | 315 | 2.2 | 7.4 | 0 | 81 |
| Publications Ecology | 300 | 0.8 | 2 | 0 | 18 |
| Publications Unconventional Oil Technology | 315 | 1.1 | 2.5 | 0 | 18 |
| Publications Renewables | 315 | 3.1 | 6 | 0 | 60 |
| | | | | | |
| Patents in all Technology Areas | 315 | 404.6 | 693 | 0 | 5571 |
| Patents Drilling | 315 | 30.1 | 73.8 | 0 | 647 |
| Patents Geophysics | 315 | 10 | 17.4 | 0 | 117 |
| Patents Improved Oil Recovery | 315 | 139.9 | 215.5 | 0 | 1687 |
| Patents Offshore | 315 | 9.5 | 21.8 | 0 | 193 |
| Patents Reservoir Engineering | 315 | 28.6 | 58.1 | 0 | 465 |
| Patent Well Completion | 315 | 186.6 | 323.3 | 0 | 2462 |
| Patents Unconventional Oil Technology | 300 | 102.7 | 119.6 | 0 | 464 |
| Patents Renewables | 300 | 89 | 114.9 | 0 | 623 |
| | | | | | |
| Political Stability in Production Areas | 275 | 51.2 | 11.5 | 36 | 89 |
| Political Stability in Areas of Exploration Success | 217 | 51.3 | 11.6 | 26 | 95.5 |
| Political Stability in Areas holding Reserves | 112 | 58.6 | 9.4 | 41 | 90 |
| Political Stability in Areas holding newly acquired OilRights | 206 | 45.2 | 12.3 | 20 | 89 |
| Political Stability in Areas holding Oil Rights | 206 | 45.2 | 12.3 | 20 | 89 |
| | | | | | |
| Total Production | 269 | 476.9 | 415 | 9.59 | 2237.9 |
| Numbers of Employees | 209 | 43661.1 | 38938.2 | 1000 | 129955 |
| Oil Price | 315 | 29.3 | 22.8 | 11.82 | 104.43 |

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Publications in all Technology Area** | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | **Publications Well Completion** | 0.15 ** | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | **Publications Reservoir Engineering** | 0.12 ** | 0.00 ** | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | **Publications Offshore** | 0.90 *** | (0.06) | 0.08 | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | **Publications Improved Oil Recover** | 0.10 * | 0.03 | 0.83 *** | 0.05 | 1 | | | | | | | | | | | | | | | | | | | | | | |
| 6 | **Publications Geophysics** | 0.11 * | 0.00 | 0.94 *** | 0.06 | 0.75 *** | 1 | | | | | | | | | | | | | | | | | | | | | |
| 7 | **Publications Drilling** | 0.12 * | 0.00 | 0.94 *** | 0.08 | 0.84 *** | 0.90 *** | 1 | | | | | | | | | | | | | | | | | | | | |
| 8 | **Publications Ecology** | 0.53 *** | 0.07 | 0.51 ** | 0.44 *** | 0.28 *** | 0.50 *** | 0.33 *** | 1 | | | | | | | | | | | | | | | | | | | |
| 9 | **Publications Unconventional Oil Te** | 0.53 *** | 0.16 | 0.06 | 0.47 *** | 0.08 | 0.02 | 0.06 | 0.26 *** | 1 | | | | | | | | | | | | | | | | | | |
| 10 | **Publications Renewables** | 0.39 *** | 0.08 | 0.19 ** | 0.40 *** | 0.43 *** | 0.16 ** | 0.24 *** | 0.38 *** | 0.46 *** | 1 | | | | | | | | | | | | | | | | | |
| 11 | **Patents in all Technology Areas** | 0.28 *** | 0.00 | (0.02) | 0.24 *** | (0.01) | (0.02) | 0.01 | 0.12 * | 0.21 ** | 0.09 * | 1 | | | | | | | | | | | | | | | | |
| 12 | **Patents Drilling** | 0.23 *** | 0.01 | (0.01) | 0.28 *** | 0.00 | (0.02) | 0.03 | 0.06 | 0.17 ** | 0.05 | 0.93 * | 1 | | | | | | | | | | | | | | | |
| 13 | **Patents Geophysics** | 0.27 *** | 0.06 | (0.02) | 0.21 ** | (0.01) | (0.02) | 0.00 | 0.13 * | 0.19 ** | 0.04 | 0.87 *** | 0.76 *** | 1 | | | | | | | | | | | | | | |
| 14 | **Patents Improved Oil Recovery** | 0.35 *** | 0.01 | (0.02) | 0.31 *** | (0.01) | (0.02) | 0.02 | 0.18 ** | 0.26 *** | 0.15 * | 0.98 *** | 0.87 *** | 0.85 *** | 1 | | | | | | | | | | | | | |
| 15 | **Patents Offshore** | 0.21 ** | 0.00 | (0.01) | 0.22 ** | (0.01) | (0.02) | 0.03 | 0.06 | 0.17 ** | 0.06 | 0.90 *** | 0.97 *** | 0.72 *** | 0.85 *** | 1 | | | | | | | | | | | | |
| 16 | **Patents Reservoir Engineering** | 0.24 ** | 0.02 | (0.02) | 0.20 ** | (0.01) | (0.02) | 0.02 | 0.08 | 0.18 ** | 0.06 | 0.96 *** | 0.96 *** | 0.87 *** | 0.91 *** | 0.93 *** | 1 | | | | | | | | | | | |
| 17 | **Patent Well Completion** | 0.24 *** | 0.00 | (0.03) | 0.21 *** | (0.02) | (0.02) | 0.00 | 0.09 | 0.18 ** | 0.08 | 0.99 *** | 0.90 *** | 0.87 *** | 0.97 *** | 0.86 *** | 0.94 *** | 1 | | | | | | | | | | |
| 18 | **Patents Unconventional Oil Technc** | 0.50 *** | 0.02 | 0.47 *** | 0.43 *** | 0.36 *** | 0.37 *** | 0.40 *** | 0.33 *** | 0.41 *** | 0.42 *** | 0.68 *** | 0.47 *** | 0.63 *** | 0.75 *** | 0.46 *** | 0.57 *** | 0.68 *** | 1 | | | | | | | | | |
| 19 | **Patents Renewables** | 0.28 *** | (0.03) | 0.24 *** | 0.35 *** | 0.16 ** | 0.23 *** | 0.31 *** | 0.16 ** | 0.18 ** | 0.17 ** | 0.89 *** | 0.73 *** | 0.77 *** | 0.91 *** | 0.72 *** | 0.81 *** | 0.90 *** | 0.83 *** | 1 | | | | | | | | |
| 20 | **Political Stability in Production Are** | (0.21) *** | (0.08) | (0.02) ** | (0.14) * | (0.21) *** | (0.20) *** | (0.17) *** | (0.16) ** | (0.17) ** | (0.24) *** | (0.35) *** | (0.23) *** | (0.35) *** | (0.39) *** | (0.24) ** | (0.29) *** | (0.35) *** | (0.50) *** | (0.46) *** | 1 | | | | | | | |
| 21 | **Political Stability in Areas of Explor** | (0.14) ** | (0.04) | (0.11) * | (0.13) *** | (0.15) ** | (0.14) * | (0.09) | (0.11) | (0.18) ** | (0.22) ** | (0.19) ** | (0.08) | (0.22) ** | (0.23) ** | (0.12) | (0.13) * | (0.20) ** | (0.35) *** | (0.29) *** | 0.51 *** | 1 | | | | | | |
| 22 | **Political Stability in Areas holding I** | 0.21 * | 0.04 | (0.17) ** | 0.24 *** | 0.15 | 0.13 | 0.15 | 0.11 | 0.29 ** | 0.17 * | (0.01) | 0.06 | (0.07) | (0.02) | 0.07 | 0.02 | (0.04) | (0.11) | (0.10) | 0.25 ** | 0.08 | 1 | | | | | |
| 23 | **Political Stability in Areas holding newly acquired OilRights** | (0.39) *** | (0.02) *** | 0.40 *** | (0.34) *** | (0.24) ** | (0.37) *** | (0.31) *** | (0.22) ** | (0.21) ** | (0.25) ** | (0.30) *** | (0.22) ** | (0.31) *** | (0.33) *** | (0.23) ** | (0.29) *** | (0.30) *** | (0.55) *** | (0.41) *** | 0.53 *** | 0.39 *** | (0.15) | 1 | | | | |
| 24 | **Political Stability in Areas holding (** | (0.39) *** | (0.02) *** | 0.40 *** | (0.34) *** | (0.24) ** | (0.37) *** | (0.31) *** | (0.22) ** | (0.21) ** | (0.25) ** | (0.30) *** | (0.22) ** | (0.31) *** | (0.33) *** | (0.23) ** | (0.29) *** | (0.30) *** | (0.55) *** | (0.41) *** | 0.53 *** | 0.39 *** | (0.15) | 1 | 1 | | | |
| 25 | **Total Production** | 0.46 *** | 0.22 ** | 0.40 *** | 0.36 *** | 0.30 *** | 0.36 *** | 0.31 *** | 0.38 *** | 0.40 *** | 0.55 *** | 0.26 *** | 0.11 * | 0.34 *** | 0.33 *** | 0.14 * | 0.20 ** | 0.25 *** | 0.58 *** | 0.35 *** | (0.41) *** | (0.35) *** | 0.35 ** | (0.40) *** | (0.40) *** | 1 | | |
| 26 | **Numbers of Employees** | 0.52 *** | 0.23 ** | 0.47 *** | 0.51 *** | 0.38 *** | 0.51 *** | 0.35 *** | 0.32 *** | 0.38 *** | 0.32 *** | 0.24 ** | 0.09 | 0.35 *** | 0.31 *** | 0.12 | 0.19 ** | 0.24 ** | 0.70 *** | 0.42 *** | (0.45) *** | (0.39) *** | (0.13) | (0.50) *** | (0.50) *** | 0.72 *** | 1 | |
| 27 | **Oil Price** | (0.27) *** | 0.12 * | 0.41 *** | 0.34 *** | 0.38 *** | 0.37 *** | 0.41 *** | (0.08) | (0.12) * | 0.43 *** | (0.15) ** | (0.10) | (0.14) * | (0.18) ** | -0.08 | (0.12) * | (0.15) ** | (0.22) ** | (0.13) * | (0.12) * | 0.08 | 0.05 | 0.15 * | 0.15 * | 0.08 | 0.07 | 1 |

**Table 5: Correlation Matrix**

## Table 6: Linear Regression Fixed Effects Models

| Variables | Model 1 Publications Reservoir Engineering | Model 2 Patents in all Technology Areas | Model 3 Patents Reservoir Engineering | Model 4 Patents Geophysics | Model 5 Patents Unvonventional Oil Technology | Model 6 Patents Renewables | Model 7 Publications in all Technology Areas | Model 8 Publications Offshore | Model 9 Patents in all Technology Areas | Model 10 Patents Drilling | Model 11 Patents Offshore |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Political Stability in Production Area | 0.0279*** | (0.0161)* | (0.0202)** | (0.0240)* | (0.0170)** | -0.0219 | | | | | |
| | -0.0102 | -0.00831 | -0.00958 | -0.0133 | -0.00673 | -0.00705 | | | | | |
| Political Stability in Areas holding Reserves | | | | | | | 0.0383** | 0.0404** | -0.0243 | 0.0433* | |
| | | | | | | | -0.0181 | -0.0198 | -0.0119 | -0.0244 | |
| Political Stability in Areas holding Oil rights | | | | | | | | | | | 0.014* |
| | | | | | | | | | | | -0.00736 |
| Number of Employees | -6.21E-08 | 1.50e-05*** | 7.95e-06** | 0.00000524 | 8.31e-06*** | 5.13e-06* | 1.23e-05* | 0.00000851 | 1.06-05*** | 0.000000472 | 1.12e-05*** |
| | -0.00000519 | -0.00000264 | -0.00000347 | -0.00000442 | -0.00000269 | -0.00000291 | -0.00000665 | -0.00000597 | -0.00000345 | -0.00000519 | -0.00000398 |
| Oil Price | (0.0346)*** | (0.0185)*** | (0.0157)*** | -0.00838 | (0.0283)*** | (0.0181)*** | (0.0294)*** | (0.0330)*** | (0.0261)*** | (0.0292)*** | (0.0216)*** |
| | -0.00652 | -0.00363 | -0.00395 | -0.00457 | -0.00298 | -0.00292 | -0.00574 | -0.00781 | -0.00437 | -0.00489 | -0.00541 |
| Total Production | (0.000995)*** | 0.0000863 | 0.00564*** | 0.000711*** | 0.000326** | -0.000492 | -0.000297 | 0.000105 | -0.000366 | 0.000612** | 0.000338 |
| | -0.00038 | -0.00021 | -0.000206 | -0.00025 | -0.000158 | -0.000153 | -0.000403 | -0.000394 | -0.000234 | -0.000267 | -0.000286 |
| Constant | 3.840*** | 1.162** | 1.474** | 1.19 | 2.568*** | 2.487*** | -0.9 | -1.362 | 2.348*** | -0.629 | -0.119 |
| | -0.792 | -0.484 | -0.577 | -0.773 | -0.427 | -0.42 | -1.097 | -1.213 | -0.697 | -1.228 | -0.394 |
| Observations | 198 | 198 | 182 | 168 | 182 | 182 | 111 | 111 | 111 | 98 | 179 |
| Nb of Companies | 15 | 15 | 14 | 13 | 14 | 14 | 15 | 15 | 15 | 13 | 14 |
| Wald chi2(4) | 48.94 | 74.8 | 45.68 | 26.38 | 125.3 | 74 | 44.5 | 34.13 | 60.42 | 43.79 | 24.83 |
| Prob | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| Loglikelihood | -343.66936 | -976.10758 | -545.43894 | -413.49621 | -721.8014 | -713.12661 | -293.74042 | -231.301 | -517.72374 | -273.52971 | -399.77156 |

*Note.* *$p < .10$, **$p < .05$, ***$p < .01$.

## Table 7 Linear Regression Random Effects Models

| Variables | Model 12 Patents in all Technology Areas | Model 13 Patents in all Technology Areas | Model 14 Patents Reservoir Engineering | Model 15 Patents Offshore | Model 16 Patents Geophysics | Model 17 Patents Unvonventional Oil Technology | Model 18 Patents Renewables | Model 19 Publications in all Technology Areas | Model 20 Publications Reservoir Engineering | Model 21 Publications Offshore | Model 22 Publications Unvonventional Oil Technology | Model 23 Publications Renewables |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Political Stability in Production Area | (0.0176)** | | (0.215)** | (0.0208)** | (0.0263)** | (0.0178)*** | (0.0228)*** | | (0.0226)*** | | | |
| | 0.00826 | | -0.00944 | -0.0102 | -0.013 | -0.00665 | -0.00699 | | -0.0102 | | | |
| Political Stability in Areas holding Reserves | | -0.0272 | | | | | | 0.0389*** | | 0.0370*** | 0.0639** | 0.0347* |
| | | -0.0117 | | | | | | -0.0134 | | -0.0135 | -0.0272 | -0.021 |
| Number of Employees | 1.55e-05*** | 1.23e-05*** | 9.40e-06*** | 9.74e-06*** | 7.40e-06* | 9.07e-06*** | 6.09e-06** | 1.38e-05*** | 0.00000561 | 8.05e-06* | 1.90e-05** | 2.00e-05*** |
| | 0.0000026 | -3.44E-06 | -0.00000336 | -0.00000367 | -4.25E-06 | -0.00000262 | -0.00000283 | -4.35E-06 | -0.000000481 | -4.13E-06 | -7.75E-06 | -6.58E-06 |
| Oil Price | (0.0816)*** | (0.0259)*** | (0.0157)*** | (0.0204)*** | (0.00829)* | (0.0283)*** | (0.0180)*** | (0.0295)*** | (0.0370)*** | (0.0331)*** | 0.0174** | -0.00537 |
| | -0.0036 | -0.00432 | -0.00391 | -0.00484 | -0.00454 | -0.00294 | -0.00289 | -0.00566 | -0.00667 | -0.000708 | -0.00786 | -0.00636 |
| Total Production | 0.000107 | 0.000437** | 0.000556*** | 0.000168 | 0.000698*** | 0.000321** | 0.000480*** | -0.000143 | (0.000617)* | 0.000249 | 0.000593 | 0.000338 |
| | -0.000204 | -0.000214 | -0.0002 | -0.000263 | -0.000242 | -0.000154 | -0.00015 | -0.000331 | -0.000366 | -0.000323 | -0.000524 | -0.00036 |
| Constant | 1.208** | 2.365*** | 1.471*** | 1.793*** | 1.175 | 2.587*** | 2.499*** | -1.109 | 2.926*** | -1.227 | -3.201 | -1.788 |
| | -0.791 | -0.69 | -0.477 | -0.634 | -0.749 | -0.419 | -0.414 | -0.878 | -0.791 | -0.902 | (4.967)) | -1.365 |
| Observations | 198 | 111 | 198 | 198 | 198 | 198 | 198 | 111 | 198 | 111 | 111 | 111 |
| Nb of Companies | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Wald chi2(4) | 81.87 | 69.82 | 53.07 | 34.73 | 32.94 | 133.7 | 79.97 | 59.29 | 67.87 | 44.07 | 18.2 | 24.96 |
| Prob | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| Loglikelihood | -1120.966 | -652.91912 | -645.03082 | -501.16914 | -497.47846 | -844.16215 | -834.22457 | -375.20551 | -420.22431 | -301.19297 | -110.32767 | -180.45854 |

*Note.* *$p < .10$, **$p < .05$, ***$p < .01$.