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The Impact of Governance Uncertainty on Technology Diversification

Bettina lynda Bastian
American University of Beirut

bb21@aub.edu.lb

Christopher Tucci
EPFL

christopher.tucci@epfl.ch

Marcel Bogers
University of Southern Denmark

bogers@mci.sdu.dk

Abstract
In this paper, we address the link between governance uncertainty, which is defined as traditions and institutions by which a country?s authority is exercised and innovation output of affected companies. Governance uncertainty may interfere with organizational ownership, operations, and transfers. Our research focuses on the context of primary sector firms, notably, firms active in the upstream oil industry, which must source natural oil and gas from particular geographical areas because these resources are fixed in certain locations. For these companies, governance uncertainty is a reality with regard to numerous issues (for example, environmental legislation, share of oil rents, corruption), which may constitute a serious threat to their core business of exploitation of finite natural resources, especially when it affects access to resource deposits. Our analysis shows that companies react to this problem by

increasing their investment activities into new technology fields related to their core business (such as tar sands) or related to radically new business areas (such as renewable energies). We also observe that companies appear to respond to uncertainties that affect short-term assets (notably, production assets) with long-term solutions (diversification strategies into green technologies), and respond to uncertainties that affect long-term assets (notably, areas where companies have successfully explored new resource deposits) with short-term solutions (investments into technological subfields within their current core business). Our research is supported with an analysis of 16 years of data from diverse technology and operations areas of 15 global upstream oil and gas companies.

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Abstract. In this paper, we address the link between governance uncertainty, which is defined as traditions and institutions by which a country's authority is exercised and innovation output of affected companies. Governance uncertainty may interfere with organizational ownership, operations, and transfers. Our research focuses on the context of primary sector firms, notably, firms active in the upstream oil industry, which must source natural oil and gas from particular geographical areas because these resources are fixed in certain locations. For these companies, governance uncertainty is a reality with regard to numerous issues (for example, environmental legislation, share of oil rents, corruption), which may constitute a serious threat to their core business of exploitation of finite natural resources, especially when it affects access to resource deposits. Our analysis shows that companies react to this problem by increasing their investment activities into new technology fields related to their core business (such as tar sands) or related to radically new business areas (such as renewable energies). We also observe that companies appear to respond to uncertainties that affect short-term assets (notably, production assets) with long-term solutions (diversification strategies into green technologies), and respond to uncertainties that affect long-term assets (notably, areas where companies have successfully explored new resource deposits) with short-term solutions (investments into technological subfields within their current core business). Our research is supported with an analysis of 16 years of data from diverse technology and operations areas of 15 global upstream oil and gas companies.

Keywords: Governance and institutional uncertainty, innovation, technology diversification

INTRODUCTION

The increasing integration of the global economy, technological progress, and the diffusion of the Internet have engendered dramatic changes in international business practices and enabled firms of all sizes—from large multinationals to young start-ups that go global from inception—to operate on a global scale and seize opportunities beyond national borders. These firms hold business portfolios in various countries, which confront them with different business environments characterized by numerous environmental opportunities and challenges (for example, the rate of technological change, demand uncertainties, market instabilities). In this context, firms are also exposed to a patchwork of different institutional and governance environments with varying degrees of uncertainty. The institutional or governance situation, which is defined as traditions and institutions by which a country's authority is exercised (Kauffman et al. 1999), constitutes the framework in which economic activities take place and has a crucial impact on economic life. Two streams have been identified by research that addresses the influence of this environment. The first branch of the existing literature is concerned with the *efficiency* of certain policies (e.g. fiscal, monetary, and environmental policies) and its impact on firms (Brunetti et al. 1998). The second branch focuses on the *reliability* of the political system and stability or uncertainties within this environment (e.g. stability of political institutions, governmental effectiveness, respect for political institutions) that affect policy implementation and firms (Brunetti et al. 1998). This research project aims to make a contribution to the second stream of literature and examines how governance uncertainties affect corporate positioning with regard to technology and innovation. Much research on the impact of governance uncertainty has been concerned with the input side (investment decisions, FDI: Globermann and Shapiro 2002; Jensen 2003; Li and Filer 2007). This paper concentrates on the impact of governance uncertainty with regards to the output side, notably technology output in the form of patents and publications.

Governance uncertainty may interfere with organizational ownership, operations, and transfers. We focus on the context of primary sector firms, notably firms active in the upstream oil sector, which must source natural oil and gas from particular geographical areas because these resources are fixed in certain locations and are not available in abundance over the entire planet. For these companies, governance uncertainty is a reality with regard to numerous issues (for example, environmental legislation, share of oil rents, and corruption). In this context, governance uncertainty may constitute a serious threat to their core business of exploitation of finite natural resources, especially when it affects access to resource deposits. Moreover, companies are constrained in their response strategies due to location dependency on specific host countries.

Our analysis shows that companies react to this problem by increasing their activities in new technical fields related to their core business (such as tar sands) or related to new business areas (such as renewable energies). We also observe that companies appear to respond to uncertainties that affect short-term assets (notably, production assets) with long-term solutions (diversification strategies into green technologies), and respond to uncertainties that affect long-term assets (notably, areas where companies have successfully explored new resource deposits) with short-term solutions (investments into technical subfields within their current core business). Moreover, we analyze the impact of different components of uncertain governance environments on technology choices of firms. It appears that managers are sensitive to exposure to governance uncertainties related to the repatriation of profits and to corruption issues more than other common components of governance uncertainty. In these sensitive cases, firms tend to invest more into unconventional and green technology fields.

The research contributes to a better understanding of the role of uncertain governance environments with regard to technology and innovation decisions, which is especially pertinent for the current situation in many MENA states. We show that uncertainty does not impede innovation. Rather, companies adapt to uncertain environments by diversification of technology portfolios and innovation and thus they enlarge their strategic options for the future. For the upstream oil industry, governance uncertainty seems to function as a lever that also triggers entry into radically new fields, notably green and renewable technologies. 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 (for example, the dependence of certain sectors on Chinese manufacturers).

THEORETICAL BACKGROUND

Governance Uncertainty

Kauffman et al. (1999) refer to a country's governance or institutional situation, which they define as traditions and institutions by which a country's authority is exercised. This includes (1) how governments are selected as well as indicators such as political accountability and stability (Kauffman et al. 2002) and political risk (Asiedu 2006; Alessina et al 1996); (2) governmental effectiveness expressed through indicators such as quality of bureaucracy or regulatory quality (Kauffman et al 2002); (3) respect for the political institutions, expressed for example in the rule of law (e.g. the enforceability of contracts (Kauffman et al 2002)) as well as the degree of corruption (Kauffman et al 2002; Asiedu 2004).

Environmental variables such as these constitute the framework in which economic activities and actions take place and therefore matter for business and investment decisions (Brunetti and Weder 1998; Wei 2000). However, the governance environment in many countries presents managers with high uncertainties that make it impossible to assign probabilities, as known from risk management, concerning future states (Milliken 1987) and future events in certain locations. In this context, it is difficult to predict the effect (Milliken 1987) of events linked to governance uncertainty on the organization. Scholars have shown empirically that the general governance situation is a key factor influencing investment decisions. For example, Hennart and Park (1994) find that the interplay of governance and strategy variables influences FDI of Japanese manufacturers. Globerman and Shapiro (2003) propose that good governance is positively correlated with FDI. Jensen (2003) uses cross sectional and longitudinal data and finds that democratic political systems attract significantly more FDI than authoritarian regimes.

Different components of governance have been studied in detail—such as strength and impartiality of the legal system, popular observance of law, strength and quality of bureaucracy and government stability in host countries—and have proven to have a crucial effect on FDI decisions (Mishra and Daly 2007). Concretely, instabilities and uncertainties concerning the general governance situation have shown to have deterring and negative effects on investments by globally active companies (Asiedu 2006, Busse and Heffeker 2007, Schneider and Frey 1985), because factors that are external to the firm such as *governance uncertainty* may change the value of investments regardless of organizational actions (Pindyck 1993) which may lead to increased costs and reduced benefits. In this context, scholars find that within uncertain environments, management becomes more costly (Dundas and Richardson 1980), as it requires increased degrees of organizational differentiation and integration, as well as high organizational flexibility and adaptation. This raises organizational costs, such as transaction, coordination and bureaucratic costs (Jones and Hill 1988). Moreover, the opportunity costs of deploying resources, are very sensitive to what Pindyck (1993) terms *input cost uncertainties,* and firms—especially when faced with projects that include irreversible large sunk costs—may be quite reluctant to make these investments (Dixit and Pindyck 1994).

Uncertainty and Innovation

Research suggests that firms will be more innovative and open to explore new technologies and business fields to offset negative consequences from environmental uncertainty (Damanpour and Gopalakrishnan 1998). Research has focused much attention on external threats stemming from innovation and technology changes—based e.g. 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). Empirical research reveals that innovation, in this context, holds an important role as a strategic response. Firms with high levels of technological capabilities tend to use innovation activities proactively to adapt to increased market competition, and technological change to counteract potential organizational decline (such as, declining profits, negative cash flows, loss of market share, decrease in share price, bankruptcy, and organizational death (Greenhalgh 1982)) (Mone et al. 1998).

In this sense, innovation allows firms to enter technical subfields (Mitchell 1989) based on new knowledge (Tushman and Anderson 1986) and not having been used in previous processes or products (Roberts and Berry 1982), which enables the creation of emerging and promising markets (Shane and Venkataraman 2000) within their existing business. Moreover, it also allows firms to enter new technical fields within new markets other than their core business, which have previously not been targeted and which are thus unfamiliar to firms in terms of characteristics and business patterns (Roberts and Berry 1982).

Regarding uncertainty stemming from the political and institutional environment, scholars have extensively studied regulatory uncertainty. To date, the debate is open as to how far regulatory uncertainty affects technology decisions of firms. On one hand, research frames those regulatory uncertainties as opportunities rather than as threats, and shows how proactive strategies can help firms improve their competitive position (Hart 1995; Aragon-Correa and Sharma 2003) by, amongst others, increasing production process efficiencies (Porter and van der Linde 1995), and finding different applications in new technology and business contexts for firm-owned resources (such as pollution prevention and ecological production: Berchicci and King 2007). In this way, firms can benefit from cost savings (e.g., reduced legal liabilities: Sharma and Vredenburg 1998) and improve their competitive advantage. On the other hand, research argues that a lack of regulatory control increases uncertainty concerning future pay-offs (Bittlingmayer 2001), creates major planning insecurities (Marcus and Kaufman 1986), and prevents the development of long-term perspectives and strategies (Paulsson and Malmborg 2004). Against this backdrop, managers are likely to postpone irreversible investment decisions and wait until regulatory uncertainties have been resolved. Uncertainty concerning the political institutional system has not received much attention in the context of technology decisions. Governance uncertainty may constitute a serious threat to firms in connection with dependencies (e.g., natural resource access) wherein companies are restricted in their autonomous actions. Environmental uncertainties of that and other kinds are seen as an important antecedent to technology development when they present a threat to a firm's core business and put the revenue base of that company at stake (Mitchell 1989). In that case, firms invest early in new technologies to extend their business activities into areas unaffected by previous uncertainties and to protect their competitive positions and profits (Schoenecker and Cooper 1998). We expect that this is the case for their core business as well as for activities within new and unfamiliar business areas. From this follows:

Hypothesis 1: In portfolios exposed to higher levels of governance uncertainty, firms will exhibit higher levels of diversification into new technical fields within their existing core business and within new business areas.

However, research also shows that decision outcomes of managers differ greatly regarding the nature of uncertainty. Schrader et al. (1993) distinguish between *uncertainty* and *ambiguity*, in which the former refers to a situation where decision makers understand the structure of a problem but lack information regarding the values attached to relevant variables. The latter refers to a situation in which decision makers are confronted with a lack of clarity about potentially relevant variables for a problem as well as a lack of clarity with regard to the functional relationships between the different variables (Schrader et al. 1993). The governance situation affecting present operations fulfills all criteria of "uncertainty" because possible problems stemming from the political and institutional system as well as relevant players are known and understood, but no probabilities can be attached to relevant variables (Schrader et al 1993). With regard to existent governance uncertainty, we expect firms to react as predicted by previous research (see hypothesis 1).

On the contrary, when governance uncertainty is of potentially long duration and poses a threat to a firm's long-term operations and assets (for example newly discovered and exploitable oil fields) the situation may be different. In this case, governance uncertainty refers to challenges stemming from future social and political constellations and factors that are not yet known. In this context, managers lack knowledge regarding the future structure of the political and institutional system and of all potentially relevant players and variables involved. Moreover, decision makers cannot determine relationships between potential variables (Martin and Meyerson 1998). This situation is ambiguous (Schrader et al 1992) and unforeseeable (Sommer and Loch 2004) regarding future outcomes and the time until or whether these outcomes may affect the company negatively (Ahlbrecht and Weber 1997). Research suggests that managers present biases when it comes to decisionmaking under conditions of lack of accurate knowledge and information (Kahneman et al 1982). When the situation is distant and highly uncertain (Wade-Benzoni 1999), decision makers tend to irrationally discount the future (i.e. they give less importance to future costs as well as benefits than to current ones). This bias leads managers to more heavily weigh short term external threats and to restrain from investments into projects that offer solutions with deferred returns (Bazerman and Hoffman 1999). From this follows:

Hypothesis 2: In portfolios exposed to higher levels of long-term governance uncertainty, firms will exhibit lower levels of (a) diversification into new technical fields within their existing core business, and (b) diversification into new technical fields within new business areas

CONTEXT: THE CASE OF THE UPSTREAM OIL INDUSTRY

Our research analyzes responses of upstream oil companies to regulatory uncertainties. The core business of these firms is oil and gas extraction and refining, and their business model relies on petroleum sales (Stabell 2006). For upstream oil companies, natural resources are not a simple production input and resource advantage (Hitt and Ireland 1985). Instead, they represent a key factor of strategic importance (Amit and Shoemaker 1993), as an oil firm's financial valuation is very much contingent on long-term resource perspectives and reserve replacement. That means that current resources and future reserves are critical inputs into the determination of financial results and an important measure for company performance. In fact, the value of a firm is driven by how many resources the firm can extract from the ground now *and* in the future. Company activities concerning exploitation of currently available resources and exploration of future resource potential, are reflected in their different areas of operational performance: production (indicates the current oil and gas production situation), reserves (estimates about the future size of hydrocarbon reservoirs as well as their recoverability), exploration success (productive new wells recently discovered and drilled), as well as oil rights (which are contractual agreements between host countries and companies that fix the conditions of resource exploitation, see Table 1).

Access to natural resource deposits and further biophysical availability of natural resource stocks are vital for companies' sustained competitive advantage and performance. Governance uncertainty can negatively affect the core business when it interferes with access to, ownership, and operations of resource deposits and/or complementary facilities (Stabell 2006). Concerning the biophysical availability of resources, empirical evidence shows that the effective natural resource base has increased or remained stable over time due to technological advancements that have enabled discoveries of new deposits and made use of lower grade ores possible (Brown and Wolk 2000). In this sense, technological development seems to have compensated for a natural depletion of resource stocks. Moreover, most oil reserves are presently held by national oil companies (60%), whereas international oil companies have equity access to only 24% of the world‘s oil and gas reserves (Marcel 2006).

The ability of firms to preserve the level of their overall natural resource endowment is central for companies to stay competitive (Parry 1999) and to exploit investment opportunities based on the prospects of their assets (Weston et al. 1999). This undertaking is capital-intensive, requiring resource portfolios with growth potential, as well as significant financial, technical and commercial capacities. Firms have tried to efficiently increase their resource base and access to acreage through structural changes in the industry, notably through mergers and acquisitions (M&A). Especially since the 1990s, there has been an accelerating rate of M&A activity in the industry, the most visible result of which was the 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). Table 2 sketches the most important changes which took place between 1971 and the year 2000. The gains from this strategy are bound to level off because all oil companies face similar challenges with regard to overall regulatory uncertain environments in the area of conventional resource deposits. Firms can also enlarge strategic options in the future while exploiting business opportunities based on innovation in their core business as well as in radically new business fields and the development of fundamentally new capabilities.

Within the upstream oil industry, this refers notably to the development of unconventional technologies and renewable technologies. Unconventional technologies allow for the exploitation of deposits, which are difficult to access and to develop (e.g. natural gas liquids, heavy oil). They require investments into multiple technologies and technological capabilities that typically underpin exploration and production activities (e.g. mechanical, chemical and electronic engineering, materials technology, physical and computer-science based technologies: Acha 2002). Such technological development involves a high degree of technological uncertainty in terms of exploration outcome and costs, as well as with regard to the probability of success of actually extracting oil from the ground. Firms must also invest in capabilities and innovation that build on new knowledge in order to seize opportunities in new technical subfields. In addition, other potential sources of energy could replace petroleum—for example, liquid hydrocarbon fuels and renewable energies like solar and wind power. Here again, alternatives confront firms with radically new technological innovation that builds on scientific methods that are new to companies and are based on an entirely different knowledge area, or present a novel recombination of already existing firm knowledge with new knowledge bases (Hill and Rothaermel 2003). However, investments in unconventional and renewable technologies represent a strategic decision by firms to enter new technological subfields. This allows for timely responsiveness to environmental challenges and the creation of a better fit (Greve and Taylor 2000) between organizations and uncertain environments— it represents a definite change in strategic emphasis (Siggelkow 2002) towards more ecologically sustainable technologies.

METHODS

The Research

We collected data for 13 international oil and gas companies continuously active in the upstream petroleum sector between 1988 and 2008. The analysis focuses on the relationship between firms' exposure to governance uncertainty and their R&D outcome 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 leading global data and information provider in the energy sector, with the most exhaustive information on worldwide exploitation and exploration of liquids and gas. Data concerning governance uncertainty variables and values stem from the International Country Risk Guide (ICRG) data set of the Political Risk Services group (PRS). PRS provides macroeconomic data as well as data on regulatory and political risk and uncertainties. Among various suppliers of various macroeconomic 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 their risk and uncertainty rankings.

The 13 international oil companies studied are Shell, Exxon Mobil, BP, Chevron Texaco, Total, ConocoPhillips, ENI, Hess, Kerr McGee, Marathon, Occidental, Repsol, and Anadarko. For each country in which oil companies of our sample have had operations, values of different components of governance uncertainty were calculated for each year (1988 to 2006): governmental stability, law and order, provision and quality of bureaucracy, repatriation of earnings, democratic accountability, and corruption. ICRG weighs the uncertainty by assigning points to each uncertainty on a scale from 0 to 100, where 100 represents the most certain situation -- ICRG measures uncertainty in terms of degree of reliability. A data set was constructed that linked each country's governance stability values 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). 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). Moreover, these different operational areas represent different operational time horizons in terms of performance. Production has a short-term perspective, whereas exploration success, for example, does suggest that firms can expect economic returns in the future as a result from their exploration efforts through sales of the exploration prospects or sales of the future development rights, or the future exploitation of the resources. However, it is difficult in all cases for companies to define when and to what extend economic benefits will appear. Exploration success therefore has more of a mid-to long-term time horizon until economic returns show up. We link this information to data concerning data on their technological portfolios as evidenced by their patenting and publications in various technological domains. Patenting is a means to appropriate technological advances as well as firms' signals of their perceived technological strengths and advantages. Publications are the outcome of scientific activities that may indicate early moves into a technological field and the construction of firm capabilities.

Variables

Governance Uncertainty

This paper analyses a range of dimensions of the (un)certainty of the political and institutional environment (Brunetti et al. 1998), or in other terms, the governance situation (Kaufmann et al. 1999) and intends to pinpoint their relative importance for technology decisions of firms. In line with the dimensions as defined by Kaufmann et al. (1999) as well as research on efficiency of institutions for investment decisions (Gastanaga et al. 1998; Wei 2000), we specifically address *governmental stability, law and order, provision and quality of bureaucracy, repatriation of earnings, democratic accountability* and *corruption*.

Governmental Stability. Political economists show empirically that countries facing frequent governmental changes display significantly lower growth than countries with governmental stability (Alesina et al. 1996). These countries may have a reduced level of uncertainty when it comes to executive changes, as these are expected, however uncertainties with regard to policy changes remain high especially when the composition and characteristics of successor government are unclear. These uncertainties regarding future policies (Brunetti and Weder 1998) have deterring effects on decisions of economic actors especially with regard to resource deployments (Barro 1998), investments and savings (Alesina et al. 1996). Risk averse companies may refrain from investment decisions. Similar effects are expected for foreign investors that are likely to prefer more stable political environments (Alesina et al. 1996; Papaioannou and Siourounis 2008).

Law and Order. "Law and order" or the "rule of law" refers to the strength and impartiality of the legal system and popular observance of the law (PRSGroup 2009). The rule of law assures an efficient and transparent legal system that includes judicial institutions capable of protecting property rights and enforcing regulations, which requires substantiated political institutions, a fair judicial infrastructure, and independent and strong courts (Campos and Kinoshita 2003). Countries with an efficient and effective legal infrastructure attract more investors as transaction costs between economic actors are expected to be low, compared to an inefficient legal system that raises transaction costs for economic actors and engenders higher investment costs (Campos and Kinoshita 2003). Weak legal systems create uncertainty and mutual insecurity between market participants regarding the enforcement of contracts (Perry 2000), inconsistent administration of property and contract laws, and regarding governments that can reconfigure commercial rules at their disposition, which reduces the likelihood of companies to commit resources and to invest.

Provision and quality of bureaucracy. La Porta et al. (1998) measure bureaucratic quality in terms of "good governance" outcomes. However, bureaucracies evolve in different cultural and historical contexts and therefore vary from country to country (Barzely and Galego 2010). A well functioning bureaucracy works as an absorber of uncertainty (O'Toole and Meier 2003) that roots in unanticipated and/or potentially disruptive political situations, by means of standard operating procedures, reliance on certain rules, operational criteria of consistencies (O'Toole and Meier 2003). It assures continuous governing without interruption in services. Bureaucracy upholds government functions even under drastic regime or government changes. Countries with weak bureaucracies experience policy change as traumatic for policy formulation and administrative services (PRSGroup 2009). Efficient bureaucracy is an important institution underlying the local business environment and contributes in combination with other political institutions to attract investments (Campos 2003).

Repatriation of earnings. Firms that invest in foreign countries want to make profits abroad and be able to repatriate them to their home countries or move the earnings to a different country. There is no automatic right to repatriation as it is the host country that decides. Changes in governments or in government policies as well as extraordinary circumstances may lead to problems with regards to repatriation. For example, Argentina faced problems with exchange shortfalls and faced the collapse of its currency, the *peso*, in 2002. The government previously allowed totally free repatriation and profits. However, in the aftermath of the crisis the government decided that all pre-existing contracts become "pesofied" and devalued at the post-crisis rate of exchange. Uncertainty arises when governmental policies with regard to repatriation and control of foreign assets stay opaque or undergo sudden changes due to unstable political, social and economic conditions. Research claims that restrictive and opaque policies with regard to repatriation impede foreign investment (Rugman 1979).

Democratic accountability. Political economists argue that democracies are more credible with regard to protection of property rights than dictatorial regimes (North and Weingast 1989; Olson 2000). Greater checks and balances in the form of multiple veto players (e.g., supreme courts, federal governments, separation of executive and legislative: Henisz 2000), as well as the fact that democratic leaders are held accountable for their actions (e.g., when reneging promises) and may face electoral backlashes impose greater constraints (Harms and Ursprung 2002; Jensen 2003) on potential predatory behavior (e.g., expropriation: Li 2009). Empirical research supports the fact that companies are more likely to invest in countries with high democratic accountability (Jensen 2003, Busse and Hefeker 2007).

Corruption. Corruption generally describes the abuse of public authority for private benefit (Uhlenbruck et al. 2006); when public officials have discretionary power over access or distribution of resources to the private sector (Rose-Ackerman 1999). According to Transparency International, corruption has increased during the financial crisis within Africa, North Africa, and the Middle East, as well as newly independent states of the former Soviet Union with up to 56% of the people paying bribes. However, research shows that countries that are well endowed with natural resources have also been subject to high levels of corruption under less economically tense conditions (Lane and Tornell 1995). This may be so because politics in many of these countries relies on the rents earned from resource exploitation, which often leads different fractions of society to compete and fight for shares of the resource rents (Sachs and Werner 2001). Corruption leads to political and macroeconomic uncertainties, when, as Shleifer and Vishny (1993) show, the availability of rents from natural resources lead to more rent seeking behavior and competition in terms of rent distribution between different tribes and ethnic groups. Moreover, corruption often presents more promising opportunities to make money than productive work, which attracts highly talented people to also engage in rent seeking (Murphy, Shleifer and Vishny 1991). Finally, corruption has been shown to lead to inferior public infrastructure when corrupt agents are responsible for public procurement contracts as well as to ineffective governmental spending when government officials prioritize expenditures that promise interesting bribes (Mauro 1996). For firms, corruption bears numerous direct and indirect costs (Fisman 2001). Managers are aware that parts of their profits may be claimed by corrupt agents in the form of bribes (Mauro 1996). They therefore perceive corruption as a tax with high uncertainties in terms of transparency, illegality, and need for secrecy (Shleifer and Vishny 1993). This uncertainty decreases the incentives to invest as research on foreign direct investment has shown (Bhardan 1997) and pushes firms to lower risk exposure in the form of non-equity entry strategies (Uhlenbruck et al. 2006) to adapt to the uncertain and capricious environment (Uhlenbruck et al. 2006).

Governance Uncertainty is measured in terms of governance stability. For each country in which oil companies of our sample have had operations, an uncertainty value was calculated for each year 1988-2006. This value is based on a measure derived from the International Country Risk Guide (ICRG) data set of the Political Risk Services group (PRS). The ICRG data cover 12 political, socioeconomic, and commercial risk components (see Table 1). 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 governance situation (PRSGroup 2009).

--- Please insert Table 1 about here ---

A data set was constructed that linked each country's governance 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). 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 governance uncertainty ratings (see Table 2).

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Innovation in technology 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 technology and innovation management research (Rosenkopf and Nerkar 2001) to determine the scope of capabilities of firms and 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. In this paper, we refer to two categories.

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First, we refer to technologies that fulfill the criteria of technical subfields (Mitchell 1989) but are related to the current upstream core business, notably technologies for "unconventional" oil and gas search and exploitation (e.g., tar sand, shale oil). Developing fossil fuels from these sources requires capabilities that are different from traditional oil and gas exploitation techniques. Second, we refer to a category that corresponds to renewable energies technologies, which we relate to new technical fields within new business areas.

Patents. We used the same technology categories identified for the publications and based on the Petroleum Abstracts classifications. 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.

Control variables: We control for the influence of the oil price as well as the size of the company on technological diversification. Moreover, we include vertical integration, as empirical research shows that different degrees of firm integration significantly affect firm behavior and the allocation of organizational resources (Mullainathan and Scharfstein 2001). For example, Mullainathan and Scharfstein (2001) examine integrated and nonintegrated chemical manufacturers and their investments in production capacities. They find that integrated companies are more internally oriented with regard to capacity building and that they do not pay much attention to external market demand changes. Instead, their capacity depends mainly on their internal demand–in this case for vinyl chloride monomer (VCM) for PVC production–largely ignoring changes in external demand for the product. Based on these findings, we may also expect differences in behavior between integrated and non-integrated oil and gas producers within the upstream oil industry with regard to (natural) resource capacity building. We gathered information on whether each of the companies in our sample engaged in business activities that employ oil or gas as inputs for further production (Fan and Lang 2000). We created a proxy measure for which we coded a 1 if the firm had further business activities of that sort; otherwise, we coded a 0. Companies that have midstream activities but no downstream activities are coded as 0 as well. The reason for this is that midstream activities involve only the transportation of natural resources from the extraction sites to refineries. Even though these activities are processes that require highly technical capabilities, these firms are not involved with refinery products or energy generation. We then created a vertical integration measure for each firm in each year.

Modeling: To test the direct effects of hypothesis 1a and b, we use fixed effects and random effects panel data models. Random effects models 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 16 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 various governance uncertainty variables.

RESULTS AND DISCUSSION

In our analysis and discussion, we focus on the maximum value of governance uncertainty that firms had to encounter within a certain year in their portfolio. In other words, when firms had production sites in three different countries, our analysis indicates that technological diversification actions are associated with the riskiest site in which they are operating. It could be that managers "over-weight" the worst case, perhaps exaggerating the risk they perceive, perhaps being prudent by hedging against the worse case.

Our data show a direct relationship between governance uncertainty and innovation. It demonstrates that higher overall governance uncertainty gives firms incentives to adjust by engaging in technological capability development as well as innovation to broaden their strategic options. Firms in our sample appear to be susceptible to uncertainties that affect long-term operations and assets (newly discovered oil and gas fields) as well as reacting to uncertainties in areas in which they currently produce (assets exploitable now or in the very short term). This supports Hypothesis 1, but contradicts hypothesis 2a and 2b that assume that managers do not respond with investments into new technologies (within their core business or within new markets) because of decision biases that focus on short-term threats. Instead, we can observe a strong trend that companies respond to short-term threats with long-term solutions and to long-term threats with short-term solutions. Concretely, companies tend to respond with investments into renewable energy technologies (new technologies within a new business) and a strategy of long-term diversification into green technologies (as evidenced by patents and publications) when they are faced with threats to their current production. On the other hand, companies tend to react more strongly with investments into unconventional technologies within their current business and remain in the current technological paradigm in response to long-term threats in areas of exploration success.

Firms' strong tendency towards investments into renewables in the face of uncertainty that threatens current assets is interesting, as it is a technology field and business field they are unfamiliar with (Roberts and Berry 1985) and in which they still must acquire and develop capabilities, assets, markets and relations, and outcomes in this field are less certain than within their core business. It most likely has a long development horizon and may prove an inadequate solution strategy for immediate uncertainties and threats. However, their overall response strategy is long-term oriented—patenting alone has a time frame of 3-5 years with the patent lag and returns from the patent at least two years beyond that. Publications strategies have time spans from 5-10 years. For the upstream oil industry, overall, governance uncertainty seems to function as a lever that triggers entry into radically new fields, notably green and renewable technologies.

Regarding the different dimensions of overall regulatory uncertainty, we find that managerial sensitivities with regard to the six analyzed uncertainty dimensions vary. In descending order they react most sensitively to (1) repatriation of profits, (2) corruption, (3) law and order, (4) bureaucratic quality and finally to (5) democratic accountability and (6) governmental stability. The last two items appear to be "irrelevant" (not salient) with "government stability" showing no significant association with firm innovation activities. Bureaucratic quality and law enforcement show no results for renewable technologies, however, governance uncertainty in these areas correlates with increased investment in unconventional core business technologies. Results for repatriation of profits were not surprising: Repatriation of profits is clearly a key factor that influences decisions on foreign direct investment (FDI) and determines whether FDI turns out to be profitable. Markets with liberal laws concerning profit repatriation and low trade barriers are therefore more attractive to investors. However, the strong impact of corruption, which is defined as the abuse of public power for private gain, seems a bit surprising. Companies in our sample that were exposed to high levels of corruption on average tend to publish and patent more in unconventional areas and patent more in renewable energies. In the literature, the role of corruption with regards to innovation seems ambiguous: The metaphor "sand versus grease" (Meon and Sekkat 2005) characterizes this contradiction, where on one hand, corruption is claimed to hamper investment as it causes additional and higher costs and uncertainties, and on the other hand, corruption may actually help to bypass ineffective regulation and institutions and thus compensate for additional costs and uncertainties. With regard to innovation activities in particular, corruption is usually regarded as having deleterious effects on outcomes as it renders market competition less relevant: Corrupt firms spend their resources on bribes rather than on innovation and un-corrupt firms have no incentive to invest in innovation as they cannot be sure to appropriate the profits from their effort. Corruption is also thought to render access to market of newly developed products unlikely (Anokhin and Schulze 2009).

Although oil and gas companies are fairly independent from corrupt host countries when it comes to R&D and innovation activities, corruption does affect their operations negatively, and it appears that it might motivate them to find solutions that render them more independent from corrupt environments. The situation is not likely to change very quickly as major energy companies hold large parts of their portfolios in countries more often associated with higher corruption rates. In fact, many resource-rich countries seem prone to continued corruption as reliable democratic control institutions may not always exist to control governments that try to profit from resource windfalls. It could be that managers are sensitive to the corruption itself, or it could be the perceived volatility or reliability of the corrupt system: "paying bribes to an unstable or unpredictable government, on the other hand, requires a leap of faith and a quick exit strategy" (Fisman 2011).

In summary, governance uncertainty does not appear to impede the upstream oil companies from innovation. Instead, firms adapt to particular aspects of uncertain regulatory environments by diversification of technology portfolios and innovation and therefore enlarge their strategic options for the future.

IMPLICATIONS FOR PRACTITIONERS

Scan the environment for strategic technological options in addition to financial ones. Especially for firms whose core business is exposed and vulnerable, instant solutions (traditional risk mitigation strategies and financial hedges) will not resolve the fundamental threats. Instead managers may want to go beyond these approaches and scan their environments for alternative strategic options in technology fields that they can enter to become less exposed and vulnerable with regard to regulatory uncertainties. By investing into new technological subfields, firms secure the value of their resources and capabilities for continuous deployment in areas of long-term strategic potential. To concurrently invest into new market niches and to exploit current core businesses seem to provide companies with a better balance between hedging against the risk and generation of profits. Under this backdrop, response choices can be seen as real options: an investment in real assets similar to financial options but applied to managerial decisions (Dixit and Pindyck 1994). Companies do not need to make huge investments to buy flexibility in response to threats. Because of the sequential nature of most investments, it is possible that, based on additional information gained throughout the development process, some of these investments will be abandoned as they become financially unattractive (Amram and Kulatilaka 1999).

Match the time frame of the uncertainty with the time frame of the solution. It appears that companies in our sample are responding with investments into long term diversification when they are faced with relatively short term uncertainties, which is consistent with cognitive research (for example, discounting the future). However patenting strategies cannot resolve a short-term problem, especially when the increased effort is in such a distant business area as renewable technology. "Threat to core business" appears to be a central motivator that may induce firm entry into new technical subfields. Research on the minicomputer industry showed that entry timing was reduced by three years compared to R&D activities that hastened entry only by four to five months (Schoenecker and Cooper 1998). Pre-production knowledge (Carrol et al. 1996) and experiences in related fields (Klepper and Simons 2000) have substantial influence on post-entry success and performance of firms: experienced firms enter earlier, survive longer and gain larger market share. Successful diversification into fields such as renewables require a long time horizon for research, market development, and business relations to be established, and may therefore not prove a suitable response for short-term challenges. Firms may do better aligning the time frame of the uncertainty and the threats derived from it with the time frame of the solution.

Consider different dimensions of governance uncertainty. In a 2010 Ernst & Young study on the top risks for oil and gas companies four out of the top five items were related to regulatory and governance uncertainty: (1) uncertain energy policy, (2) access to reserves, (4) worsening fiscal terms, and (5) climate concerns. In this study, we have analyzed different dimensions of governance uncertainties to find out if companies reveal higher salience with regard to particular dimensions of regulatory uncertainty. Our analysis shows that companies tend to react to repatriation and taxation issues, corruption, and to a much lesser degree to law enforcement and other traditional dimensions of regulatory uncertainty. While it is important to maintain simple heuristics for decision-making, we speculate that the focus on one or two components may lead to missed opportunities or expose firms to unnecessary risks. This speculation was also borne out in interviews with industry experts.

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ANNEX

Table 1: 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
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
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	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. Oil Rights 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.

Table 2: Oil Industry Change

1971	2000
Esso	Exxon/Mobil
Royal Dutch Shell	Royal Dutch Shell
British Petroleum	BP-Amoco-Arco*
Chevron	ChevronTexaco
Gulf Oil**	
Mobil	
Compagnie Francaise des Petroles	TotalFinaElf

*now renamed BP

**disappeared

Table 3: Descriptive Statistics

Variable	Obs	Mean	Std. Dev	Min	Max
Patents Renewable	300	88.97333	114.8717	0	623
Patents Unconventional	300	102.73	119.6006	0	464
Publication Ecology	300	0.8433333	2.014692	0	18
Publication Renewable	315	3.101587	6.008155	0	60
Publication Unconvention	315	1.126984	2.457875	0	18
Bureaucratic Quality (Exploration Success)	217	32.94931	22.69048	0	100
Corruption (Exploration Success)	217	32.31567	19.13622	0	100
Democratic Accountability (Exploration Success)	217	33.50615	25.19953	0	100
Democratic Accountability (Production)	275	28.45455	23.92636	0	100
Government Stability (Exploration Success)	217	59.2742	16.03735	25	95.8333
Law Enforcement (Exploration Success)	217	43.8812	21.31104	16.6667	100
Law Enforcement (Production)	275	36.01166	25.81026	0	100
Repatriation (Exploration Success)	217	47.08621	21.65424	12.5	100
Repatriation (Production)	275	43.77273	23.5524	12.5	100
Number of Employees	209	43661.12	38938.24	1000	129955
Oil Price	315	29.32714	22.79325	11.82	104.43
Production	269	476.9	415.0194	9.59	2237.88

Table 4: Linear Regressions, random effects models

Variables	Model 1 Patents Renewables	Model 2 Publication Renewables	Model 3 Patents Renewables	Model 5 Patents Unconv.	Model 6 Publications Unconv.	Model 4 Patents Renewables	Model 7 Patents Unconv.	Model 8 Publications Unconv.	Model 9 Publication Renewables	Model 10 Patents Unconv.	Model 11 Publications Unconv.
Repatriation (Production)	(0.0129***)	(0.01943***)									
	0.0031	0.064									
Repatriation (Exploration Success)			(0.0063***)	(0.00481**)	(0.01912**)						
			0.00254	0.00225	0.00972						
Corruption (Exploration Success)						(0.0048*)	(0.0062***)	(0.0142*)			
						0.0027	0.0023	0.0081			
Law Enforcement (Production)									(0.0141**)		
									0.0065		
Law Enforcement (Exploration Success)										(0.031*)	(0.033***)
										0.018	0.079
No. of employees	5.21E-06	5.42E-06	6.44E-06	7.89E-06	0.0001	6.82E-06	2.24E-06	0.000013	-4.20E-06	7.86E-06	0.0001
Oil price	-0.514	0.006	-0.319	-0.04703	-0.2307	-0.0359	-0.0542	0.0061	0.0061	-0.0551	0.0058
Total Production	.00023	0.002	0.002	0.00019	0.0013	0.002	0.00017	0.0011	0.0034	0.0013	0.0096
Constant	3.8048	2.2905	2.421	2.8329	2.3122	2.43	3.18	-0.267	1.449	3.211	4.594
Observations	198	198	191	191	191	191	191	191	198	191	191
No. of companies	15	15	15	15	15	15	15	15	15	15	15
Prob.	***	***	***	***	***	***	***	***	***	***	***
WaldChi2	193.99	56.57	178.18	182.58	62.48	168.73	183.15	63.47	51.98	178.82	98.55
Loglikelihood	-779.4533	-331.35	-774.092	-781.575	-196.823	-775.641	-780.496	-197.364	-333.567	-782.589	-190.516

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