MAIN ARTICLE

How do oil prices and investments impact the dynamics of firm value?

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Abstract

The purpose of this study is twofold: (i) to analyze the impact of investment policy decision on the firm value given the uncertain oil and gas prices and (ii) to propose policies that enhance firm value. The study develops a system dynamics model that integrates the financial and operational activities of oil firms. The simulation results reveal that, when oil and gas prices increase, positive future expectations lead to increased investments and reduced cash flows. Greater volume of investments over the firm's current investment policy decreases its future cash flows and the total firm value over the first 20 years of the simulation period; it increases thereafter. To support higher investments, the firm would issue a higher number of shares, and consequently the market price per share would be lower, and vice versa. The simulation results suggest a relatively lower volume of investments to increase the market price per share.

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Introduction

Creating and sustaining firm value is an overriding corporate objective that may help enhance owners' wealth and the wealth of society by maximizing economic output (Gardner *et al.*, 2012). The estimation of a firm's fair market value is the source of fundamental debate in the corporate finance industry (Copeland et al., 2000). Every firm operates in the market to create value for its stakeholders at every stage of its life cycle (Damodaran, 2016). Firms are concerned about their market value for a variety of reasons. First, the market value is a foundation in investment, financing, and many other corporate decisions (Palepu *et al.*, 2013). In particular, investment considerations include the assessment of how such investments impact the firm value in the long term. Value is created from the difference between the capital invested and the present value of the future net cash flows from those investments (Koller *et al.*, 2010). When investments generate higher profits than the cost of capital, the firm value increases, and vice versa. The impact of

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investment policy on firm value is extensively addressed in the literature, and there is evidence of a relationship between the two concepts (Del Brio *et al.*, 2003). This study addresses the research question of how investment policy decisions impact the firm value per share, given the expectations formed regarding the development of oil and gas prices and the uncertainty associated therewith. The findings in this regard will help propose an investment policy that increases the firm value per share.

The investment policy decision significantly impacts the firm value in the oil industry, which is associated with high risk and return (Gardner *et al.*, 2012). The investments in the oil industry are generally huge and enduring, characterized by the features that represent uncertainty, such as longer planning horizon and the irreversibility of the physical capital (Hvozdyk and Mercer-Blackman, 2010). These characteristics are particularly present in the context of the Norwegian continental shelf, in which oil is to be extracted from the seabed resulting from relatively significant irreversible investments. Meanwhile, oil and gas prices that determine expectations about future oil and gas prices and consequent expected return on those investments are associated with uncertainty and cyclicality (Dixit and Pindyck, 1994). Thus, investments and the expected firm value have a direct relationship because stakeholders expect investments to increase the future cash flows and subsequently the firm value (Triani and Tarmidi, 2019). Agency theory (Jensen and Meckling, 1976) discusses the agency problem between managers and shareholders and provides theoretical support for the future cash-flows hypothesis that managers use excessive future cash flows to invest in projects with negative net present value (NPV). Consequently, for firms with high future cash flows, higher investments may lead to a decrease in firm value.

In the context of an oil firm, oil and gas prices impact its free cash flows (FCFs) and the market value. When oil and gas prices are higher, firms have a greater supply of cash, and FCFs are higher (Nåmdal and Meling, 2015). However, an increase in prices also leads to an increase in the volume of investments, which reduces cash flows and leads to a decrease in the firm value in the marketplace. The reverse occurs in this case if prices are low. Oil and gas price expectations are one of the major components in the investment policy decision and the expected cash flows of the firm.

Corporate managers engage in strategic planning to increase and sustain firm value in the long term (Palepu *et al.*, 2013). Strategic planning is the process of translating the corporate objectives into policies that govern resource allocation decisions (Lyneis, 2009), wherein the policy governing investments is key. There are a variety of tools being employed by firms when devising policies in the strategic planning process to increase firm value (Stenfors *et al.*, 2004; Groesser and Jovy, 2016). It is commonly observed that the tools used for strategic planning and policy design are particularly inadequate when dealing with the significant dynamic complexity

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found in the firms and in the economic environment in which they operate (Sterman, 2000; Warren, 2005; Hajiheydari and Zarei, 2013). These tools are inadequate, as they cannot integrate the whole strategic planning process for the firm to assess the causes and effects of the process, and they omit many variables of interest. The resulting disconnect is one of the major reasons for firms' underperformance. This problem could be mitigated by incorporating a systematic approach that integrates the different corporate functions of the firm. Such an approach can help illuminate the interrelationships among the critical variables (Nibouche and Belmokhtar, 2009) by providing a holistic view of the business (Naylor, 1979) and thus lead to effective resource-allocation decisions and improved policies (Wild, 2011).

System dynamics is one such systematic approach (Forrester, 1961) used in this study to develop a corporate planning model for an oil firm (Roberts *et al.*, 1968; Cosenz, 2017). The purpose of this model development is to facilitate an analysis of an investment policy and an assessment of the consequent firm value. System dynamics provides multiple tools that facilitate the modeling of structure and the elicitation of dynamics of non-linear and complex systems (Bianchi, 2010; Cosenz and Noto, 2016). The system dynamics model developed for this study uses Equinor, a multinational oil and gas firm headquartered in Norway, as a case study. The model incorporates integrated financial statements[1] based on the standard accounting principles that provide the rules for reporting and organizing accounting and financial data into financial statements. The system dynamics method allows for the integration of production and financial modules, thus providing an overall view of the business. The integration of financial and production modules provides an engine utilized to test the investment policy and performs firm valuation. This study employs the discounted cash-flow valuation model (DCF) to estimate firm value (Shrieves and Wachowicz Jr, 2001; Janiszewski, 2011). First, the model is simulated to estimate the firm value with the current investment policy of the firm given the role of oil and gas price expectations in the policy formation to assess the current policy. Then, some alternative investment policies are tested to propose future investment policies that better achieve the firm-value-enhancement objective. Oil and gas prices account for the external risks for the company. Operational risks are modelled through delays and nonlinearities involved in the investment and production processes of oil and gas.

The rest of the article is organized as follows. The method and the model structure grounded in the relevant theories are illustrated in the Method and Model Structure section. The Model Validation section builds confidence in the model. The Scenarios and Policy Design section describes the scenarios and policy framework. The results are discussed in the Results and

[1]Balance sheet, income statement, and cash flow statement

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Discussion section, and a conclusion is provided in the Conclusion, Implications, and Limitations section.

Method and model structure

The grounding principle of system dynamics method is that the system's structure determines its behavior (Richardson and Pugh, 1981; Davidsen *et al*., 1990; Sterman, 2000). In our case, this system behavior results in firm performance. System dynamics focuses on the identification and understanding of the causal relations underlying firm performance by integrating resource acquisition and depletion processes in policies designed to enhance that performance (Warren, 2008). To design a well-coordinated set of policies (i.e. a strategy for the purpose of increasing firm value), one must understand the relationship between the structure of the firm and its environment and the consequent behavior of the firm. An understanding of this relationship helps identify high leverage points and influence them in favorable ways (Qureshi, 2007; Ghaffarzadegan *et al*., 2011). Corporate strategies in a static context that do not allow for modeling and testing of the policies' impacts, including their short-term and long-term trade-offs, often lead to the failure of such strategies (Bianchi *et al*., 2015).

The system dynamics model[2] developed in this study has three interacting modules: a financial module, a production module, and a valuation module. The financial module contains all of the firm's key financial accounts and policies. The production module represents the structure that drives the investment and the production of oil and gas. The valuation module represents how the firm valuation is being carried out. Extensive research about the oil and gas industry along with the data obtained from Equinor's annual reports, publicly available information, and the website[3] contributed not only to formulating the organic structure of the model, but also to initializing and calibrating it.

The firms in the oil industry decide their investments and production based on the future projections of prices (Howard and Harp Jr, 2009). The analysis assumes that oil and gas prices are exogenous to the firm and that they are governed by the supply and demand ratio as perceived by the international market. As such, considering Equinor to be a "price taker," our analysis focuses on the firm-specific characteristics and the unique risks that oil firms face (Quirin *et al*., 2000). A detailed description and the associated, simplified stock and flow diagram of each module are given below.

[2]We used Vensim™ software to develop this model.

[3]See www.statoil.com

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The financial module

The financial module integrates the aggregated financial statements, namely the balance sheet, income statement, and cash flow statement (Lyneis, 1980; Yamaguchi, 2003; Qureshi, 2007). Figure 1 depicts a simplified overview of the financial module structure that highlights the key variable interactions in the integrated financial system.

Production, an input from the production module, generates the sales subject to the prevailing oil and gas price in the market. The calculation of sales minus all relevant expenses gives net income before taxes. After paying taxes and dividends, the remaining amount flows into the retained earnings. Capital expenditure is dependent on the desired capital budget subject to the financing available. The desired capital budget is determined by the desired capacity based on future expectations for oil and gas prices and production costs. The desired capacity is an input from the production module. Moreover, the desired capital budget represents the firm's desired investments to build future capacity and for which the internal sources are the first financing choice. However, if the firm requires more capital to meet the desired investment target, external financing is the next option, one that includes external debt and equity. Thus, the actual capital expenditure that flows into investments to create new assets is financed by internal cash flow, new debt, and new equity. The firm utilizes these assets to produce oil and gas based on the corporate strategies and the investment policies devised and employed to meet the future.

The production module

The production module presented in Figure 2 characterizes the physical production of oil and gas into three basic processes: proved reserves, developed reserves, and cumulative production (Davidsen *et al.*, 1990). Proved reserves are those in which one has a high degree of confidence to be produced. Developed reserves are those proved reserves that are economically feasible to extract using existing resources and operating methods. Cumulative production is the total accumulated production over time. The firm invests in order to explore potential reserves beneath the surface, and successful exploration leads to an increase in the stock of proved reserves. After a delay, the time required to develop the reserves becomes the developed reserves, making production possible. The total quantity of oil and gas is finite. As the oil and gas are explored, developed, and produced, the quantity in place depletes, *ceteris paribus* making them costlier to extract marginally. A continuous increase in the cumulative production of oil and gas leads to a reduction in the remaining resource recoverable, resulting in increased marginal-extraction costs. This leads us to model the production costs as a nonlinear function of the cumulative production stock. The quantity of oil

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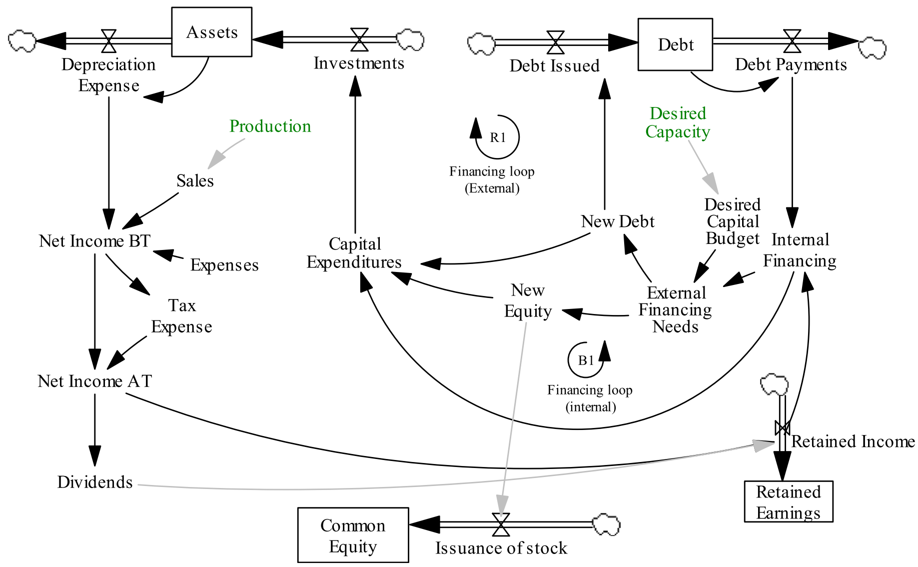

Fig. 1. An overview of the simplified feedback structure of the financial module [Color figure can be viewed at wileyonlinelibrary.com]

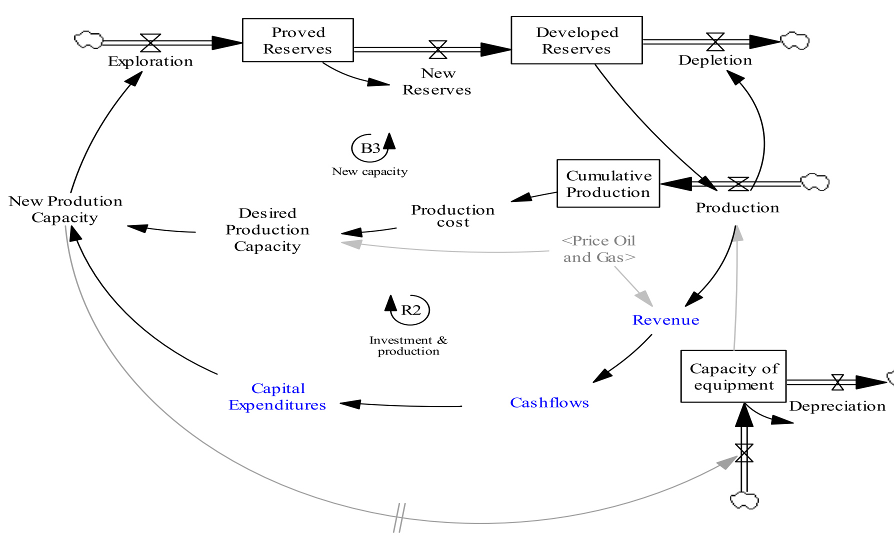

Fig. 2. An overview of the simplified feedback structure of the production module [Color figure can be viewed at wileyonlinelibrary.com]

and gas extracted from the reserves defines production, which depletes the developed reserves. Depreciation is associated with the deterioration of the equipment, reflected in the accounting value development over time in the financial module. Consequently, depletion, depreciation, and expansion add to the need for investment in the exploration and development of new reserves and capacities (Bhaskaran and Sukumaran, 2016). The expectation

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of a high profit margin in the future leads to an increased desire for new capacity that governs the desired capital budget estimate. Capital expenditure that integrates the financial module into the production module is the actual investment made to explore and develop the oil and gas resources and to build and maintain both the existing and new equipment capacities. There are major delays involved in building production capacities in the oil industry. These delays partially explain the discrepancy between demand and supply of oil and gas and the consequent fluctuations and uncertainty (Morecroft John, 2015). This point highlights the interaction between the short-term nature of price fluctuations and the long-term nature of investments in the industry. For the most part, investment decisions consist of three core challenges. First, the return on investment is uncertain (Elder and Serletis, 2010). Second, the investment decision is partially or fully irreversible. Third, the choice of time to invest includes trade-offs among risks, benefits, and costs to invest in partial information or wait for complete information (Dixit and Pindyck, 1994).

Norway is a non-OPEC[4] country and is thus considered an independent producer that produces oil based on commercial criteria. Independent producers' production volume is dictated by the available production capacity, and the main driving force to expand their capacity is the expected profit (Morecroft John, 2015). Thus, the expected profit subject to future price development becomes the basis upon which to determine the desired production capacity and ultimately the investments.

The valuation module

The value of an enterprise is fundamentally determined by the current value of its assets based on their future profitability and potential endogenous growth net of its liabilities (Barlev and Haddad, 2003). Information is at the core of any valuation effort. In this case, investors cannot observe managers' actions, and that leads to an asymmetry in the information held by shareholders and managers (Kennedy, 1997). Accordingly, information asymmetry could influence not only corporate decision-making, but also the firm valuation in the market place (Chung *et al.*, 2015). Agency problem is another prominent factor that affects the inclination and level of disclosure by managers. Agency theory (Jensen and Meckling, 1976) assumes that managers often opt for personal short-term benefits at the cost of the long-term benefits of the shareholders. The investors take the decisions of the managers as market signals that may have a significant influence on the firm value of the marketplace. Less than full information disclosure is otherwise crucial to obtain a better valuation in the marketplace, as it reduces information

[4]Organization of the petroleum-exporting countries

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asymmetry (McLaughlin and Safieddine, 2008). This then leads to different investor behavior from that resulting from access to perfect information (Morellec and Schürhoff, 2011; Shibata and Nishihara, 2011). Furthermore, uncertainty regarding the existence of reserves is also a vital industry-specific factor that can affect the information disclosure offered by the firm (Ani *et al.*, 2015). To reduce information asymmetry among stakeholders, firms provide financial as well as nonfinancial information. We use all such publicly available information not only to develop all three modules, but also to estimate the associated parameters. Potential investors also have access to publicly available information only, and that puts this modeling effort on par with potential investors in terms of access to information.

Various methods aim to determine the best fair value of a firm due to the complexities surrounding it. This study uses a popular approach called the discounted cash flow method (DCF) (Fernández, 2007). The DCF is built on the premise that the capability of a firm to enhance its value relies on its capability to generate endogenous growth and cash flows from its operations. Cash flows are used to finance investment opportunities to materialize growth targets and to distribute the financial benefits to the shareholders. Additionally, the ability of the firm to source external financing is subject to the projection of FCF. Dynamic interaction between the investment and the financial decisions is the key value driver for the firm. The valuation module (Figure 3) is integrated with the financial and production module to obtain an engine used to perform an impact analysis of the investment policy regarding firm valuation. We operationalize the DCF by grounding it on the two major pillars of FCF and discount rate (Benninga, 2008) in the valuation module to estimate the market value of the case firm. The FCFs become available after fulfilling all obligations and can be reinvested, distributed, or retained by the firm. The value of a share or firm today depends on the future cash stream it is expected to generate (Ivanovska *et al.*, 2014). Effectively, the DCF approach calculates the present value of the firm's expected FCFs, thus suggesting that the amount an investor is willing to pay for the share reflects what he or she expects to receive from it over time. For valuation in all types of investment decisions, FCFs are extremely important (Brealey et al., 2011). As the shares have no maturity, the value of the share is the present value of an infinite stream of FCFs. While this can seem quite simple, in practice it is quite complex and requires precise estimation of FCFs, discount rates, and terminal values (Copeland et al., 2000). The firm valuation loop R4 in Figure 3 illustrates the operationalization of the DCF theory. The discount rate is the weighted average cost of capital (WACC) that includes debt and equity. The FCFs are estimated from elements originating in the financial module and depicted as shadow variables in Figure 2. The firm value is estimated using the present value of FCFs and the terminal value. Each new-year value of the discounted FCF flows into the firm-value stock and

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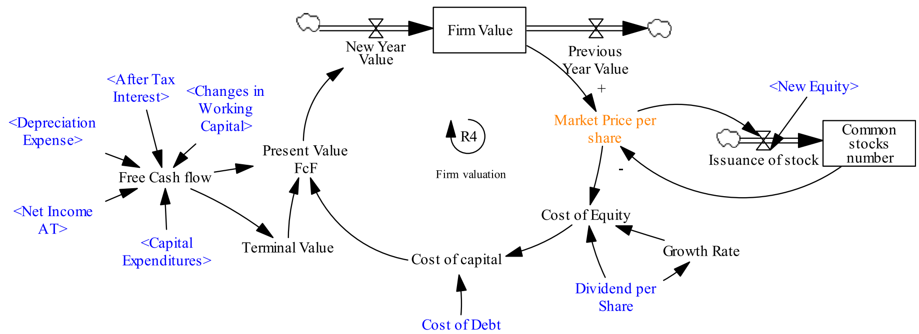

Fig. 3. An overview of the simplified feedback structure of the valuation module [Color figure can be viewed at wileyonlinelibrary.com]

the previous-year value flows from that stock. This ensures accumulation of the firm value based on the latest information available. Market price per share represents the firm value per share and is one of the major factors used to determine the WACC.

The rationale for using the DCF is that the method effectively addresses the firm valuation issue. System dynamics facilitate the modeling of the method by capturing the properties of the system under study. The DCF incorporates the major assumptions and future expectations about the business that have been subject to reality checks and sensitivity tests to ensure robustness and reliability. Another advantage of the DCF is its long-term perspective that uses short-term changes in the market conditions to shape its expectations for FCFs in the long term. The method is also appropriate to use when the objective is to value a single firm, as it does not require any comparable measures and focuses on the valuation of that single firm in great detail (Koller *et al.*, 2010).

Feedback structure of the model

The causal loop diagram, portrayed in Figure 4, reports the major loops driving the behavior of the model. The loops represent the structure governing the interaction of the financial and physical processes of the firm and the firm valuation based on the endogenous variables portrayed in Figure 4. The exogenous input is the oil and gas price determined by the market.

Capital expenditure, being the key variable, leads to dynamic consequences resulting from the interaction of the balancing and reinforcing loops. The investment and production loops (B2, R2) represent the structure underlying the interaction between the physical and financial subsystems. The capital expenditure constitutes the volume of investments into the capacity and reserves of exploration and development. These investments build the assets of the firm after a certain time delay. The higher the investments, the higher the firm's capacity will be the next time. Oil and gas are

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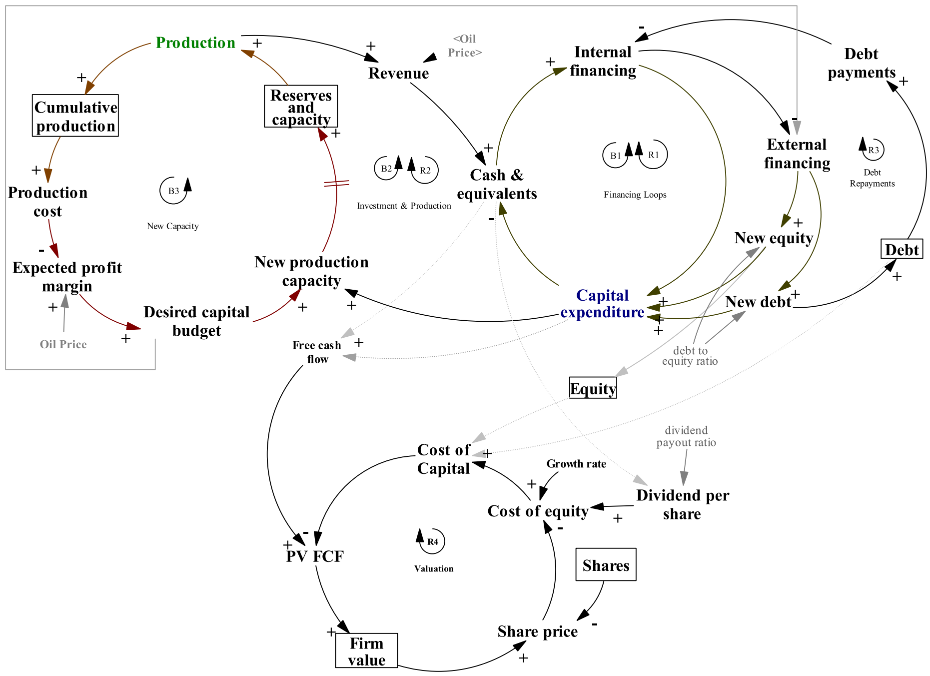

Fig. 4. An overview of the simplified causal loop diagram of the model [Color figure can be viewed at wileyonlinelibrary.com]

extracted from these resources, thus determining the quantity of production. Increased levels of capacity lead to larger quantities of oil and gas production. From the production module, we obtain oil and gas production as the input to the financial module to estimate the revenue based on the oil and gas price in the market. After accounting for all expenses, surplus cash flows constitute the internal financing of the firm. The higher the internal cash flows, the higher the investments closing a reinforcing loop (R2) via internal finances will be. Furthermore, if the firm has a greater internal cash flow available, it would require less external financing and vice versa (R1). Consequently, external capital requirements are estimated to finance the capital expenditure necessary to acquire new production capacity and to increase production after a delay. The investment and production loops summarize the production and financial processes and their interactions.

The production module is summarized by way of the new capacity loop (B3). Capital expenditure is the input to the production module. An increased investment leads to increased capacity. If the capacity is high, it leads to increased volumes of production. Increased production then results in an increase in the cumulative production, indicating a depletion of the resource available. This causes an increase in production costs, as the remaining quantity of oil in the reservoir would have declined and would call for additional capacity to be identified and produced. Thus, given the

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oil and gas prices, one can assert that, as production costs increase, the expected profit margin decreases, thus reducing the desired future capacity, limiting the resource allocation, and balancing the capacity.

Financing (B1, R1) and debt repayment (R3) make up the major loops in the financial module. The firm finances the investments using internal and external sources. Internal sources are the cash flows available from the firm's profits, whereas debt and equity are the external sources. The financing loop (B1) represents the internal finance mechanism. An increase in the revenue results in an increase in FCF, leading to a possible increase in capital expenditure. An increase in the capital expenditure reduces the FCF available the next time. Financing loop (R1) is the feedback process of external finances, debt, and equity. The larger the cash flows are from internal operations, the less external financing the firm needs, and vice versa. The debt finance loop (R3) represents the debt-financing mechanism through which debt payments are made at the cost of internal finances and increase the need for external financing, causing an increased debt level the next time.

Given this financial and physical structure, the firm valuation loop (R4) depicts the DCF valuation of the firm wherein FCFs discounted by WACC constitutes an estimate of the present value of FCFs. Lower WACCs yield a higher present value of FCFs that result in higher firm value and higher share price. Consequently, a higher share price lowers the WACC the next time. This loop highlights the notion that higher valuation leads to higher market price per share. A higher market price per share leads to lesser return on equity, all else being equal. This enables the firm to access capital at a lower cost (Brealey et al., 2011).

Data sources

A system dynamics model is expected to portray and project the behavior of important variables, although point-to-point prediction is not expected (Hadjis, 2011). As a first step towards this purpose, we portrayed the organic relationships in the model described above. Then we estimated the model parameters by using various information sources, such as numerical data and the literature (Ford and Flynn, 2005; Xiao *et al.*, 2017). This includes the firm's annual reports, information available on the firm's website, information available about oil and gas reserves and production processes in Norway, and other relevant but publicly available information. Although it is ideal to estimate all of the parameters on the basis of case-specific information, in reality, limited resources and time constrain the efforts spent on empirical research. Consequently, logic is utilized to estimate the parameters by way of educated guess (Homer, 2012). We gathered all possibly available case-specific information and then utilized the Vensim optimization tool to estimate the appropriate values for some of the parameters to calibrate the

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Table 1. Estimated parameters

Variable name	Value	Source of data
Interest rate	2.5%	Annual reports
Average collection period	0.11/year	Estimated[a]
Debt retirement time	10 years	Annual reports
Average age of fixed assets	12 years	Annual reports
Tax rate	68%	Annual reports and calibration
Debt ratio	60%	Annual reports and calibration
Oil field lifetime	30 years	Annual reports
Time to adjust production capacity	15 years	Estimated
Ordering time	5 years	Estimated
Time to develop reserves	8 years	Estimated
Production time	6 years	Estimated

[a]Parameters estimated are based on the knowledge from various sources from literature, websites, oil industry, and model calibration.

model. Table 1 summarizes the estimated parameters and their corresponding values in the model.

Model validation

The validity of the model in a model-based study defines the validity of the results (Barlas, 1996). Validity tests for model structure and behavior build confidence in the model (Forrester and Senge, 1980; Homer, 2012). We engaged in model validation at every stage of the modelling process in one way or another. Dimensional consistency, structure, and parameter confirmation tests were performed during the model-building process, especially during the conceptualization and formulation phases (Forrester and Senge, 1980; Barlas, 1996; Sterman, 2000). We applied the extreme conditions test (Forrester and Senge, 1980) to certain parameters to assess the reliability of the results under extreme conditions. These results suggest that model behavior is realistic. Behavior sensitivity tests were performed on important parameters to ensure that the behavior is realistic.

The size and the complexity of the model determine the amount of effort needed to calibrate the model (Walker and Wakeland, 2011). The model was calibrated to reproduce the time-series data for Equinor, and behavior pattern tests were performed to establish behavioral validity. The simulation results portrayed in Figure 5 of some of the key variables suggest that the behavior mimics the historical data reasonably.

The firm value is a stock referring to the total value of the firm estimated by way of the DCF method. The market price per share, on the other hand, is considered an indicator of the firm's value reflecting all publicly available

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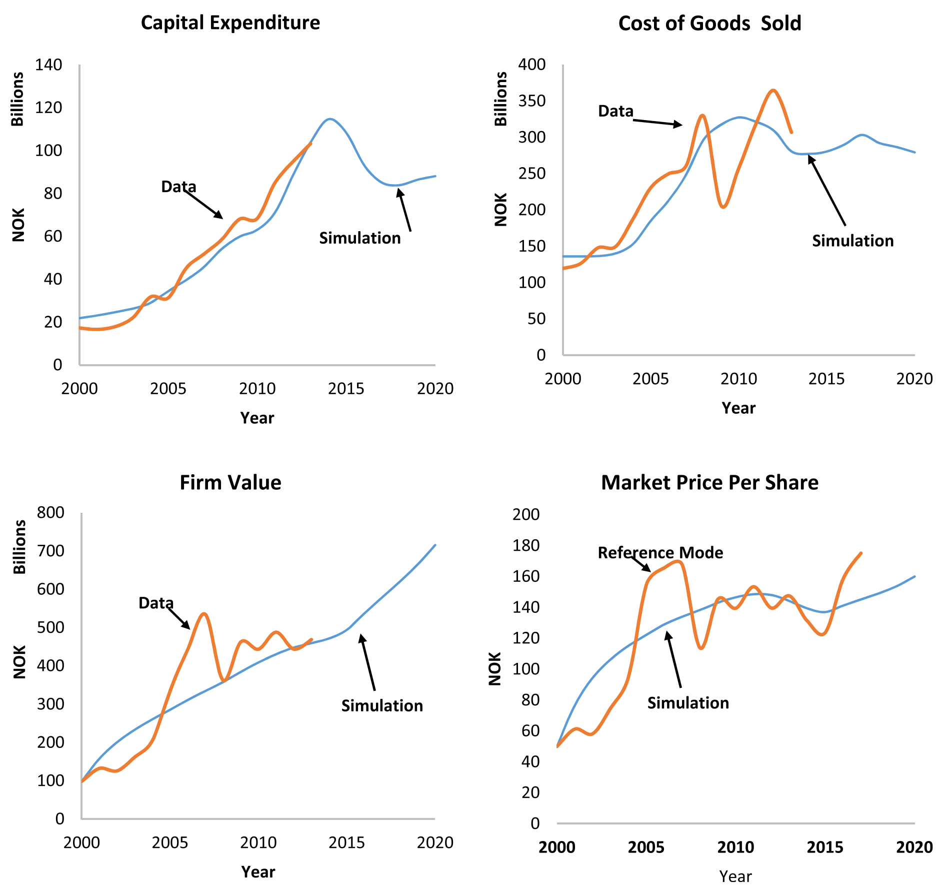
Fig. 5. Simulation results behavior against historical data [Color figure can be viewed at wileyonlinelibrary.com]



information (Ehrhardt and Brigham, 2016). Shareholders are the owners of the firm, and market price per share reflects the shareholders' perception of the firm value per unit of ownership. The goal of value maximization is the maximization of market price per share (Hillier *et al.*, 2014). The simulation results show that the model adequately replicates the reference mode represented by the market price per share as well as the firm value.

To test the model's goodness of fit, the results of an error analysis in terms of Root Mean Squared Percent Error (RMSPE) and Theil inequality statistic (Sterman, 1984) for some the key variables are given in Table 2. The RMSPE represent a normalized measure of error magnitude, and MSE measures the total error between historical and simulated errors. Considering capital expenditure, RMSPE is 0.19, which indicates that the model replicates behavior adequately. Of this magnitude of error, almost 9% is due to bias, 37% is due to unequal variation, and 54% is because of unequal covariation.

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Table 2. Model fits to historical data (error analysis)

Variable	RMSPE	MSE (units)	U^m	U^S	U^C
Capital expenditure	0.19	4.00E+19	0.089	0.372	0.540
Cost of goods sold	0.19	1.96E+21	0.008	0.00	0.992
Firm value	0.26	6.06E+21	0.094	0.313	0.593
Market price per share	0.24	5.19E+02	0.009	0.292	0.699

The cost of goods sold represents the RMSPE of 0.19, and a major portion of this error is unequal variation at 99%. Firm value and market price per share have RMSPEs of 0.26 and 0.24, respectively, and a major portion of the magnitude of error is decomposed into an unequal variation of 59% and an unequal covariation of 69%, respectively. This indicates that simulated behavior captures the historical trend reasonably accurately but diverges point by point (; Qudrat-Ullah and Seong, 2010).

Scenarios and policy design

We designed the oil and gas price scenarios and investment policies to identify their impact on firm value (Table 3). Scenario analysis enables decision-makers to anticipate change, prepare for it in a timely manner, and improve policymaking. In the current study, scenarios are tested to capture alternative developments in the oil and gas price to reflect the underlying uncertainty in order to test its impact (Table 3). Scenario analysis has been extensively used in the oil industry because of high risk and uncertainty in the industry associated with the long-term nature of its investments and the volatile nature of oil and gas prices (Schoemaker, 1993). Conversely, policy is a tool to achieve the objectives of the firm. Business policies are the decisions that establish the direction of the firm and outline the future (Kessler, 2013). For example, an investment policy defines the level of investments decided upon by a firm to support the firm's value-enhancement objective. The investment policy may prescribe the investment level to be conditioned upon a variety of factors, such as oil and gas price.

The historical data reveals that the firm is investing in assets over and beyond its equilibrium needs as reserves and assets grow, and the firm prefers internal financing to external financing. If internal financing is insufficient, the firm raises its external financing, including debt and equity. We assume a percentage of debt in future external financing along with a percentage of dividend payout based on our estimation from the historical data. We assume this to be the initial framework for the past investment, financing, and dividend policy, i.e. a business as usual (BAU) scenario for the future. The model assumes no other exogenous market variable except for oil and gas price. Since the study aims to explore the impact of the firm's

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Table 3. Scenarios and policies

Scenarios	Variable	Change
Optimist	Oil and gas price	10% growth
Reference mode	Oil and gas price	0% change
Pessimist	Oil and gas price	10% decline
Investment Policies	**Policy Variable**	**Policies**
Aggressive policy	Desired production capacity	120%
Business as usual (BAU)	Desired production capacity	100%
Conservative policy	Desired production capacity	80%
Scenario and Policies		
Optimist scenario + investment policies		
Pessimist scenario + investment Policies		

investment policy on the firm value, the model assumes that the historical financing and dividend policies are continued (i.e. BAU).

Table 3 characterizes the scenarios and investment policies designed. Scenarios are built to reflect uncertain future oil and gas prices by assuming alternative price developments (i.e. growth and decline) against the reference mode. We simulate these scenarios to investigate their impact on firm value. Within the investment policy, two major alternatives are tested along with the BAU case, which assumes that the current policy would continue. An aggressive policy implies that the firm invests 20% more than what the BAU indicates, whereas a conservative policy implies that the firm invests 20% less than the BAU investment. We test investment policies with the oil and gas price scenarios to investigate the interaction of the policies and scenarios.

Results and discussion

Results

Using the experimental design (reported in Table 3) as the basis for policy and scenario analyses, Figure 5 presents the firm value and market price per share under the BAU case. The model has been simulated into the future to test the scenarios. Figure 6 characterizes the behavior of the market price per share under the price scenarios that have been designed with the BAU case. The results demonstrate that an increase in oil and gas price leads to a decrease in market price per share, and a decrease in the oil and gas price causes an increase in the market price per share. A plausible explanation for this is that an increase in the oil and gas price leads to positive future expectations that motivate the firm to increase investments, resulting in reduced cash flows and consequently reduced firm value.

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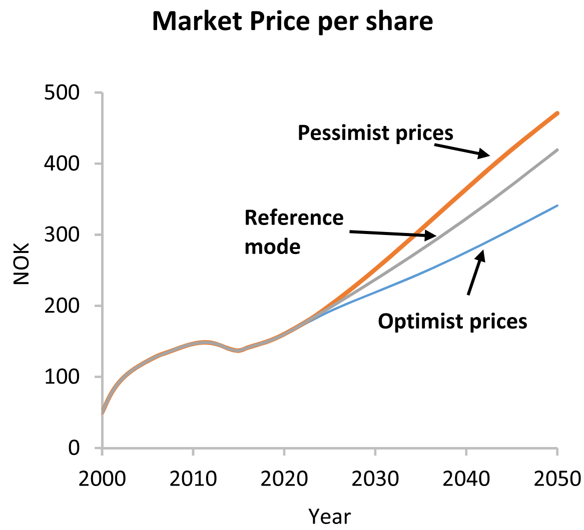

Fig. 6. Market price per share under the three oil and gas price scenarios and BAU case [Color figure can be viewed at wileyonlinelibrary.com]

The model is then simulated for investment policies, including aggressive, BAU, and conservative policy to identify the impact of alternative policies on market price per share, firm value, FCFs, and the number of shares under the reference-mode price scenario. The simulation results presented in Figure 7 demonstrate that the conservative policy (i.e. investment lower than the BAU case) increases market price per share, whereas the aggressive policy (i.e. investment higher than the BAU case) has a negative impact on the market price per share. Please note that, from the model structure in Figure 3, the market price per share (Figure 7) is a result of the firm value divided by the number of shares, wherein the firm value is a stock representing the total value of the firm. The results of the various investment policies with respect to the firm value indicate the short-term versus long-term trade-off faced by decision-makers. For the market price per share, although a conservative policy outperforms other investment policies, the firm value increases at a slower pace than the aggressive policy. Similarly, the aggressive policy underperforms all other investment policies, while the firm value increases at a higher pace. These trends continue around 20 years into the future. Then there is change in the outcome as the BAU policy subsequently outperforms the conservative policy. For about 2 years, the BAU policy outperforms the other investment policies. Thereafter, however, the aggressive policy takes over and outperforms the other investment policies.

Investments play a dual role in the system. Investments reduce FCF now, and after some delay, these investments yield returns and increase FCF. Consequently, we observe an interesting behavior of the FCF resulting from alternative investment policies (Figure 7). In the beginning, as the volume of

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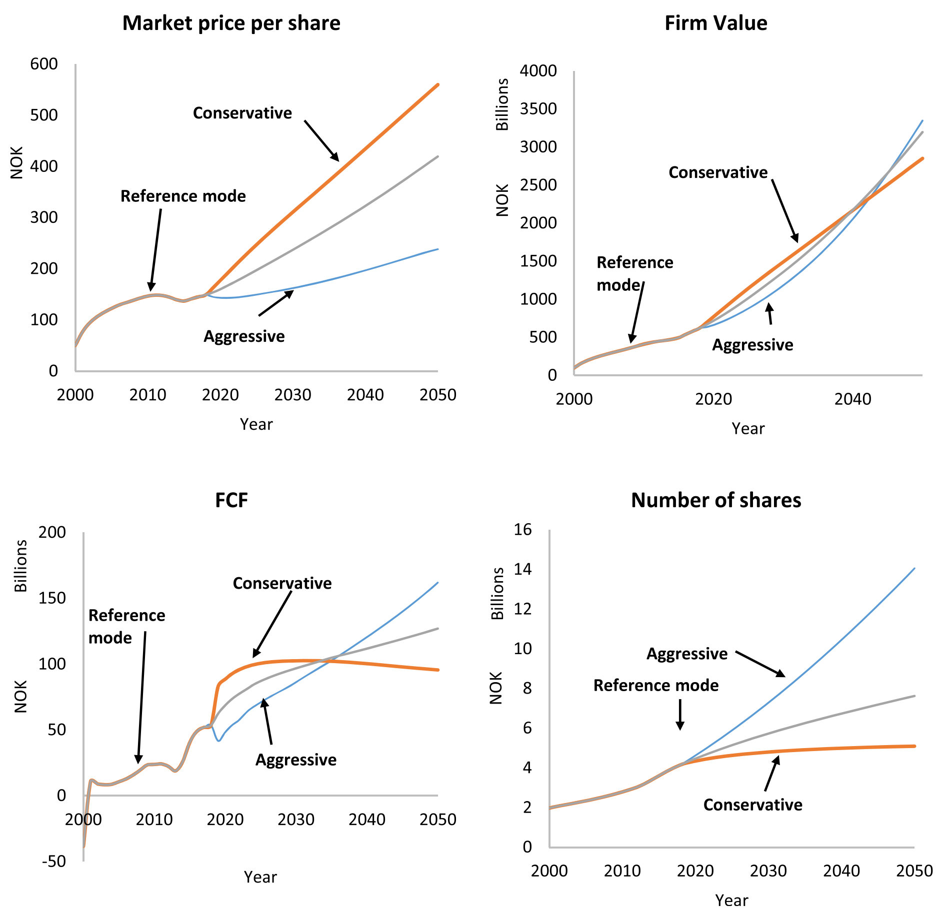

Fig. 7. Simulation results with investment policies under the reference oil and gas price scenario [Color figure can be viewed at wileyonlinelibrary.com]

investments increases in the case of an aggressive policy, the FCF decreases. However, the investments made now subsequently become productive and provide impetus for FCF over the life of those investments. Alternatively, lower investments under the conservative policy lead to higher FCF in the short term, but the lower investments slow down the growth of FCF in the long term. After around 20 years into the future, the conservative policy loses ground to the aggressive policy in terms of FCF. We argue that business managers normally do not enjoy a long tenure, and therefore they have an incentive to forego the long-term benefits to the firm to produce higher short-term performance. Moreover, the number of shares increases in the case of an aggressive policy (Figure 7) due to the need for an increase in external equity. In the case of a conservative policy, the number of shares is the lowest because the firm requires less external equity and, consequently, issues a smaller number of shares. The model has been simulated under the

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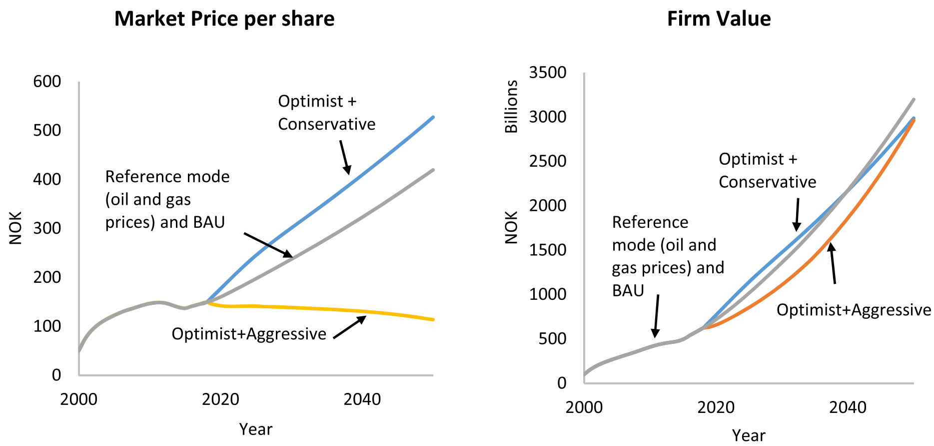

Fig. 8. Market price per share and firm value resulting from optimistic oil and gas price scenario and investment policies compared to the BAU under the reference oil and gas price scenario [Color figure can be viewed at wileyonlinelibrary.com]

reference oil and gas price scenario (Figure 7). As a result, we conclude that conservative policy maximizes the market price share, and aggressive policy maximizes the firm value in the long-term after underperforming in the short term.

Now, the model is simulated to investigate which investment policy would increase the market price per share under optimist and pessimist price scenarios. We present the simulation results of the optimist price scenario in Figure 8. The simulation results suggest that the conservative investment policy increases the market price per share (assuming an optimist price scenario). As the firm issues new shares to finance the increased investments as a result of aggressive policy and optimist prices, the market price per share is lower than the BAU case. The results are similar for total firm value with aggressive policy and optimist prices in the short term. This is a result of the fact that, when the firm is financing these aggressive investments by issuing shares in the market along with the debt, the market would react by discounting the share price. However, conservative investment policy increases the total firm value in the early years of the simulation period. However, in the long term, the BAU outperforms aggressive and conservative investment policy when optimist prices are assumed. When the firm is investing more than the conservative policy in the BAU case, the value first deteriorates because of higher investments in the form of cash outflows. Subsequently, however, when these investments yield returns, the firm value is enhanced.

Furthermore, volatility in the oil market motivates oil firms to assess how the market price per share is influenced by pessimistic oil and gas prices as well. The simulation results of pessimist price scenario are represented in Figure 9. The simulation results indicate that the conservative investment policy assuming pessimist price scenario increases the market price per

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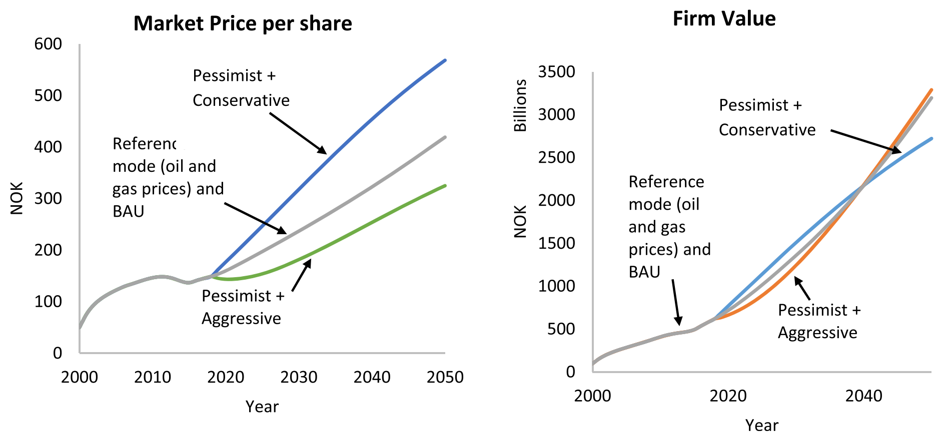

Fig. 9. Market price per share and firm value resulting from pessimistic oil and gas price scenario and investment policies compared to the BAU under the reference oil and gas price scenario [Color figure can be viewed at wileyonlinelibrary.com]

share. As the firm retains the cash flows rather than reinvesting, the increased liquidity yields a rise in the market price per share as DCF relies upon cash flows for valuation. However, the FCF and total firm value reveal the short-term versus long-term trade-off if the firm is cutting down on investments (Figure 9). In the short-term, a conservative investment policy improves the FCF and the firm value. However, in the long term, aggressive policy and BAU outperform this conservative policy. Initially, when the firm makes lesser investments, the FCF improves, but in the long term, profitability is affected, and thus the firm value deteriorates. Note, however, that the conservative investment policy results in the highest market price per share because the firm issues less shares, potentially indicating the role of a financing policy to determine the firm value. The financing policy, however, is beyond the model boundary and will be considered in our next study.

The results of investment policies show that, as the firm invests conservatively, the firm has more FCF available as compared to the other (BAU and aggressive) policies. With respect to the market price per share, the simulations suggest that a conservative policy outperforms the other policies both in the short and the long term. That is primarily explained by the external financing loop (B1) and firm valuation loop (R4). As in the aggressive investment policy case, the firm invests a higher volume, resulting in the need for increased external financing and the number of shares. A higher number of shares results in lower market price per share provided that the firm value does not increase correspondingly. The results suggest that lowering the investment volume would have a positive impact on the market price per share. The aggressive policy that characterizes an increase in the volume of investments lowers the FCF available now and consequently the market price per share. The results are consistent with the agency theory and the FCF hypothesis (Jensen and Meckling, 1976). An implication of the agency

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theory is that firms with a higher FCF tend to initiate investments that decrease value in the short term. As the firm continues to invest, the marginal utility of the investments decreases, resulting in a deterioration of the firm value. The FCF theory implies that the market value of the firm with a high FCF decreases when there is an increase in investments (Del Brio *et al.*, 2003).

The total firm-value behavior reveals interesting dynamics involving short-term and long-term trade-off as a result of investment policies' analysis. In the early years of the simulation period, total firm value decreases with aggressive investment policy. However, toward the end of the simulation period, the total firm value indicates that the aggressive policy yields the best results. These results are supported by the endogenous growth theory (Jones, 1995), which advocates reinvestment as the engine of sustainable growth. The results emphasize the fact that, to create value in the long term, the firm must invest at the cost of its short-term benefits. The conservative policy would be an explanation of short-termism, which focuses on short-term results at the expense of long-term benefits. The aggressive policy suggests that, if managers forego short-term benefits by reinvesting the FCF rather than distributing it across its shareholders, it leads to an increase in the firm value in the long term. Simultaneous consideration of the market price per share and the firm value indicates towards the role of the number of shares and the plausibly complimentary role of the financing policy of the firm along with its investment policy in the firm-value management.

Discussion

Oil and gas price fluctuations have a vital impact on the outcome of an investment policy. The firm must consider this uncertainty and fluctuations when designing an investment policy aimed at value management. Oil and gas prices have a two-way effect on the firm value. There is one instantaneous or short-term effect, favorably influencing profits. When oil and gas prices increase, sales revenue and profit increase. Then, there is a long-term effect, in that capacity and production expansion takes place. An increase in oil and gas prices leads to optimistic expectations about the future oil and gas prices that motivate the firm to expand so as to produce more in the expectation of higher profits. This expansion policy governs the decision to increase investments. An increase in the investments would lead to a decrease in the FCF and the market price per share.

The results for investment policy analysis under the reference oil and gas price scenario reveals that the impact of increased investments volume on the market price per share is negative in all tested oil and gas price scenarios. Note that, in terms of the total firm value, the impact of increased investments has also been negative during the first 20 years of the simulation period, whereas in the long term, the impact of increased investments is

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positive on the firm value. The simulation results also emphasize the contrast between agency theory and endogenous growth theory. It may be challenging to resist the agency mechanism causing managers to adopt policies that deliver immediate or short-term results at the expense of long-term value creation. Therefore, while negotiating the agency mechanism, management should follow an investment policy that considers both the long-term and the short-term policy impacts on firm value.

Due to the high demand for oil and gas in the market and the fact that Equinor is an independent producer, the firm, in an effort to maximize firm value, pursues an investment policy that causes the capacities to remain a bit higher than the current production level. However, we argue that the firm must also consider the short-term versus long-term trade-offs while employing its capital. In the short term, the conservative policy yields an increased market price per share because the firm would invest less. Consequently, a larger cash flow is available within the firm, leading to higher valuation of the firm. The total value of the firm, however, increases with the conservative policy only during the first 20 years of the simulation period. Thereafter, the aggressive policy outperforms the conservative one. This is because long-term investments in the oil industry yield returns after certain delays, and cash flows from these investments improve the firm value. Thus, in the short term, the firm value is lower due to the increasing investments cash outflow. However, when these investments yield returns after some delay, the firm value increases often at a rate larger than the share-issuing rate. A combination of investment policies and oil and gas price scenarios reveals that conservative investment policy is the best option in all oil and gas price scenarios. This is true for total firm value in the short term. However, in the long term, BAU outperforms in the optimist oil and gas price scenario, and aggressive policy outperforms in the pessimist oil and gas price scenario. These results emphasize that the underlying long-term trend of the oil and gas prices has an impact on firm value. While designing an appropriate investment policy, managers must aim for long-term effects, and they must also be mindful of the short-term nature of oil and gas prices and have the flexibility to hedge against these fluctuations when designing their policies.

Conclusion, implications, and limitations

The study explores the impact of different investment policies on firm value in the presence of uncertain oil and gas prices. The focus of this study is on how the interaction between oil and gas prices, being uncertain and short term in nature whereas investments are long term in nature, impact firm value. The model embodied in the study illustrates the corporate planning model for an oil firm aimed at enhancing firm value. The model highlights

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and explains the organic interaction of the reinforcing and balancing feedback loops that balance the system and limit growth. The feedback loops portray the complex nature of the structure relating the key variables to explain the interactions that underly the physical and financial system of the firm. The firm value was estimated using the DCF valuation method.

The model assumes oil and gas prices as a basis to design the scenarios describing the market. Under these scenarios, the model is simulated to examine the impact of the oil and gas prices on firm value under a variety of investment policies. The results for oil and gas price scenarios reveal that an increase in oil and gas prices has a negative impact on firm value. This is because the oil and gas prices are the basis for future expectations about the market and investment decisions. When oil and gas prices are higher, positive future expectations lead to increased investments and reduced cash flows.

The results for investment policies demonstrate that a higher volume of investments over BAU decrease the firm's future cash flows and total firm value over the early 20 years of the simulation period. However, after 20 years, future cash flows and total firm value increase with higher investments. To support higher investments, the firm would issue a higher number of shares, and consequently the market price per share would be lower, and vice versa. This means that a conservative investment policy that assumes an investment rate lower than the BAU outperforms the other investment policies for market price per share. This policy increases the total firm value in the short term. In the long term, however, an aggressive investment policy that assumes an investment rate higher than the BAU increases the total firm value. Results for combinations of policies and scenarios reveal that market price per share is higher with conservative policy in all oil and gas price scenarios. Total firm value confirms the same results with conservative investment policy in the short term. However, under optimist price assumptions, BAU increases the total firm value in the long term. While assuming pessimistic oil and gas prices, aggressive investment policy outperforms regarding total firm value in the long term. The apparent conflict in the results for the market price per share and the firm value indicate a complimentary role of the firm's financing policy that is assumed exogenous.

The study also confirms the FCF hypothesis that investing firms with high FCF face a deterioration of the firm value. Nevertheless, the total firm-value results suggest modification to this implication of the FCF hypothesis: the investing firms with high FCF face deterioration in firm value in the short term. However, in the long term, they would enhance the firm value. The managers of firms with high FCF should sensitize themselves to the short-term versus long-term trade-off while formulating an investment policy to enhance firm value.

Although the study has focused on the relationship between the investment policy and the firm value, there are potential limitations of this study as well. For example, the study assumes the presence of unlimited reserves to be explored and exploited. This may be true for a limited 30-year time

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horizon (simulation period) but may not hold in the very long term. Moreover, the study assumes that the financial policy is exogenous. However, the potential implications of the financial policy in the firm-value dynamics are indicated. Consequently, we plan to address this aspect in our next study. Also, the human resources available and the intangibles present have not yet been modeled. This calls for further future research.

Biographies

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Pål Ingebrigt Davidsen is Professor of System Dynamics (SD) at UiB, Norway. He has served with Professor Jay W. Forrester (MIT) as Associate Chair of the Pre-College Education Project. At UiB, he founded the System Dynamics Group and the Educational Information Science and Technology Programme and is co-founder of the European Masters Programme in SD. He served as President and as VP of Publications in the System Dynamics Society (SDS) and received the SDS Outstanding Service Award. Davidsen has published e. g. on natural resource management, public health, analysis of complex, dynamic systems, and model-based interactive learning environments.

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