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Analytical Models to Characterize Trade-Offs Between Technological Upgrading and Innovation

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ABSTRACT

The authors propose two analytical models to characterize the relationship between technological upgrading and innovation in the oil and gas industry. The first one is an "optimization model" which focuses on the trade-offs between profit maximization and environmental compliance cost. The other has been developed based on "predator-prey" model which captures the dynamics of biological systems. The study contributes to the strategic planning process for sustainable development by providing the insight that optimal allocation process is determined by multiple operational factors, including a firm's competitive ranking among its industrial competitors, industrial consent on the concurrent rate of return on capital investment, the projected demand of oil and gas in future, and a change in environmental compliance cost. Further, the authors add to the robustness of the optimal allocation process by providing binding conditions of the set of solutions.

KEYWORDS

Capital Investment, Corporate Social Responsibility, Environmental Protection, Strategic Planning, Sustainable Development, Technological Advancement

1. INTRODUCTION

The oil and gas industry is vital to the United States (U.S.) economy supporting nearly 10.3 million jobs in the US and nearly 8% of the nation's gross domestic product (American Petroleum Institute [API], 2018). The oil and gas industry spurs global economic growth in both developed and developing countries by supplying 57% of the commercial energy between 2015 and 2018 (British Petroleum, 2019). Approximately 10% of the value of the world's stock markets is invested in the oil and gas industry (Deloitte LLP, 2015). To continue to support and expand the industry, the oil and gas trade operates by engagement of exploration, production, refinery, storage, transformation, marketing and serving activities. However, recent degradation of the natural environment raises concerns among corporate America and in turn, companies are starting to realize that sustainable development is the unmistakable pathway for all firms who are currently leaving irreversible environmental footprints on Earth (Bhowmik et al., 2000, J. Gonzalez-Benito & O. Gonzales-Benito, 2005, Yurtsever & Firat, 2019). Industrial companies such as those in the oil and gas industry are, to a great extent, responsible for this degradation and must strategically aim to enhance their corporate social responsibility by going beyond profits (Arya, et al., 2019; Tung, et al.,2014). While governments hold primary responsibility to prioritize and incentivize while promoting sustainable development and growth, the private sectors

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and civil societies are critical stakeholders to carry on (Carmichael, 2019; Geels, 2002; Geels, et al., 2017; Nelson & Allwood, 2021).

The historical technological advancement in the oil and gas industry has always been accompanied with systematic industrial changes. America's oil and natural gas industry spends an average of $227 billion in investment on America's infrastructure annually (International Energy Agency [IEA], 2020). According to Deloitte LLP (2015), investments in the oil and gas industry range from "mega" to "minor". For example, Deloitte LLP (2015, p.14) reports "as of March 2014, the world's four biggest super-major oil and gas companies were spending roughly 40% of their capital budgets on megaprojects (those with capital investments of $1 billion or more)". Notably, it mentions that a full 50% of 40% of the capital budget goes to technically complex projects, such as the Gorgon LNG project in Australia, the Pearl GTL project in Qatar, the Kashagan project in the Caspian Sea and the Sakhalin project in Russia. The remaining budgets go to minor projects such as Integrated Project Delivery (IPD) which aims to improve collaboration across the supply chains, Advanced Analytics Project which relies on "big-data" to identify critical factors in the decision-making process, and other projects which mainly improve process rather than develop breakthroughs in technological advancement. For instance, the depletion of light oil reserves has caused the change in the average crude quality. As a result, refineries had to upgrade their physical plants, properties, and equipment to deal with the low API gravity and impurities problems. The investment decision (i.e., major vs. minor) is a challenging operation issue unavoidable for oil and gas companies (Deloitte LLP, 2015).

The term "sustainable development" in oil and gas industry refers to the sustainability of human existence by carefully balancing social, economic, and environmental capital in a continuously changing world (Gross, et al., 2018; Perkins & Neumayer, 2005; Weyant, 2011). Technologically complex and financially volatile, the oil and gas industry is experiencing tremendous challenges during the sustainable development transformation. The industry has been charged with the responsibility of environmental degradation, including air pollution, acid rain, greenhouse emission, ozone layer depletion and global warming (Hsu, et al., 2013, Zailani, et al., 2012). A challenge in the oil and gas industry and in any heavily regulated sectors which have experienced rapid technological changes and regulation requirements, is the dilemma of how to improve operating efficiencies by balancing profit maximization, while also maintaining environmental protection. Consideration should be taken into account as to if firms should upgrade incumbent, fixed assets to generate quick returns at the cost of relatively high levels of potential environmental hazards or invest in long-term innovative projects in anticipation of becoming a market mover and reduce potential environmental liabilities. Examination of the time it takes for leapfrog technology to become obsolete and whether an optimal mixture between upgrading and long-term innovation/invention effort exists should be considered as well.

Following the anecdotal discussions and extant literature, the authors categorize the investment activities in the oil and gas industry into technological upgrading and innovating. Both upgrade and innovation result in change, and both are attempting to make improvements. Upgrades are typically incremental and an iterative process, as each cycle builds on the previous one. When the incremental approach reaches its limit, some substantial steps must incur to solve a problem the incremental approach fails. This is where innovation plays a role (J. Gonzalez-Benito & O. Gonzales-Benito, 2005; Gotschol, et al., 2014; Gross et al., 2018; Jensen 2001; Kanter, 2011). When original operation plans do not work out as efficiently as they should be, upgrading is a standard action taken by firms to address an obsolete technology or a particular matrix of equipment. This is a less technologically challenging approach that can provide a quick turnaround. It is a replacement process or maintenance or minor elevation process that does not exceed the bound of current technology. Conversely, innovation is a breakthrough of an entire new technology and fundamentally overhauls the status quo of the current production process. Innovation involves developing something or some processes that did not exist in the past or currently. It will significantly improve future productivity or help the firm enter a new marketplace. There is an assumption that upgrading and innovating activities are distinct from each other by defining the timing of returns they can produce, though there is a realization technological

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