Essays in Corporate Finance

Aima Khan

Thesis for the degree of Philosophiae Doctor (PhD)
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UNIVERSITY OF BERGEN

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Abstract

Firm value creation and maximization is the primary objective of any firm and the most debated issue in corporate finance. Firms operate in the market to create value for the stakeholders. Valuation plays its role in many areas such as mergers and acquisitions, portfolio management and corporate finance. Corporate finance focuses on maximizing the value through the corporate strategy development, policy design, and financial decisions, as the value can be directly influenced by the decisions a firm makes, such as investments it makes, how they are financed, and the dividends offered. Feedback mechanisms formed by the variety of physical and managerial processes in the firm, the associated physical and financial accumulation processes, and their synergies formed by the non-linear interrelationships between them, contribute to the dynamic complexity of firm value creation and thus to its maximization over time.

To manage the firm value effectively over time, strategic planning is called for, that aims at translating the corporate objectives into policies that govern the resource allocation decisions. A variety of tools are employed for strategic planning purposes. The inadequacy of long-range planning tools is, however, a commonly cited reason for corporate failure to achieve the stated objectives. Specifically, the complexity is at the core of strategic corporate finance management, yet research on that complexity has rarely been the subject of non-linear, dynamic feedback analysis.

This dissertation enriches the corporate finance literature that deals with the firm value maximization by exploring the dynamic complexity of firm value maximization objective in the oil and gas sector, that is associated with high risk and return. The dissertation uses an international oil and gas firm, Equinor, headquartered in Norway, as a case. In its very nature, the oil and gas sector is very complex and the decisions made are characterized by uncertainty. For example, long-term and irreversible investment decisions are made based on uncertain and volatile oil price expectations. Thus, the value creation and its maximization become challenging and requires a systemic approach to the strategy development, policy design and decision making, - an approach that can account for the prevailing complexity characterizing both the firm and the environment in which it operates. Despite the extensive literature that exists on this topic, the debate on how strategies, policies and the resulting decision making affect the variety of physical and financial processes in such a firm, and how the interaction between these processes determines the outcome performance, i.e., the value creation and maximization over time, is sparse. Thus, the core objective of this dissertation is to contribute to the understanding of firm value creation and maximization. For this purpose, the dissertation applies the system dynamics method to address the five major research questions, - each at the core of an article. System dynamics is suitable for this study because it enables us to represent and analyze the non-linear feedback mechanisms and the associated accumulation processes, all present in a firm aimed at maximizing its value. It thus provides us with tools to adequately address the complex dynamic problems and to design and assess the impact of policies over time.

The dissertation consists of an overall introduction followed by five articles. The purpose of the first article is to address the impact of the investment policy on the firm value in the presence of uncertain oil prices and, moreover, to propose an investment policy, that maximizes the firm value, given the prevailing oil and gas price expectations. The article documents a system dynamics model that portrays the case firm, incorporating the aggregated financial and physical processes of the firm required to produce oil and gas. The model

operationalizes the discounted free cash flow (DCF) valuation method applied to perform the valuation of the firm. Testing various policy alternatives for the investment policy reveals that increasing the volume of investments over the current volume, reduces the cash flows and the total firm value over the first twenty years of the simulation period, but it increases the firm value thereafter as the new investments then yield returns. However, the investment policy which assumes a higher volume of investments than the current level decreases the market price per share, which is quite counter intuitive that I explain as follows. The capital required to finance the increased volume of investments requires issuance of higher number of shares that leads to decrease in the market price per share. The results highlight the short-term versus long-term trade-off faced by the firm managers; either to lower the volume of investments compared to the current level to increase the market price per share in the short-run, or to increase the volume of investments compared to the current level to realize the increased market price per share in the long-run after affording decreased market price per share in the short-run.

The second article addresses the financing policy as a tool to enhance the firm value. The article builds on the base model from the first article and incorporates a module that incorporates the causal relationships between the factors that make up the financing policy, - as postulated by the theories. Various policy alternatives of debt and equity mix are analysed under different scenarios to assess their impact on the firm value and to identify the financing mix that maximizes the firm value. The simulation results reveal that increasing the debt percentage in the financing mix of the firm increases the total firm value and the market price per share and vice versa.

The third article analyses the impact of dividend policy on the firm value and proposes the best combination of investment, financing, and dividend policies for the firm value maximization. Building on the system dynamics model developed in article 2, this article integrates a dividend policy by adding a structure based on the relevant theories. Various dividend policy alternatives and scenarios combinations have been simulated and analysed to identify the policies that maximize the market price per share. The simulation results reveal that lowering the volume of investments, increasing the percentage of debt in the financing mix, and lowering the dividend payment increases the market price per share as compared to the base case that assumes that the firm continues with the current policies. These policies lead to the increased future cash flows of the firm and reduced discounting rate, thus increased market price per share as per the discounted cash flow method. This study has implications for the policy makers and concludes that the combined outcome of the policies should be considered to achieve the value maximization objective.

Article 4 develops a model of exchange rate determination and forecasting to provide a reasonable long-term forecast for the exchange rate. As described by the interest rate parity (IRP) and the purchasing power parity (PPP) theories, the model developed for article 4 incorporates the nonlinear relationships between the exchange rate and the macroeconomic factors, including the interest rate, inflation, per capita income, terms of trade and the oil prices. The simulation results reveal that the model can mimic reasonably well the historic behavior of long-term exchange rate and thus provides insightful long-term forecasts for the future development of the exchange rate. This study has implications for individuals, businesses, and the Government because they are affected directly or indirectly by the exchange rate movements, and the study contributes to the debate on exchange rate determination and forecasting.

Article 5 explores as how the changes in exchange rate (i.e., appreciation or depreciation of the local currency) influence the value of an international firm – the case firm. The study integrates the system dynamics-based model from article 4 into the model developed in article 3 to endogenize the exchange rate and analyze its impact on value of the case firm. The results reveal that an appreciation of the local currency, Norwegian Kroner (NOK), against the US dollar leads to an increase in the market per share of the firm. The simulation results are quite counter intuitive and oppose many studies that report the positive influence of depreciation of local currency on firm value. The study has implications for the policy makers of the firm as well as Norway because any change in the macroeconomic factors and the consequent change in the exchange rate have an impact on the case firm as well as the Norwegian economy, as the case firm is a major contributor to the Norwegian exports. Understanding of the key factors involved and their impact on any possible change is vital to effectively manage the firm as well as the economy.

Overall, the five articles contribute to the firm value creation and maximization debates on the methodological, the conceptual as well as the applied level. The dissertation contributes to the conceptualization of the elements involved to manage the firm to maximize the firm value, as well as the strategy (combined set of policies) and its underlying decisions that may help enhance the firm value while considering the macroeconomic factors beyond the control of a single firm. The dissertation translates the relationships between investment, financing, and dividend policies as well as macroeconomic factors to determine the exchange rate as described by the prior published theories into a system dynamics model and extend the span of the methodologies applied to study these intertwining relationships and the resulting firm value. The use of system dynamics, its peculiar focus on the accumulation processes and nonlinearities prevalent in the structure of the system that drive the behavior, reveal that the strategies and the policies are subject to organic, endogenous, and dynamic interactions that can contribute to the enhancement or detraction in the firm value. Thus, along with contributing to the discipline specific knowledge, the dissertation advocates the complementary benefits of system dynamics that facilitates the integration of the relationships described by different theories in a comprehensive model to prescribe the actions taken by the decision makers (resulting from the strategies developed and policies designed) to manage the firm to create the value and maximize it over time.

Dedication

I dedicate this work to my late father, Khadim Hussain khan, and my mother, Parveen Tahira whose unconditional love, support and faith in me has enabled me to accomplish this.

List of Publications

Paper	Reference	Status
Paper 1	Khan, A., Qureshi, M. A., & Davidsen, P. I. (2020). How do oil prices and investments impact the dynamics of firm value? *System Dynamics Review*, *36*(1), 74-100.	Published
Paper 2	Khan, A., Qureshi, M. A., & Davidsen, P. I. (2020). A system dynamics model of capital structure policy for firm value maximization. *Systems Research and Behavioral Science*.	Published
Paper 3	Khan, A., Qureshi, M. A., (under review) Policy analysis to maximize the Firm Value: Performing Firm Valuation using system dynamics. Manuscript submitted for publication in Journal of Modelling in Management.	Under Review
Paper 4	Khan, A. (2020). A System Dynamics Model of Exchange Rate Determination and Forecasting. *SEISENSE Journal of Management*, *3*(4), 44-55.	Published
Paper 5	Khan, A., Qureshi, M. A., (under review) Modelling the dynamics of firm valuation: An assessment of impact of exchange rate fluctuations on firm value using system dynamics. Manuscript submitted for publication in Journal of Simulation.	Under Review

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Articles

Article 1: How do oil prices and investments impact the dynamics of firm value?

Article 2: A system dynamics model of capital structure policy for firm value maximization.

Article 3: Policy analysis to maximize the firm value: performing firm valuation using system dynamics.

Article 4: A System Dynamics Model of Exchange Rate Determination and Forecasting.

Article 5: Modelling the dynamics of firm valuation: An assessment of impact of exchange rate fluctuations on firm value using system dynamics

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Model Documentation
Data

Introduction

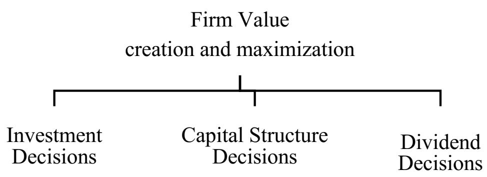
1. Background and Research Problem

Creation and maximization of firm value is the core objective of any firm and the central topic of financial management theory (Copeland et al., 2000). Value creation as a primary objective for a firm serves many purposes. A firm dedicated to the creation of value provides more opportunities for a variety of stakeholders including the shareholders, and in this process helps build a stronger economy and improves the living standard in the community, the nation or even the region in which the firm operates. Value creation - earning returns on capital invested higher than the cost of capital, - not only maximizes today's share price of the firm, but also involves sustaining it in the future (Koller et al., 2005).

Valuation, determining the fair price for the firm, is performed by various stakeholders to guide their decisions and perspectives. Valuation plays a vital role in decisions by the stakeholders and the firm, such as portfolio management, mergers and acquisitions, and corporate finance strategic decisions. Investors perform valuation to determine whether the firm is under or overvalued and to manage their portfolios based on their assessment of the value. An increase in firm value attracts more investors and provides the firms with the access to cheaper capital. Corporate finance strategic decisions are one of the key tools of a firm to achieve the objective of value maximization for a firm.

Corporate finance literature classifies corporate strategic decisions into three categories (Damodaran, 2001) that we present in the following Figure 1.

Figure 1: Corporate Strategic Finance Decisions and Firm Value



- *Investment Decisions*: This category involves the decisions leading up to the investment of the resources or capital of the firm.

- *Capital Structure/Financing Decisions*: This category encompass decisions regarding the composition of the capital raised to finance the investments made by the firm.

- *Dividend Decisions*: This category involves the decisions about allocation of profits to the shareholders such as how much and in which form the firm should distribute the profits between the shareholders.

This dissertation addresses the challenge of firm value maximization by focusing on each of these three major categories of decisions in a comprehensive and integrated framework. To manage the firm value and devise these policies wisely, the managers engage in strategic planning (Palepu et al., 2000), translating the objectives of the business into the policies that govern the resource allocation decisions (Lyneis, 1980). A variety of tools are employed to devise the policies incorporated in a strategic planning process (Stenfors et al., 2004; Groesser and Jovy, 2016). But often these tools are inadequate when dealing with the significant complexity of the company processes and the economic environment within which it operates (Sterman, 2000). Often there is lack of a comprehensive understanding of the integration that is formed by the company processes and, in a model thereof, of the cause-and-effect relationships between the factors that represent such a company and its environment. By incorporating a comprehensive (i.e., systemic) approach that integrates the various functions of a firm (Naylor, 1979), the strategic planning process could be improved and would thus lead to an improved design of policies that govern decision making (Wild, 2011) with the purpose of achieving a maximization of the firm value objective. In that regard, there are three major limitations in the literature on corporate finance:

First, the researchers, while examining the effect of different factors on firm value, have dealt with the system in parts rather than as a whole. The phenomenon of firm value is intertwined in a complex feedback process that involves several different subsystems. The literature typically lacks an integrated system approach that recognizes that corporate financial behavior is produced by the interaction of a variety of system components.

The second limitation of these studies is that most of the research lacks the consideration of accumulation processes and nonlinearities prevalent in the structure of the system that drive the behavior. The creation and management of the firm value is governed by a structure that encompass feedback loops and their nonlinear interactions. Research in system dynamics has its precedents in the business and finance field such as (Yamaguchi, 2003; Lyneis 2020; Warren, 2008; Qureshi, 2007), but the slim body of literature fails to address comprehensively the firm value maximization issue as such. Consequently, there is a need to address the issue from systemic and endogenous perspective.

The third limitation of the studies carried out, is that most of them concentrate on the hard variables, ignoring the soft variable such as expectations. One plausible explanation may be that researchers normally have a hard time determining and modelling agents' motives and expectations. These soft variables should be considered and modelled explicitly in the decision-making process. Although there are examples (such as Lyneis, 1980; Morecroft, 2015; Hines, 1987; Sterman, 2000; Warren, 2008), little is known as to how these soft variables impact the firm value dynamics. Therefore, this dissertation is based on an explicit modeling of expectations to investigate the fundamental principles in corporate finance and international financial management by way of modelling and simulation using the system dynamics approach, with focus on firm valuation.

"the whole history of man, even in his most, non-scientific activities, shows that he is essentially a model-building animal" (Rivett, 1980)

In problem solving, modelling has been fundamental (Schlosser, 1989). System Dynamics is a computer-aided method that provides techniques and tools that help us adequately understand, describe, and analyze complex dynamic problems and to design the policies and assess their impact over time. During the modelling process, the modeler uncovers the causal relationships that are considered responsible for the dynamic development observed over time, including policies that govern decision making. Altogether these relationships constitute a structure that may be re-designed and implemented to modify that development. This is typically a stepwise process alternating between identification of relevant factors and their organic interrelationships described by the relevant theories, the collection of empirical evidence, the formulation of hypotheses in the form of models (whether they are descriptive or normative) and the testing of these hypotheses. This process gradually increases our understanding of the relationship between the structure and the behavior in such systems and ensures consistence and coherence leading up to a comprehensive understanding and policies (i.e., a strategy) that govern the future dynamics. Such a learning process not only challenges the existing mental models about the system that shape the current policy framework, but also helps us identify the leverage points in the existing structure or possible structural changes to better achieve the corporate policy objectives.

The financial sector has not often been the subject of non-linear, dynamic feedback analysis in corporate financial design and operations. The system dynamics corporate planning model, developed in this dissertation, contributes to a better understanding of the financial performance of the firms and the dynamics involved. The model interrelates the internal operations, macroeconomic factors, and a variety of market related factors, and it thus provides a useful vehicle that effectively informs strategic decisions.

In this dissertation, I develop a model using Equinor, an internationally operating oil and gas firm headquartered in Norway, as a case firm. The model includes financial as well as physical processes of the firm. Firm valuation is performed using the discounted cash flow (DCF) valuation method. The dissertation consists of a set of five articles with 'maximization of firm value' as their common topic. In the first article I develop a system dynamics model that focuses on the impact of the investment policy and of oil price fluctuations on the firm value by addressing the first category of corporate strategic finance decisions as depicted in Figure 1 above. In the second article, I focus on the second category and address the impact of the financing mix decision, taking into consideration a variety of scenarios addressing changes in taxation. The system dynamics model in this article builds on the model developed in article 1. The third category of the dividend decision is the subject of my third article and focuses on the impact of the dividend policy on the firm value. This article explores the impact of three major policies interacting nonlinearly in the feedback loops to propose an integrated policy framework that maximizes the firm value.

After exploring the impact that the three policies of the firm, designed internally, have on the firm value, I then analyze the impact of exogenous changes in macroeconomic factors on the firm value. For this purpose, in a fourth article, I develop a model, based on fundamental theories of exchange rate determination, to forecast the long-term dynamics of exchange rates. Using these models of exchange rate determination and firm valuation, I explore, in a fifth article, the impact of exchange rate fluctuations on the firm value through changes in key macroeconomic factors, such as interest rate, inflation rate, exports, imports, and oil prices.

The model developed for the purpose of this dissertation, includes the factors and their relationships described in the literature. The model consists of three major modules: The financial module, the production module, and the valuation module.

The financial module includes the endogenized financial statements, representing the major aggregated financial accounts of the firm in a feedback relationship. The production module represents the oil and gas production processes of the firm illustrating, in an aggregate way, the operations of an oil firm to understand and analyze the interrelationships between the physical and the financial co-flows. In the firm valuation module, I operationalize the DCF valuation method, a widely used method for firm valuation based upon reliable measure of free cash flows. This operationalization emphasizes the feedback loops involved in the valuation through DCF. The model developed can be taken as a template for strategic planning of any other firm, primarily in the energy sector and, by customizing the physical operations, for any business in general to prescribe a comprehensive policy framework to create and maximize firm value. This emphasizes the applicability and generalizable implications of the dissertation.

This dissertation contributes and enriches the relatively slim body of long-range planning tools aimed at sustaining and maximizing the firm value (i.e., literature that explores the dynamic and endogenous interactions among factors for the purpose of firm valuation). The dissertation focuses on the development of a system dynamics model for corporate financial planning, aimed at value maximization of the firm to facilitate the decision-making by way of policy design and scenario analysis.

What follows in this dissertation is organized this way: Section 2 reports on objectives and research questions. Section 3 briefly introduces the case firm, Equinor. Section 4 describes the description of domain. Section 5 discusses the rational for using system dynamics. Section 6 outlines the model description. Section 7 provides an overview of the articles, and Section 8 presents the conclusions. I provide references at the end.

2. Objectives and Research Questions

The estimation of a fair market value is at the core of corporate finance. There are three kinds of strategic corporate finance decisions that affect the fair market value of a firm: investment decisions, financing decisions, and dividend decisions. The following three research questions addressed in this thesis focus on these policies. Each of them is addressed in the first three articles:

1. How does the choice of an investment policy impact the firm value per share, given the expectations formed regarding the development of oil and gas prices and the uncertainty associated therewith?

2. How does the choice of a financing mix policy impact the firm value per share?

3. How does the choice of corporate finance policies, namely investment, capital structure and dividend policies, impact the firm value per share?

Answers to these research questions will contribute to our understanding of firm value maximization - specifically how the corporate finance policies may serve as a tool to maximize the firm value. These research questions address the key policies to be designed by the firm and how these policies should be consolidated in an overall strategy to enhance the firm value. There are, however, many other market and economy related factors that are beyond the control of the firm that will have an impact on the policy outcomes, in the form of the firm value. The next two articles focus on this aspect by addressing the changes in exchange rate due to changes in macroeconomic factors. The research questions addressed are as follows:

4. Do fundamental theories of exchange rate determination explain the long-term exchange rate movements?

5. How do the exchange rate fluctuations, caused by changes in macroeconomic factors, affect the value of an oil-exporting firm?

The answers to these research questions will contribute to the understanding of how changes in macroeconomic factors affect the exchange rate and, ultimately, the value of the firm. Thus, this would emphasize the need for considering such factors in decision making to achieve the stated objectives.

The five research questions stated above are intended to provide an endogenous perspective on the strategic planning and policy design by the firm to address the dynamic complexity characterizing the firm value maximization. Each of the research question is addressed in an article, presented as a chapter in this dissertation.

Table 1 provides an overview of the dissertation purpose, research objectives, and a brief detail of each article.

Table 1. PhD Dissertation Overview (Research Questions)

Study Purpose	The dissertation contributes to the debate on firm value maximization, by developing a system dynamics model for corporate financial planning, aimed at firm value maximization to facilitate the decision making through policy design and scenario analysis.				
Main research Question	How to maximize the firm value through corporate finance policies, namely investment, financing, and dividend policies, given the impact of exchange rate through macroeconomic factors?				
Papers	Paper 1	Paper 2	Paper 3	Paper 4	Paper 5
Title	How do oil prices and investments impact the dynamics of firm value?	A system dynamics model of capital structure policy for firm value maximization	Policy analysis to maximize the firm value: performing firm valuation using system dynamics	A System Dynamics Model of Exchange Rate Determination and Forecasting	Modelling the dynamics of firm valuation: An assessment of impact of exchange rate fluctuations on firm value using system dynamics
Research Questions	How does the choice of 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?	How does the capital structure policy impact the firm value per share?	How does the choice of corporate finance policies' decisions impact the firm value per share?	Do fundamental theories of exchange rate determination explain the long-term exchange rate movements?	How do the exchange rate fluctuations caused by macroeconomic factors, affect the value of an oil exporting firm?
Methodology	System Dynamics methodology and corporate finance theories and principles for formulation of equations				
Data	The dissertation uses yearly data (2001-2020) of Equinor. Due to the need of the data for market price per share, year 2001 is chosen as first year because the firm got listed on stock exchange in 2001. All sources of secondary data have been used including literature, the firm specific information through the website and the annual reports, the data from Norwegian Petroleum directorate, petroleum			Data for macroeconomic factors has been obtained using secondary sources of data	Secondary data sources have been used

	industry data and processes information.		
Theoretical Framework	-Standard accounting principles -Corporate finance theories - System dynamics principles	-Fundamental exchange rate theories -System dynamics principles	-Finance theories and principles -System dynamics principles
Data Analysis Framework	- System dynamics model - Statistical analysis for model validation - Scenarios, policy design and testing		

3. The Case Firm

To answer the research questions stated above, I develop in this dissertation a comprehensive system dynamics model using Equinor, an international firm, as the case firm. My choice of the case firm is determined by the importance of the oil and gas sector in the Norwegian economy as well as abroad (internationally). The oil and gas sector is associated with uncertainty and complexity (Hvozdyk and Blackman, 2010). These characteristics are well embodied in the selected case firm operations.

Equinor, headquartered in Norway, is a broad energy firm operating in oil, gas, wind, and solar energy in more than 30 countries and is the largest offshore operator worldwide. The firm was founded in 1972 and was registered on the Oslo Stock Exchange in 2001, with the Norwegian state as its major shareholder (70.9%). Except for the years 2007 – 2009, the firm was named Statoil until 2018 and changed name to Equinor in 2018. (In 2006, the firm merged with Norsk Hydro and took the name StatoilHydro in which the state owned 62.5%. In 2009, the name was again changed to Statoil ASA). After 2018, the firm has been named as Equinor with the State ownership of 67%. The Equinor share is listed on the Oslo Stock Exchange as well as the New York Stock Exchange with a market value of around NOK 480 billion as of December 2020.

The firm operates in exploration, production, refining and shipping of oil and gas. Equinor produces around 2 million barrels of oil equivalents per day, and which constitutes about 70% of the total Norwegian oil and gas production. The produced crude oil and gas are transformed into everyday commodities such as petrol, heating oil, diesel, and other consumer ready natural gas products by the refineries and processing plants of the firm. Predominantly, the customers are in continental Europe. But the firm also exports to UK, Asia, and North America[1]. The firm is operating in renewable energy, including renewable offshore wind energy and is partner in two solar energy projects in South America. Equinor provides electricity to more than one million homes in Europe from offshore wind farms in the UK and Germany. Many other renewable wind energy projects are on their way, including the world's largest floating offshore wind farm (Norway) and the world's largest offshore wind farm (UK).

Equinor's operations and financials are representative for oil and gas related firms. The model developed in this dissertation uses Equinor as the case firm, yet this model is portable and expected to be useful for policy design and scenario analysis for the maximization of

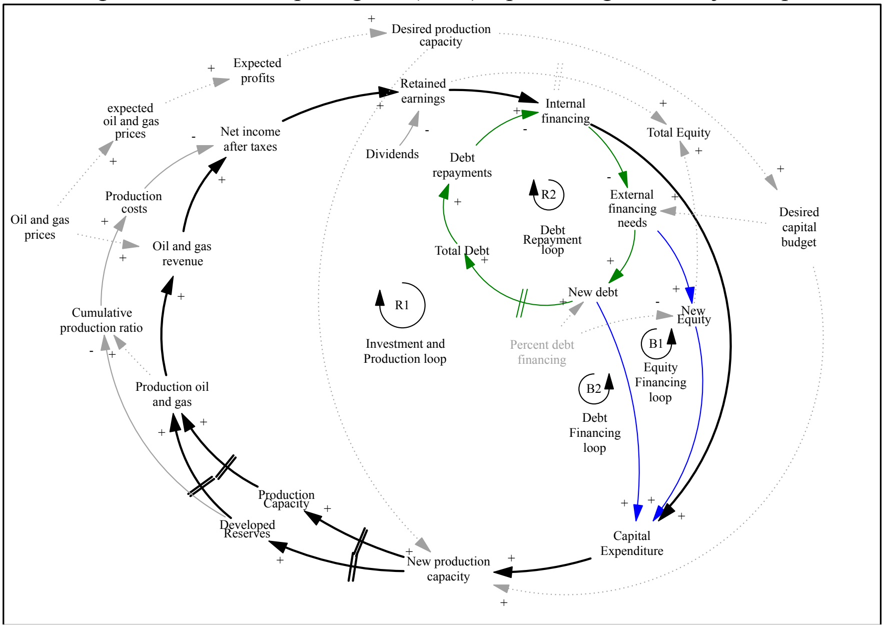
[1] https://www.equinor.com/en/about-us.html

firm value by any other firm in the oil and gas sector with analogous properties, and, after customizing the production processes to their domain of production, by any other business. The model is developed on the principles outlined in system dynamics and explained in detail in the following section.

4. Description of domain

To answer the research questions given in Section 2, a system dynamics model has been developed for Equinor. The physical and financial processes in any oil firm are characterized by a significant degree of complexity involving accumulation processes, feedback loops, and nonlinear interactions between the feedback loops that altogether produces the firm value. Accumulation processes cause delays to arise, and nonlinearity means that each feedback loop conditions the behavior caused by the other feedback loops in the system. Positive or reinforcing feedback loops cause divergent, e.g., growth behavior and negative or balancing feedback loops cause convergent, e.g., goal seeking behavior. The system under study involves the nonlinear interactions of these feedback loops that determine the behavior of the firm value. There are a variety of feedback loops in the system that have been included in the current model and that are discussed in the articles in this dissertation.
To give an example of the complexity of the system, Figure 2 presents the feedback loops characterizing a few fundamental physical and financial processes in this system. The causal loop diagram represents the system structure that connects the cause (corporate policies) and effect (the firm value) in a feedback relationship.

Figure 2: Causal Loop Diagram (CLD) representing some major loops



There are four feedback loops in the diagram: two reinforcing loops, R1 and R2, and two balancing loops, B1 and B2. The Investment and production loop (R1), the Equity financing loop (B1) and the Debt financing loop (B2) portray the interactions between the physical and the financial processes of the firm and the two key decisions: investment and financing. Oil and gas price expectations are the basis for the desired capacity. When the oil and gas price is expected to rise (i.e., the expectations are positive), there would be increase in the desired capacity (in the form of a non-linear response) and vice versa. However, there are delays involved in this nonlinear process of determining the desired capacity based on oil price expectation. Based on this desired capacity and its associated costs, the desired capital budget is determined. The desired capital budget determines the capital expenditure, given the availability of capital to the firm. Capital expenditure is the capital made available through the internal financing (retained profit) and the external financing (debt and/or equity) to make the investments required to develop the new production capacity. Developing new production capacity includes the development of reserves and the capacity of equipment that both involve major delays. New production capacity is added to the stocks of reserves and the capacity. The quantity of oil and gas produced is dependent upon the developed reserves available, conditioned by the capacity to produce and the production time. Oil and gas revenues are determined by the production quantity and the current market price. Net income after taxes is available after meeting all the production costs and operating expenses. Dividends are paid from the net income after taxes and the rest is retained income. Retained income is added to total equity stock to make up the internal financing available to the firm for the firm's desired capital expenditure.

The reinforcing loop R1 represents the structure underlying the firm's endogenous growth, i.e., the firm's ability to earn profit and retain some of it to make investment from the retained earnings. The R1 loop represents the fact that the higher the production quantity and the market price of oil and gas are, the higher would be the net income be. If the firm pays a relatively smaller percentage of the net income as dividend and retains more earnings, it will accumulate more retained earnings to make available more internal financing for investments in new production capacity. The increased investments would lead to increased production capacity and higher production next time around, all else being equal. However, this cannot lead to unrestricted growth as there are balancing loops involved as well by way of the costs involved, - such as operational expenses and production costs. On the margin, production costs increase nonlinearly as the cumulative production increases, - thus reducing the internal financing available for investment over time to limit the exponential growth. Furthermore, if the desired capital budget is higher than the internal financing, the firm needs to raise the external financing, represented by two balancing loops namely, the Equity financing loop (B1) and the Debt financing loop (B2). These loops are balancing and portray the fact that if the firm has increased its debt and equity financing, the result would be an increased production quantity and, thus, an increased internal financing next time around, all else being equal. Thus, there would be need for less external financing next time around.

The reinforcing loop R2 represents the debt repayment loop. When there is an increase in new debt, the total debt increases and so do the repayments of debt. These repayments reduce the internal financing available, and the firm must reach a higher debt level next time around, all else being equal. R2 represents the increase in costs related to debt financing and this loop interacts with all other loops R1, B1 and B2 by influencing the internal financing. The increase in debt payments reduces the internal financing and increases the need for external financing next time around.

This simplified four loops representation of the system illustrates the prevalent complexity in the system´s structure that can be explained and analyzed better through circular reasoning resulting from a closed feedback loop perspective. Given these structural characteristics of the system, I have identified system dynamics to be a modeling, simulation, and analysis method suitable for my study of the firm value maximization issue. System dynamics makes it possible to model the structure that creates the behavior of the system, analyze the model, and draw conclusions based on the model as how to improve the behavior with a policy that causes such a complex system to exhibit a more favorable behavior.

5. Rational for using System Dynamics

System dynamics is a vehicle by which we may elicit the behavior resulting from a complex underlying structure. In system dynamics, a model is developed to represent the real system to mimic the problem behavior that we want to address and be able to investigate the behavioral effects of a variety of combinations of policies that altogether constitute a strategy for managing the system. So, an analysis of the system is performed by way of a model to identify and recognize the characteristics of the relationships between the causing structure and the resulting behavior of the system. This insight is instrumental in the development of effective policies. In a system dynamics model, the relationships between variables are represented both in the form of graphics and equations. While the graphics facilitates the effective communications between stakeholders, experts, learners and other interested parties, the associated equations constitute the mathematical representation of the system that allows for computer simulation that represents the dynamic behavior of the system over time.

A model may be subject to simulation under a variety of assumptions regarding the context in which the system operates. These assumptions, often represented in the model by way of parameter values or exogenous time series, constitute the scenarios under which the model is tested. Such tests are indicative of the behavior that the system, represented by the model, will exhibit under such circumstances, - including (1) under historic circumstances, for the purpose of explaining current behavior; and (2) under various policy options, for the purpose of predicting and explaining future behavior. They span the domain of behavior modes that the system may exhibit and allow for, say, the assessment of policy robustness. Assuming that the model is a valid representation of a real system, the conclusions drawn are considered valid also when applied to the real system. Indications of the contrary, typically leads to a reformulation of the model under development.

The problem addressed in this dissertation relates to a system structure involving accumulation processes as well as non-linear interactions between a variety of feedback loops within which these accumulation processes take place. The example depicted in the Figure 2 represents but a few such major loops. In such non-linear systems, the emerging behavior is typically produced by shifts in feedback loop dominance. The implication is that the governance of behavior shifts from one set of feedback loops (substructure) to another many times during the system´s lifespan. It is important for managers to recognize the potential for such shifts and to develop policies that prevent unfavorable shifts and take advantage of favorable ones in the pursuit of a robust, maximum firm value.

Note that a number of the loops identified and represented in the models developed to support this dissertation, is based on a representation of the mental models of the theorists that have, each, contributed with fragments of a theory that altogether contributes to our understanding of how the firm value is created and how we may influence its formation.

What makes system dynamics particularly well suited for the kind of analysis undertaken in this thesis, is its interdisciplinary nature: The firm value is created by the interaction of a number of sub-systems (such as the production, the marketing, and the distribution systems along with the financial system), - each addressed by a distinct scientific or managerial discipline and falling under a particular sector of our society. This calls for the comprehensive approach that ensures, completeness, consistency, and coherence, for which system dynamics has been specifically developed.

6. Model Description

The system dynamics model developed in this dissertation mimic the financial and physical processes that drive the behavior in the real system. The financial processes of the firm are modelled as co-flows to the physical processes and my use of system dynamics has enabled me to model the resulting accumulation of physical and financial resources as well as the relationships between the determinants of the physical and financial flow rates that typically form feedback loops that interact non-linearly. Two modules, the financial module and production module represent these two kinds of processes in the model. This two-module structure reproduces the historical behavior so well as to be considered a valid representation of the real system. Added is then a structure that represents the firm valuation, performed by using a discounted cash flow valuation (DCF) method.

The firm valuation module of the model represents the commonly used DCF method. The DCF assumes that the value of a firm today is the present value of all the future cash flows that the firm is expected to generate. As per DCF, the value of the firm could be estimated by discounting the future cash flows by applying an appropriate discount rate (Benninga, 2008). To the best of my knowledge, this explicit, nonlinear feedback representation of the of the application of DCF has not been undertaken previously. This is the brief description of the base model which has been explained in detail in Article 1.

The model has been developed by way of a step wise process and integrates theories into the model to perform the policy analysis. I studies explanations from published, behavioral theories and built the model structure accordingly to investigate the consequent dynamics. I included a conglomerate of the theories studied, investigated how the resulting model structure was able to produce the observed dynamics and explained why this such dynamics is produced by such a structure. Theories are based on perceptions of real system, they represent what is thought to be the causal, structural foundation for the observed, dynamic behavior. One major challenge in the formation of such theories is that the dynamic behavior over time tends to feed back to the underlying causal structure and modify the parameters that characterize such a structure to modify the relative impact that the various structural components (feedback loops) have on the subsequent dynamic behavior.

Given the base model in Article 1, that addresses the investment policy, the financing policy is modelled by integrating the major financing theories documented in the literature, namely the trade-off theory, the pecking order theory, and the agency cost theory into the system dynamics model (Article 2). The trade-off theory claims that the firms choose the percentage of debt/equity to balance the costs and benefits of debt and equity financing. The optimal debt-equity mix is the result of a trade-off between the interest tax shield and the financial distress costs of debt (Kraus & Litzenberger, 1973). The pecking order theory postulates, on the other hand, that firms prefer internal financing to external financing. When they go for external financing, debt is preferred first, and the equity is issued only as a last resort. The pecking order theory´s key assumption is the existence of asymmetric information; - that the managers are better informed than the investors. When a firm issue equity, it signals to the market that the shares are overpriced. Issuing debt could also create information problems, because creditors seek privileged access to some of the information, not publicly available, about the borrowing firm to secure their credit risk. Therefore, firms prefer internal financing to debt and debt to equity. This theory provides explanation as to why profitable firms in an industry have low debt ratios (Myers and Majluf, 1984). Agency cost theory focuses on reducing the agency costs that arise because of the conflicts between the shareholders and the managers while making the financing mix decisions about debt-equity percentages. The theory claims that the optimum financing mix is the settlement that reduces the agency conflict and consequent costs (Jensen and Meckling, 1976). These theoretical explanations of financing mix decision have been integrated into the system dynamics model to endogenize the financing policy. The details regarding the feedback loop structure and analysis of the policy and scenarios are provided in Article 2.

After integrating the financing policy into the model, the next step was to endogenize the dividend policy (Article 3). The dividend policy is like a puzzle in the literature and there are a large variety of theories that predict the positive impact of dividend payout on firm value such as the signaling theory, the agency theory, and the free cash flow theory. I have incorporated the factors influencing the dividend policy as explained by these theories that predict the positive impact on firm value. The tax related theories that predict the negative impact of dividends on firm value are assumed to be captured implicitly by the tax rates present in the model. Signaling theory explains that the announcement of an increase in the dividend by the firm is a positive signal to the market about the prospects of the firm. Therefore, increasing the dividend influences the firm value positively (Miller and Rocks, 1985). Agency cost and free cash flow theories support the positive impact of an increase in the dividend as it reduces the cash flow under management control and mitigate the agency problems (Jensen, 1986). These theoretical explanations have been integrated into the system dynamics model to endogenize the dividend payout policy. The reason for integrating multiple theories to analyze the policies is that one theory is a behavioral explanation of the system´s behavior but provides only a partial view. Therefore, we need to synthesize one theory with another one to provide an enhanced explanation of the dynamic behavior produced by the underlying systems structure.

After integrating the three major policy decisions taken by the policy makers of the firm, I have added one factor, exchange rate, that is beyond the control of the firm but influences the firm value. A module for exchange rate determination and forecasting has been integrated into the model as the next step to assess the impact of changes in exchange rates, caused by changes in macroeconomic factors, on the firm value (Article 5). I have integrated the fundamental theoretical explanations of exchange rate dynamics; - the purchasing power parity and the interest rate parity. As per purchasing power parity theory, equilibrium exchange rate between the two currencies is determined by the ratio of price levels of the same basket of goods and services in two countries (Taylor et al, 2004). When there is any change in the price of goods or services, the exchange rate must respond accordingly to return to equilibrium. If the domestic price level increase, the exchange rate for that country must depreciate to reach the equilibrium as predicted by the purchasing power parity theory. Interest rate parity theory explains the relationship between the interest rates and the exchange rate of an economy. The equilibrium exchange rate is attained when the expected return on local investments is equal to the expected return on foreign investments (when converted to the local currency), implying a no arbitrage condition (Dabrowski et al., 2014). These fundamental theories of exchange rate explain the long-term dynamics of macroeconomic factors that determine exchange rate. Based on these theories and using the system dynamics method, I have modeled these relationships through accumulation processes forming the expectations about the dynamics that drive the forecasts, feedback causalities and nonlinear interaction between the interest rate, inflation, oil prices, imports, and exports. Given this model structure, the impact of exchange rate dynamics on the firm value of Equinor is reported in article 5.

7. Overview of Articles 1-5

This dissertation is based on five articles reviewed in this section.

Article 1:

Khan, A., Qureshi, M. A., & Davidsen, P. I. (2020). How do oil prices and investments impact the dynamics of firm value? *System Dynamics Review*, *36*(1), 74-100.

Article 2:

Khan, A., Qureshi, M. A., & Davidsen, P. I. (2020). A system dynamics model of capital structure policy for firm value maximization. *Systems Research and Behavioral Science*.

Article 3:

Khan, A., Qureshi, M. A., (under review) Policy analysis to maximize the Firm Value: Performing Firm Valuation using system dynamics. Manuscript submitted for publication in Journal of Modelling in Management.

Article 4:

Khan, A. (2020). A System Dynamics Model of Exchange Rate Determination and Forecasting. *SEISENSE Journal of Management*, *3*(4), 44-55.

Article 5:

Khan, A., Qureshi, M. A., (under review) Modelling the dynamics of firm valuation: An assessment of impact of exchange rate fluctuations on firm value using system dynamics. Manuscript submitted for publication in Journal of Simulation.

Article 1: How do investments and oil prices impact the dynamics of firm value?

Primary objective of a business is to create and increase the firm value. Valuation is the central topic of corporate finance and investment is the key element of value creation process. Value is created when the capital invested earns more than the cost of capital (Koller et al., 2005). Thus, the investment policy consideration is crucial in the firm valuation. Article 1 reports the impact of investment policy on the firm value (market price per share) in the presence of uncertain oil prices and proposes policies that enhance the firm value.

The article develops a corporate planning model for Equinor using system dynamics to facilitate the policy design. A variety of tools is being used by the firms to devise the policies in the strategic planning process. However, many times these tools lack in dealing with the dynamic complexity present in the environment where these firms operate. Therefore, system dynamics is used in this study that integrates the different corporate functions of the firm to facilitate the policy design. System dynamics has enabled me to account for a holistic view of the business and the involved key factors through modelling the system.

The model includes oil and gas exploration and production processes, and a firm valuation module based on the discounted cash flow valuation method along with the key financial accounts and financial policy decisions. Integration of production and financial modules along with firm valuation module provides an engine that is used to test the oil and gas price scenarios and investment policies. Oil and gas price scenarios test the impact of changes in oil and gas prices on firm value and analyze as to which investment policy would perform better under what scenario.

Simulation results reveal that the positive development in oil prices in the future would lead to increased investments and reduced cash flows. This reduces the total firm value in the early 20 years of the simulation period, but the total firm value increases thereafter because of returns from those investments.

Market price per share is reduced when there is an increase in investments and vice versa. This is because increase in investments requires more capital and thus increase in number of shares issued and consequently decrease in market price per share. The simulation results reveal that lowering the volume of investments in future than the business-as-usual leads to increased market price per share.

Article 2: A system dynamics model of capital structure policy for firm value maximization

Article 2 explores the financing policy and its impact on the firm value. Firm value, being the primary objective of the firm, is significantly influenced by the financing choices of the firm as they define the costs of capital. Financing mix refers to the proportionate composition of debt and equity utilized by a firm to finance its investments. An optimal debt-equity mix is the debt-to-equity ratio which minimizes the cost of capital and maximizes the returns.

Firms can finance their investments by issuing debt or equity, but mostly a mix of debt and equity is preferred. Debt offers the advantage of tax deductibility but also increases the risk of bankruptcy at the same time. Financing policy involves factors whose effects are long-term and interrelated with many other key factors. As the objective of every firm is to maximize the value, the consideration of costs and benefits associated with debt and equity is important to reach an optimal financing mix. Thus, the research question for this study is how does the choice of financing policy impact the firm value?

Financing policy design is one of the most debated topics in corporate finance literature due to its importance and complexity in determining the firm valuation. There are many theoretical frameworks that try to explain the relationship between financing decision and firm value, starting from Modigliani and Miller's irrelevance theory which claimed that if there are no taxes and transaction costs and there is perfect information among players, firm's financing mix decisions is irrelevant to the firm value. However, in the presence of taxation and transaction costs and imperfection in capital markets, the financing mix became relevant in the firm value determination which later led to many theories explaining the financing decision. Major theories include the trade-off theory, the pecking order theory, and the agency theory. The trade-off theory explains that firms decide their capital mix while balancing the tax-shield benefits with bankruptcy costs of debt financing. The pecking order theory ranks sequentially the sources a firm can utilize to meet the financing requirements and claims that firms prefer internal financing to external financing and opt for equity as a last choice. The agency theory accounts for consideration of agency costs in financing decision.

The system dynamics model developed in article 1 is the base model for article 2. For article 2, the financing decision is endogenized as per the theories described above. The model also incorporates the production processes for renewable energy as Equinor is involved in new energy solutions such as wind and solar. The article tests a variety of scenarios and policies and their combinations including tax rate scenarios, theory testing (which theory outperforms between trade-off theory and pecking order theory), financing policy testing in presence of tax rate scenarios and financing policy testing in presence of new energy solutions.

Simulation results reveal that increase in debt percentage in financing mix leads to increase in market price per share and vice versa. Testing the theories reveals that the pecking order theory outperforms the trade-off theory. Tax rate scenarios reveal that decrease in tax rate significantly increases the market price per share and vice versa. Adding new energy solutions to the model and testing the financing policy also confirms the results as obtained before, that increasing the percentage of debt in the financing mix increases the market price per share. Currently, the case firm is conservative in raising the debt, however, the results suggest that the firm can benefit from increasing the debt ratio in its financing mix to increase the firm value.

Article 3: Policy analysis to maximize the firm value: performing firm valuation using system dynamics

Article 3 explores the corporate dividend policy impact on the firm value to identify the policy which maximizes the firm value. This article also tests the combinations of three major corporate finance policies, namely investment, financing, and dividend policy to assess their impact on the firm value in the presences of assumed scenarios for oil and gas prices and tax rate.

The article builds on the model developed in article 2 and endogenizes the dividend policy based on the relevant theories for dividend pay-out. Dividend policy involves the decision for dividend payment which is the primary stock return to the shareholders. While devising this policy, every firm faces a dilemma, either to retain free of cost financing where shareholders would not get anything or distribute earnings to the shareholders and arrange capital with cost. Normally, the firms maintain a balance between the two approaches and devise the strategy which retains some portion of earnings and distributes the remaining earnings to the shareholders, which is also the case with Equinor.

Role of dividend pay-out policy in the firm value determination is like a puzzle in the literature. Many theories have tried to explain the relationship between the two. The irrelevance theory postulates no impact of dividend pay-out on the firm value. The signaling theory, the agency theory and the free cash flow theory propose a positive impact of an increase in dividend pay-out on the firm value whereas tax related theories propose a negative impact of an increase in dividend pay-out on the firm value.

The simulation results reveal that lowering the dividend payments from the base case leads to increased firm value. Investment policy and financing policy results suggest lowering the volume of investments and increasing the debt ratio have positive impact on the firm value. Testing various combinations of policies and scenarios reveal that the same policies give the maximized firm value under optimistic oil prices and reduced tax rates. However, under pessimistic oil price expectations, opting for conservative policies for investment, financing, and dividend pay-out results in increased firm value. The study has implications for policy makers and provides a strategic planning model where impact of the policies and the scenarios could be tested. The study concludes that the impact of the policies must be considered in combination for achievement of value maximization objective.

Article 4: A system dynamics model of exchange rate determination and forecasting

Article 4 represents a system dynamics model for exchange rate determination and forecasting. The purpose is to develop a model that determines and forecasts exchange rate to assist in the long-term investment decisions. The system dynamics model for determining and forecasting exchange rate is based on the fundamental theories of exchange rate, namely purchasing power parity and interest rate parity, which claim that the macroeconomic factors' changes explain the long-term exchange rate movements. The model incorporates the feedback relationships between the exchange rate and the interest rate, inflation, terms of trade (exports, imports), per capita income and oil prices. The model accounts for the non-linear and complex relationships among the factors to determine the Norwegian kroner per US Dollar, the exchange rate between the two currencies, to provide a portable model which can be utilized to forecast the long-term movements of exchange rate between any two currencies.

The simulation results reveal that the model can mimic the long-term movements of exchange rate in the past, and thus provides reliable long-term forecasts. The simulations under different scenarios for the macroeconomic factors represent the impact of any change in a factor, on the behavioral outcome of different related factors, providing interesting insights. The model has implications for individuals, businesses, and the Government as they are all influenced by the exchange rate movements. The model explains and provides a simplified and generic explanation of the exchange rate determination based on fundamental macroeconomic factors and can be used to determine and forecast exchange rate for different currencies for long-term perspective.

Article 5: Modelling the dynamics of firm valuation: An assessment of impact of exchange rate fluctuations on firm value using system dynamics

Article 5 analyses the impact of the exchange rate dynamics on the firm value. The paper merges the model developed in articles 4 with the model developed in article 3 to endogenize the exchange rate for the firm valuation. The system dynamics model developed and simulated in this study includes modules for physical and financial processes for Equinor, firm valuation module and exchange rate determination and forecasting module. As the case firm is an internationally operating firm, the firm value is expected to be significantly influenced by the exchange rate movements.

The study uncovers this impact of exchange rate fluctuations on firm value through changes in macroeconomic factors. Scenarios have been devised for macroeconomic factors including interest rate, inflation, terms of trade and oil prices. The simulation results reveal that a depreciation of NOK against US dollar leads to a decrease in the market per share, which is quite counter intuitive. The results explain that although the depreciation of domestic currency (NOK) increases the firm's profits, however translated through the policies of the firm a weak NOK has a negative impact on the firm value. The explanation is as follows. When the firm has increased profits, the investment volume increases, decreasing the available free cash flows and consequently decreasing the market price per share and vice versa. The study implies that consideration of foreign exchange dynamics while devising the policies will improve the robustness of policies as well as reduce the volatility in the policy outcomes.

8. Conclusions:

This dissertation contributes to the debates in corporate finance on firm value maximization. The dissertation uses system dynamics as a method. Given the system dynamics model structure, discussed in the model description above, the dissertation contributes to the firm value maximization issue in multiple ways:

- Conceptualization of the theory and principles-based framework of corporate finance and translating it into a formal model specification for a firm's strategic planning process (see article 1), offers a valuable mean by which one may connect a range of elements of the firm valuation maximization process. Article 1 identifies and represents several core physical and financial feedback processes of the firm that determine the value and how that value would develop over time, given the current policies and assumptions. The visual representation of these feedback loops and the equations thereof (in appendix) make the interrelationships between the financial and physical factors explicit and thus more easily accessible for future research. Future studies, may build upon the causal framework of this research by adding specific details to it, challenging or expanding it.

- The dissertation contributes by providing a case based financial planning model for a firm. Most of the related work, done so far in this field, consists of generic and over-simplified system dynamics models. The dissertation provides a real case firm model, including co-flows for both the production and the financial processes. This leads to a better representation of the system and adds to the utility of the work because the model can be used as a template by any other firm.

- The dissertation contributes to the debate on the impact of the investment policy on the firm value by providing significant insights into the behavior of the factors involved and their interactions. The results highlight the long-term and short-term tradeoff resulting from an investment policy. Testing the investment policy alternatives, given the uncertain oil prices, reveals that when the firm increases the volume of investments, free cash flows decrease, and the total value of the firm decreases over the first twenty years of the simulation period. However, the total value of the firm increases thereafter when investments yield returns after some delays, - and vice versa. The reason being that when the firm increases the investments, lesser free cash flows are available, and thus the market price per share decreases, - and vice versa. Another reason for a decrease in the market price per share to take place when investments increase, is the increase in the number of shares so as to raise additional equity to finance the capital expenditure for new investment (Figure 3 Article 1 provides explanation). The results imply that the formation of the investment policy needs consideration of this short-term and long-term impact on the total value of the firm.

The dissertation contributes by highlighting the complexity prevalent in the system while devising the investment policy that is often overlooked in discipline specific approaches (such as Del Brio et al, 2003) where commonly only a few factors are considered, and the others remain silent or are ignored. To the best of our knowledge, such detailed analysis of an investment policy is lacking in literature, and there are very few precedents (Qureshi, 2007). This dissertation provides an exemplary model that represents the structure responsible for the firm behavior, incorporating a comprehensive set of factors.

- The dissertation contributes to the debate on the impact of financing policy on the firm value (Article 2). As described in the model portrayal above, the model integrates the two major theories, namely the pecking order theory and the trade-off theory. The two theories are modeled, and the resulting simulations are compared to determine which theory performs better. The results reveal that the pecking order theory outperforms the financing policy in terms of explaining the firm behavior. This is in line with the theoretical explanation because the pecking order theory is an explanation of why the case firm has low debt to equity ratio despite being profitable and having larger debt capacity. Testing various debt policies reveals that increasing the debt percentage in the financing policy leads to an increased firm value and the market price per share. I have also tested the scenarios for various tax rates to analyze how any changes in tax rate would influence the policy outcomes. An aggressive debt policy, which assumes the increased debt percentage in the financing mix, proves to be the most robust financing policy in all scenario and policy simulations.

  The dissertation contributes to the debate on financing policy with reference to the firm value. Most of the literature on testing the financing theories focuses only on financing policy (Qureshi et al., 2015) or on the impact of financing policy on the firm value while ignoring the other factors (Bilafif and Ibrahim, 2019). This dissertation comprehensively integrates other factors as well, for example, investment policy, dividend policy, and exchange rate, while accounting for accumulation and non-linear feedback relationships in its analysis of the impact of the financing policy on the firm value.

- The dissertation contributes to the debates on the dividend payout policy. It articulates that the dividend decision should not be taken in isolation, but in combination with the investment and the financing decisions and depicts such a holistic view by integrating the multiple theories to endogenize the dividend decision (Article 3). The simulation results for the dividend policy alternatives challenge the agency cost theory and the cash flow explanation predicting the positive impact of an increase in dividends on the firm value (Ghosh and Sun, 2014), so as to reveal that a decrease in dividend payout ratio increases the market price per share. By providing cause and effect explanation for the impact of the dividend decision on the firm value, the study contributes to the literature and demonstrates that paying out dividends reduces the free cash flows and thus the firm value.

- The dissertation contributes to the debates on investment, financing, and dividend policies by simulating the impact of policies´ and scenarios´ combinations (Article 3). These policies come together, i.e. synergize, to determine the firm value. Thus, these policies need to be devised while considering their combined impact rather than in isolation based on their partial and individual policy outcome, i.e. they must be coordinated. Testing the possible combinations of investment, financing, and dividend policies under a variety of scenarios. oil price and tax rate provide interesting insights into the firm value dynamics resulting from the combined policy outcomes. Assuming the optimistic (high) oil price and reduced tax rate scenario, reveals that the combination of a conservative investment policy, an aggressive financing policy and a conservative dividend policy altogether maximizes the firm value. The base case oil price scenario, which assumes oil prices will continue into the future and a lower tax rate scenario will prevail, reveals that the combination of a conservative investment policy, a base case financing policy and a conservative dividend policy altogether outperforms all other combinations. Given the pessimist (low) oil price scenario and a decreased tax rate, testing reveals that the combination of all the conservative policies maximizes the market price per share. The dissertation provides evidence that the policy assessment under various scenarios leads to different policy conclusions with respect to the maximization of the firm value. Opting for maximizing policy combinations, given specific scenarios described by the key parameter values leads to an increased market price per share. Therefore, these policies need to be devised while considering their combined impact rather than the individual ones. Hence, this dissertation contributes by implying that a comprehensive consideration of factors and policies that influence the firm value is a prerequisite to the firm value maximization endeavors.

- The dissertation presents a system dynamics model for exchange rate determination and forecasting based on fundamental theories of exchange rate determination as discussed in the model description (Article 4). The model accounts for the accumulation processes in the formation of expectations regarding the exchange rate, the feedback loops and the nonlinear interactions between various macroeconomic factors and the exchange rate. The simulation results reveal that the model can reasonably well replicate the long-term exchange rate between Norwegian Kroner (NOK) and US dollar (USD). The dissertation validates that the fundamental theories of exchange rate, namely the purchasing power parity and the interest rate parity, are both capable of explaining the long-term exchange rate dynamics. Simulation results provide support for the postulated relationship by the purchasing power parity and the interest rate parity so as to reveal that an increase in the domestic interest rate leads to an appreciation of local currency and vice versa; and an increase in inflation in a country leads to depreciation of the local currency. In Norway, being an oil exporting country, oil price fluctuations play a major role in determining exchange rate fluctuations. An increase in oil prices from the base case leads to appreciation of local currency (NOK) and vice versa. The dissertation contributes to the literature by providing a portable exchange rate module that can be used to understand the exchange rate dynamics and can be applied to any oil exporting economy after calibration.

- The dissertation contributes to the debates on the impact of exchange rate fluctuations on the firm value (Article 5). The module for exchange rate determination has been added to the base model to endogenize the exchange rate by way of macroeconomic factors. Then, the impact of the exchange rate on the firm value is estimated through the financial and physical operations of the firm. The simulation results reveal that when the domestic currency (NOK) appreciates, market price per share increases and vice versa. The results are different from many studies reported in the literature that claim that a depreciation of the local currency positively influences the firm value (Mozumder et al, 2015). This dissertation contributes to the literature by providing, on the other hand, the feedback based reasoning behind the results in our case firm; - that although the depreciation of the local currency increases the profits available to the firm, the policies of the firm come into play. When the profits of our case firm increase, the investments also increase, and, consequently, the free cash flows decrease, - resulting in reduced market price per share. Thus, the dissertation reports that the value for our case firm decreases when there is a depreciation in the local currency (NOK). Alternatively, the value of our case firm increases when there is an appreciation in the local currency (NOK). These results validate the implications from the policy analysis reported earlier that a comprehensive consideration of all aspects in the planning and policy design are a prerequisite for achieving the stated corporate objectives. Failure to consider all aspects might constitute an obstacle to the achievement of the firm value maximization objective.

Table 2 provides the answers to the major research questions and provide the practical, theoretical, and methodological implications from the dissertation.

Table 2. PhD Dissertation Overview (Results)

Study Purpose	The dissertation contributes to the debate on firm value maximization by developing a system dynamics model for corporate financial planning, aimed at firm value maximization to facilitate the decision making through policy design and scenario analysis.				
Main research Question	How to maximize the firm value through corporate finance policies, namely investment, financing, and dividend policies, given the impact of exchange rate through macroeconomic factors?				
Papers	Paper 1	Paper 2	Paper 3	Paper 4	Paper 5
Title	How do oil prices and investments impact the dynamics of firm value?	A system dynamics model of capital structure policy for firm value maximization	Policy analysis to maximize the firm value: performing firm valuation using system dynamics	A System Dynamics Model of Exchange Rate Determination and Forecasting	Exchange rate and firm value: Valuation using system dynamics
Results	The simulation results for investment policy suggest that lower volume of investments as compared to base case, increases the market price per share. However, in long- run, higher volume of investments increases the total value of the firm.	The results for financing policy demonstrate that as percentage of debt increases in the financing mix, the firm value per share increases and vice versa.	The study concludes that the best combination of policies for the firm is conservative investment policy, aggressive financing policy and conservative dividend policy.	The simulation results reveal that the factors, as per their predicted relationships by the theory, can replicate reasonable long-term exchange rate behavior. However, some short-term variations might be caused by some other factors or noises.	Study reports results that exchange rate fluctuations significantly affect the value of the case firm. An appreciation of NOK currency leads to increase in market price per share and vice versa.

Implications	The managers of the 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.	The firm is conservative in its debt policy; however, the results suggest that the firm can benefit from increased debt ratio in the financing mix to enhance the firm value per share.	The study has implications for policy makers, investors, and stakeholders for understanding the firm value management, policy design and valuing a business.	The model explains and provides a simplified and generic model of the exchange rate determination based on fundamental macroeconomic factors and can be used to determine and forecast exchange rate for currencies for long-term perspectives.	The study has implications that the consideration of foreign exchange is crucial in policy design and financial planning for the firms.
Answer to main research question	To answer the research question, a step wise system dynamics model has been developed for corporate financial planning for an international firm in energy sector. Five articles are included in the dissertation where each article addresses one component of the major research question. The model simulates and analyses various scenarios and policies and their combinations. Simulation results suggest that conservative investment policy, aggressive debt policy and conservative dividend policy increase the firm value. Analysis of exchange rate reveals that appreciation of domestic currency leads to increase in market price per share.				
Theoretical Implications:	Theoretical contributions of this dissertation are that the study translates the theoretical frameworks of corporate finance and international finance into a system dynamics model. The relationships among the factors are represented through feedback loops modelled as stocks and flows as predicted by the theoretical frameworks. Free cash flow valuation method has been modelled through principles of system dynamics and corporate finance to contribute to the debates on valuation from systems perspective. These theoretical contributions have implications for stakeholders to comprehend the accumulation processes and nonlinear feedback interactions among the factors prevalent in the real system.				
Practical Implications:	The dissertation has implications for policy makers, investors, managers, and all other stakeholders involved in one way or the other in decision making and valuation. The dissertation provides useful insights into the causal relationships among the corporate finance policies and firm value and the role of macroeconomic factors in the policy outcomes.				
Methodological Implications:	The dissertation provides a comprehensive system dynamic based model for corporate financial planning for an international firm. The model is developed for a case firm, thus incorporates details as compared to the most of simplistic and generic models present in system dynamics literature. The model incorporates physical and financial co-flows for an oil and gas firm which provide insight to the composite operations of the firm. The model provides a template model for financial planning and valuation which can be utilized specifically by any oil firm and generally any other firm after customizing their physical operations.				

9. Literature

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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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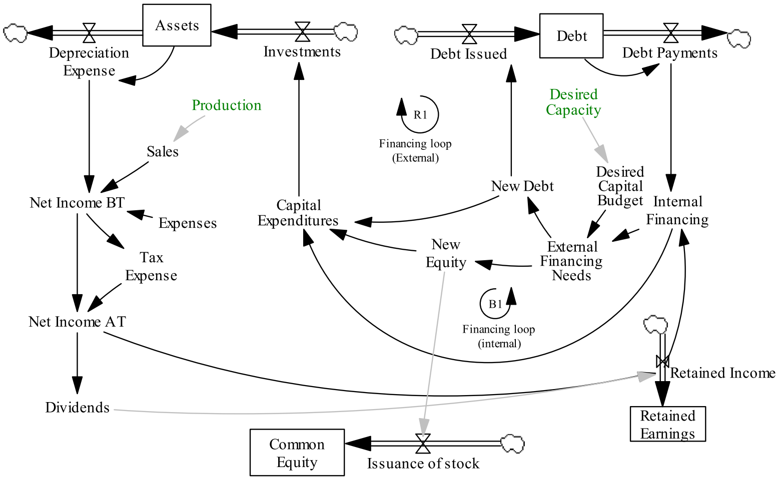

Fig. 1. An overview of the simplified feedback structure of the financial module [Color figure can be viewed at wileyonlinelibrary.com]

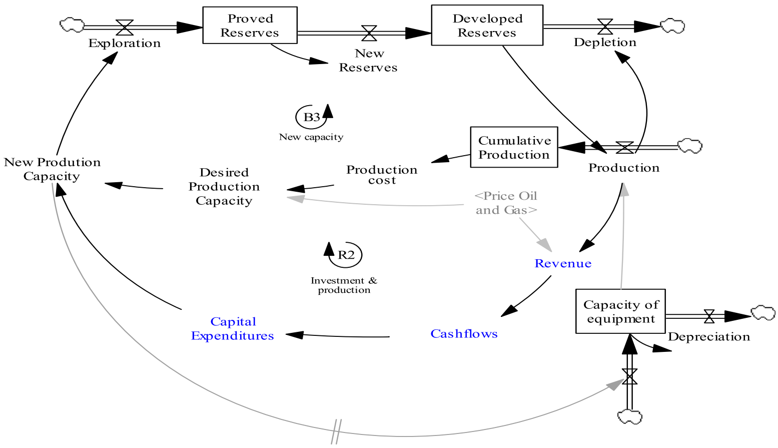

Fig. 2. An overview of the simplified feedback structure of the production module [Color figure can be viewed at wileyonlinelibrary.com]

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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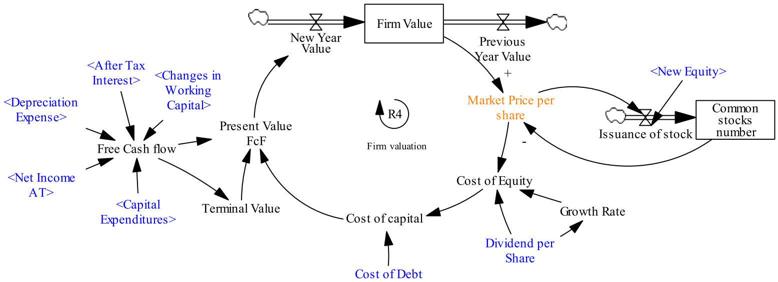

Fig. 3. An overview of the simplified feedback structure of the valuation module [Color figure can be viewed at wileyonlinelibrary.com]

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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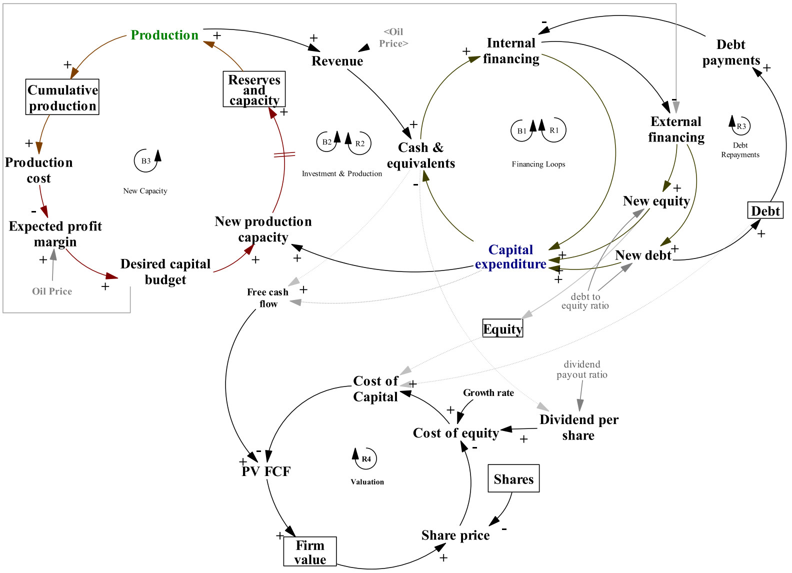

Fig. 4. An overview of the simplified causal loop diagram of the model [Color figure can be viewed at wileyonlinelibrary.com]

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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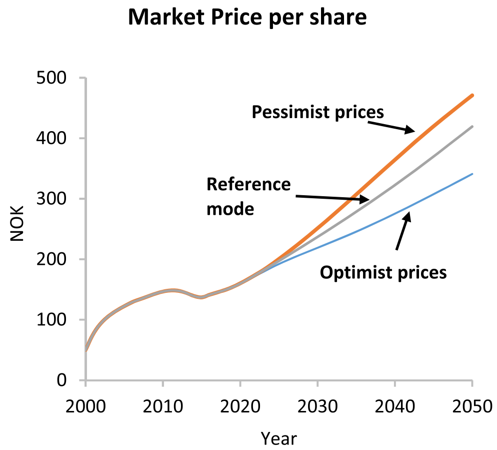

Fig. 6. Market price per share under the three oil and gas price scenarios and BAU case [Color figure can be viewed at wileyonlinelibrary.com]

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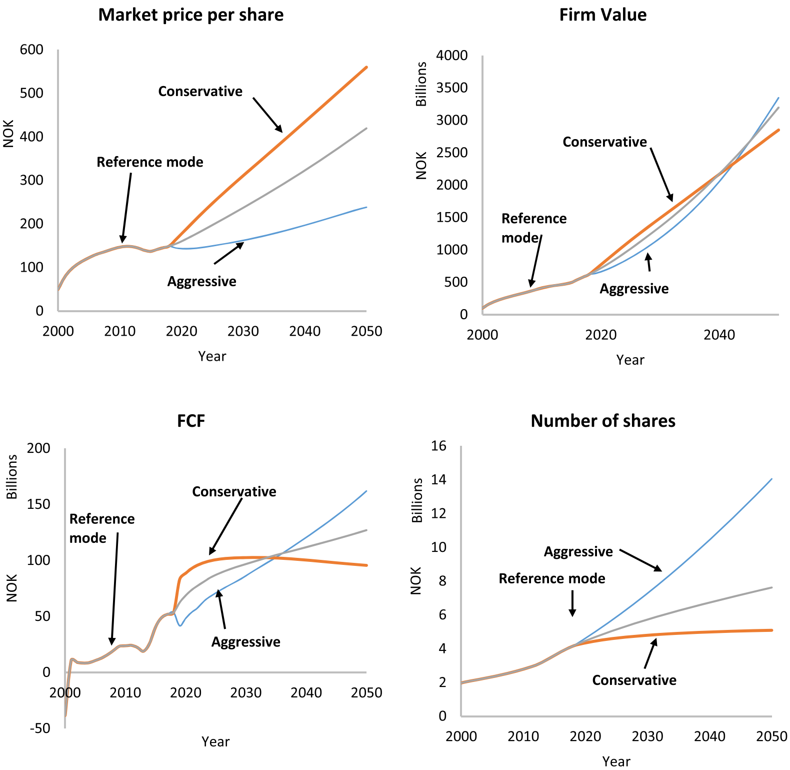
Fig. 7. Simulation results with investment policies under the reference oil and gas price scenario [Color figure can be viewed at wileyonlinelibrary.com]



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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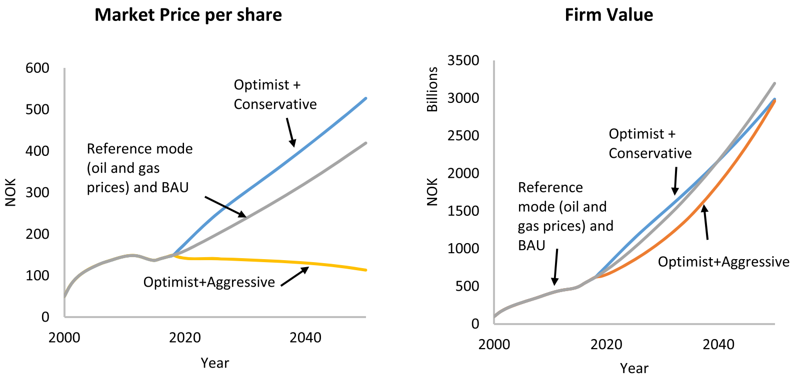

Fig. 8. Market price per share and firm value resulting from optimistic oil and gas price scenario and investment policies compared to the BAU under the reference oil and gas price scenario [Color figure can be viewed at wileyonlinelibrary.com]

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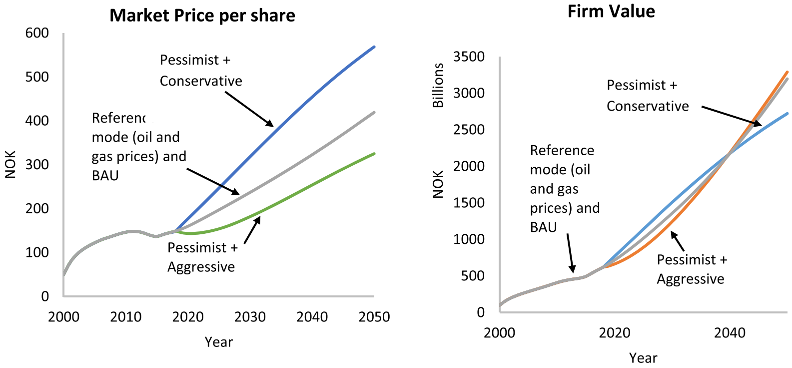
Fig. 9. Market price per share and firm value resulting from pessimistic oil and gas price scenario and investment policies compared to the BAU under the reference oil and gas price scenario [Color figure can be viewed at wileyonlinelibrary.com]



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

Aima Khan is a PhD scholar at the system dynamics group, "University of Bergen", Norway. She is a lecturer at "The women university", Multan, Pakistan. She holds MBA degree and Master of Science (MS) with specialization in finance. Her PhD project focuses on firm valuation and policy analysis using system dynamics. Her major area of interest for research involves finance using simulation as well as econometrics. She has publications scientific journals.

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RESEARCH PAPER

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A system dynamics model of capital structure policy for firm value maximization

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Abstract
The complexity surrounding the maximization of firm value agenda demands a comprehensive causal model that effectively embeds the intertwining relationships of the variables and the policies involved. System dynamics provides an appropriate methodology to model and simulate such complex relationships to facilitate decision making in a complex business environment. The objective of the study is to analyze the impact of capital structure policy, being a key managerial decision, on the firm value. For this purpose, the study develops a system dynamics-based corporate planning model for an oil firm, including the operational as well as financial processes. Various scenarios and capital structure policies have been designed and simulated to identify the policy that helps in increasing the firm value. The results demonstrate that increase in debt percentage in capital structure mix increase the firm value.

KEYWORDS
capital structure policy, financing, firm value, oil and gas production, simulation, system dynamics

1 | INTRODUCTION

The purpose of this paper is to investigate the potential impact of capital structure policy on the firm value to identify the optimal capital structure policy. Creating and maximizing firm value is the primary goal of a firm (Brealey, Myers, & Marcus, 2012). One of the tools to achieve this objective is framing the capital structure policy resourcefully (Lawal, 2014). Capital structure policy is one of the most debated topics in corporate finance literature due to its complexity and strategic importance in determining the firm value (Berk & DeMarzo, 2007; Brigham & Ehrhardt, 2002). Capital structure refers to the mix of financing sources of the firm to meet the financial requirements (Niu, 2008). Leverage irrelevance theory was put forward by Modigliani and Miller (Modigliani & Miller, 1958) that in the absence of taxes and transaction costs and perfect information among players, the value of the firm is indifferent to the choice of capital structure mix. Their later work (Modigliani & Miller, 1963) acknowledged the significance of taxes and transaction costs since real capital markets are not perfect. Tax assumption was later relaxed (Kraus & Litzenberger, 1973) proposing the trade-off theory (TOT) which recommends that firms decide their capital structure mix through the balance between the tax-shield benefits and bankruptcy costs associated with debt financing. Agency theory (Jensen & Meckling, 1976) advocates that agency costs arising due to conflict of interest between ownership and management influence the corporate financing choices. Pecking order theory (POT; Myers & Majluf, 1984) postulates the sequencing

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of the financing choices wherein firms prefer internal financing to external financing, equity being the last choice. Neither the theories nor the empirical research have arrived a consensus and there is an ongoing debate whether higher debt increases or decreases the firm value (Bilafif & Ibrahim, 2019; Li, Niskanen, & Niskanen, 2019). This study address the following research question: How the capital structure policy impacts the firm value per share? To address this question, this study develops a system dynamics model by taking a Norwegian oil firm as the case firm to identify the capital structure policy that enhances the firm value per share. The model incorporates the causalities surrounding the capital structure policy as postulated by the theories and test various capital structure policies under different scenarios to analyse their impact on the firm value.

The reason for using system dynamics for the analysis is that system dynamics facilitates the development of complex models and allows integration of nonlinearities and feedback loops existing in the real system (Richardson, 2011; Sterman, 2000). System dynamics is based on four guiding principles including the theory of information feedback systems, knowledge about the real system and decision-making processes, computer-based simulation models to represent mathematically the realistic systems, and iterative experimental modelling approach towards understanding the complex systems (Forrester, 1961). Capital structure policy involves variables intertwined with many other decision variables in feedback relationships that have long-term effects. The conflicting views grounded on internal characteristics of a firm and potential response of the market lead us to develop an integrated system dynamics model that allows us to experiment with different theoretical frameworks to understand dynamics of capital structure policy.

We employ the discounted cash flow valuation method (DCF) as a theoretical lens to perform the valuation. The DCF is based on the premise that value of a firm today is the present value of cash flow stream the firm is expected to generate in future (Ross, Westerfield, & Jordan, 2008). The DCF valuation is based upon two major elements: free cash flows (FCF) and weighted average cost of capital (WACC) (Gardner, McGowan, & Susan, 2012). Higher expected FCF would lead to higher valuation of the firm, ceteris paribus, and lower WACC would lead to higher valuation holding FCF constant. Thus, the role of financial management is to devise policies that increase the FCF to the firm and effectively reduce the WACC to increase the firm value (Gardner et al., 2012). Capital structure policy affects the firm value by having a potential significant impact on FCF as well as WACC (Brigham & Ehrhardt, 2002).

Our study embodies significance because our simulation model incorporates all the relevant operational and financial variables that embeds intertwining relationships in an effort to mimic the performance of all functional areas at an aggregate level that determine the firm performance. Separation of financial and operational decision variables leads to suboptimal decision making (Berman, Sanajian, & Abouee-Mehrizi, 2012) as they both contribute together to determine the firm performance and value. Thus, a comprehensive planning model that integrates operational as well as financial decisions and complies with the principles of accounting and corporate finance would lead to improved managerial decisions that would drive business productivity and success. This allows us to experiment with a variety of different scenarios and policies and does not constrain us to the empirical data that effectively limits the modelling choices.

Along with introduction in this section, we organize rest of the paper as follows. Section 2 represents the method. Section 3 characterizes the model structure. Section 4 validates the model. Section 5 develops the scenarios and presents the policy design whereas Section 6 provides the results and their discussion. Finally, Section 7 puts forward the conclusions drawn and policy implications. The study furnishes references at the end.

2 | METHOD

We used Vensim® software to develop the system dynamics model by using publicly available quantitative and qualitative data and other relevant information from different sources such as the firm's annual reports and its website, industry reports along with relevant academic literature. System dynamics is useful in developing the planning models for firms to understand the behavior, solving the problems, decision making, and analysis (Helo, 2000; Lyneis, 1980; Suryani, Chou, Hartono, & Chen, 2010). System dynamics is based on generating the behavior from the structure mimicking the real system, and as such, it is an appropriate tool to perform the firm valuation and policy analysis. The model is calibrated to match the real behavior in the past, and then it is simulated into the future to generate results. Forecasts generated from a calibrated model are more reliable than other approaches such as statistical models (Lyneis, 1980). The modelling process specifies assumptions and all-encompassing variables explicitly (Morecroft, 2015; Schoemaker, 1993) that facilitate understanding of the relationship between structure and behavior (Forrester, 1973) leading to comprehensive policies that ensure consistence and coherence.

3 | MODEL STRUCTURE

The system dynamics model developed for the purpose of this study uses Equinor, an international oil and gas firm based in Norway and listed in 2001, as the case firm. The model is simulated for a period of 50 years starting from year 2000. This allows sufficient time period not only for the model calibration using historical data but also to analyze expected behavior long into the future considering long-term nature of the investments in oil industry. The model comprises of three modules: financial, production, and valuation. Financial module includes integrated financial statements and financial decision variables. Production module comprises physical production processes of oil and gas, and renewable energy. Physical processes account for the delays and nonlinearities involved in investments into physical assets and construction process and ultimately production from these fixed assets (Halawa, Abdelalim, & Elrashed, 2013). The firm valuation module estimates the firm value based on DCF valuation method.

A simplified causal loop diagram in Figure 1 highlights the major loops involving financial variables and valuation. Capital expenditure into the fixed assets define the level of operations and consequent profitability of the firm. Taking the financial management approach, the firm focuses on the quantity of investments and cash flows at the first place (Qureshi, 2007). Investment decisions depend upon the availability of the capital that depends on the financing capacity and policy of the firm.

Internal financing and external financing loops summarize the investment, production, and cash flow processes. For an oil firm, capital expenditure includes investments into exploration activities to discover oil and gas reserves and production activities to produce oil and gas from the proven reserves. Cash is calculated based on the sales and expenses of the firm. If the firm has more cash available internally, it needs less of external financing. The higher the external financing needs, the higher would be the level of debt and equity. Once the required capital needs are estimated, the firm raises external funds with a mix of debt and equity based on financing decision.

3.1 | Financial module

Financial module incorporates the financial activities of the firm following the accounting principles and rules. The module incorporates aggregated financial statements

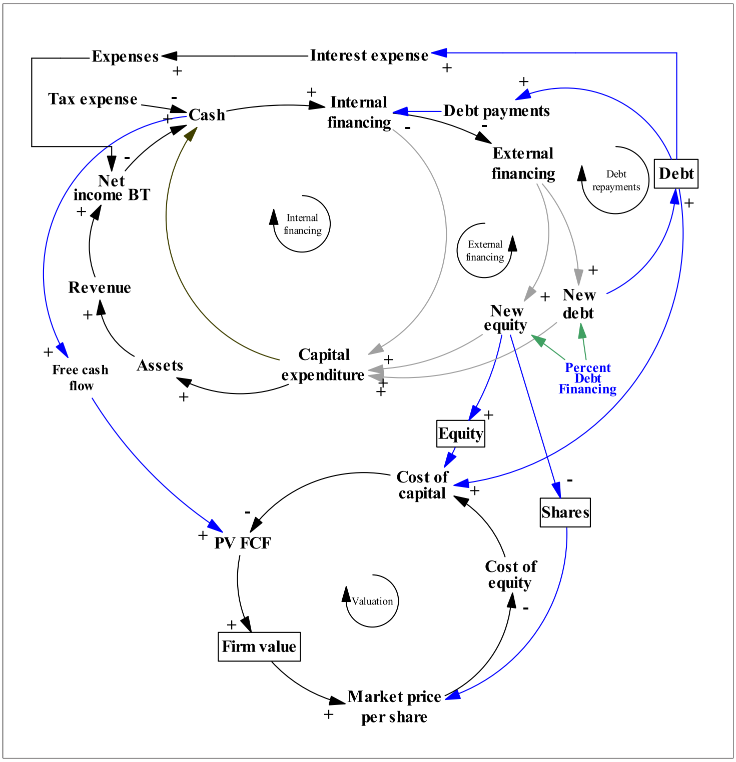

FIGURE 1 Overview of model structure [Colour figure can be viewed at wileyonlinelibrary.com]

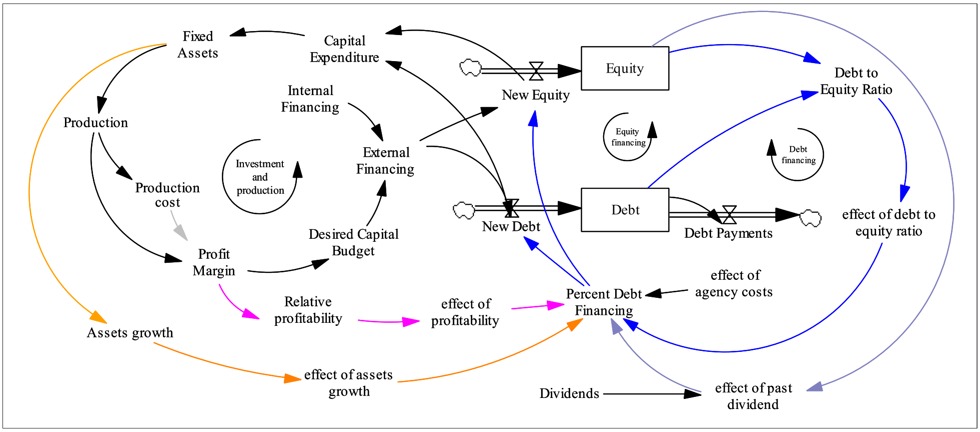

FIGURE 2 Simplified stock and flow diagram of major elements of capital structure [Colour figure can be viewed at wileyonlinelibrary.com]

including balance sheet, income statement, and cash flow statement (Yamaguchi, 2003). We demonstrate the focus of this article, capital structure policy in Figure 2 that represents the key variables, and their feedback relationships in a simplified diagram.

Percent debt financing is the key variable demonstrating the capital structure mix (equity financing and debt financing in Figure 2). The capital structure policy has multiple implications for a firm including its cost of capital that is a critical element in estimating the firm value. Based on the elements identified from relevant literature (Frank & Goyal, 2009; Qureshi, Sheikh, & Khan, 2015), we model percentage debt financing as a nonlinear function of debt to equity ratio, assets growth, profitability, agency costs, and past dividends.

$$
\begin{aligned}
\text{Percent debt financing} &= \text{debt financing ratio} \\
&* (\text{effect of profitability on debt}) \\
&* (\text{effect of debt to equity ratio on debt financing}) \\
&* (\text{effect of asset growth on debt}) \\
&* (\text{effect of past dividend on debt}) \\
&* (\text{effect of agency costs on debt financing}). \qquad (1)
\end{aligned}
$$

Table 1 presents the variables along with their measurement and their relationships with debt financing predicted by the two competing theories.

Table 1 highlights conflicting postulations of the capital structure theories about five major variables. Based on empirical observations, the POT observes that as profitability of the firm increases, firms raise less debt as they prefer internal finances to debt. However, TOT postulates that as profitability increases, firms can benefit from debt as they can earn at a rate higher than they need to pay. According to POT, as firm is growing, it raises more debt

TABLE 1 Predicted impact of variables on debt financing percentage as per POT and TOT

Variable	Measurements	POT	TOT
Profitability	Net profit before taxes/Total assets	−	+
Growth	(Total assets$_t$ - Total assets$_{t-1}$) / Total assets$_{t-1}$	+	−
Past dividend	Dividend$_{t-1}$/Total equity$_{t-1}$	+	−

to support that growth. However, TOT postulates growing firms have lesser debt in their capital structure mix. POT predicts past dividends have positive influence on debt percentage whereas TOT assumes it has negative influence. Agency costs arise due to conflict of interest between the managers and the principles. According to agency theory agency, costs reduce when there is an increase in the level of debt as monitoring costs reduce and managers have lesser cashflows available at their discretion (Jensen & Meckling, 1976). Debt to equity ratio, a measure of firm's debt risk (Allen, Brealey, & Myers, 2006) in our model determines the risk premium the firm has to pay to debtholders over and above the risk-free interest rate. As the risk of the firm increases, the firm becomes conservative to new debt issuance. We model the firm's response to the risk as a nonlinear function, which has an effect on percent debt financing. Equity financing loop demonstrates that with increase in equity financing ratio the risk of the firm reduces and so does the return, negatively affecting the FCF and the firm value. We incorporate all these causalities of debt in our model that influence the percent debt financing of the firm.

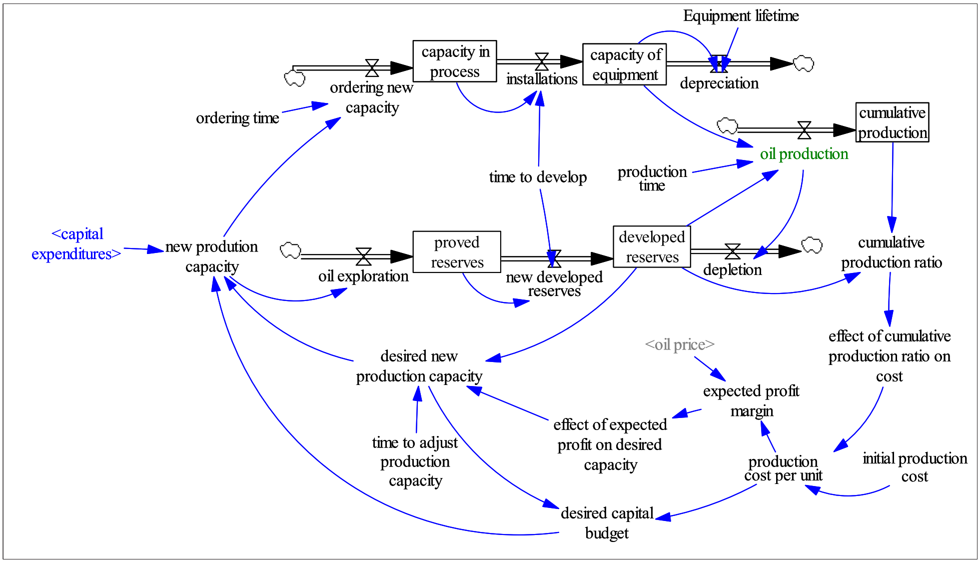

FIGURE 3 Simplified stock and flow diagram for oil and gas production processes [Colour figure can be viewed at wileyonlinelibrary.com]

The new debt and new equity determine the firm's level of debt and equity financing. Consequently, the capital structure policy determines WACC that is used to discount the FCF to determine the firm value. As such, from capital structure policy's perspective WACC is at the core of firm valuation that has long-term implications for the market price of the firm's shares.

3.2 | Production module

Production module includes the physical production processes for oil and gas and renewable energy. Oil and gas production process starts by investing to explore the oil and gas reserves beneath the seabed. Successful exploration efforts add to the proved reserves stock. Figure 3 illustrates the simplified stock and flow diagram of the production module. Time and investments are needed to develop these reserves in order to make extraction of oil possible from these reserves. Capacity to produce the oil and gas is a prerequisite for production and refers to the necessary equipment and materials required in the oil and gas extraction process. Quantity of oil and gas extracted is dependent on the quantity of developed reserves in the presence of capacity. Once there are proved reserves, they need to be developed in order to make extraction of oil and gas possible through building the capacity and all the required equipment. Given the physical capacity, extraction is possible from a reserve depending on the quantity of oil available. Production defines the depletion of the reserves, as the quantity of oil beneath the earth is finite and in place. The production processes involve many delays and nonlinearities. These delays are modelled to account for the long-term nature of the investments. Production quantity determines the production costs as they define the level of operations of the firm as well as the remaining reserves of the oil and gas. Thus, the production costs are modelled as a nonlinear function of cumulative production and developed reserves (Davidsen, Sterman, & Richardson, 1990).

Production costs and expected oil and gas prices that determine profit expectation play a significant role for deciding desired capacity for future that determines the capital expenditure. Firm needs to invest at least equal to its depletion and depreciation to maintain the steady state. However, to increase the capacity, they need to invest more than the steady state amount of investment. The capacities and reserves development involve major delays consisting of many years. The model incorporates the delays through parameters, nonlinear functions, and stocks mechanism to mimic the real system structure.

Following the recent global trends, Equinor is also moving towards carbon free energy solutions.[1] new energy solutions (NES) in the model includes offshore wind energy, solar energy and some other renewable

[1]https://www.equinor.com/en/what-we-do/new-energy-solutions.html

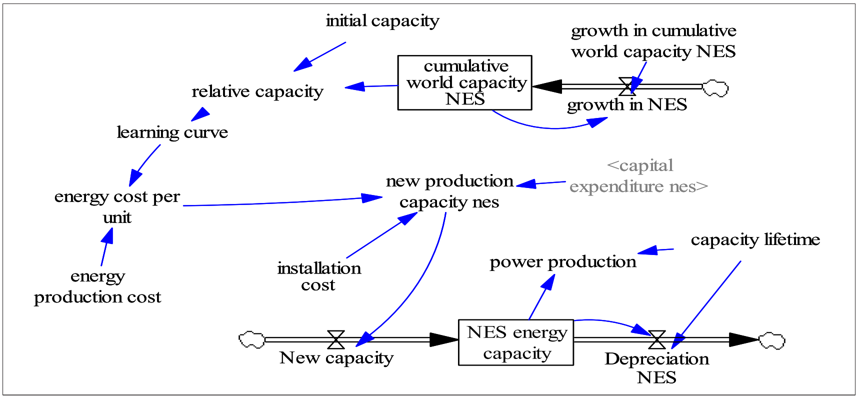

FIGURE 4 Simplified stock and flow diagram for renewable energy production processes [Colour figure can be viewed at wileyonlinelibrary.com]

energy sources included in the firm's portfolio. To simplify, we merge all these resources in one stock in our model. Figure 4 demonstrates the simplified structure for the NES.

NES are at developing phase and are expected to become cost effective in future. The costs have been calculated incorporating the learning curve (Goldemberg, Coelho, Nastari, & Lucon, 2004; McDonald & Schrattenholzer, 2001) which incorporates nonlinear effect of learning on costs. Resultantly, the model assumes that the NES becomes efficient and improved learning process decreases the production costs overtime. Energy capacity yields power production that integrates the production module to the financial module.

3.3 | Valuation module

The valuation module integrates the variables from the financial module for the DCF valuation that relies on the estimation of the FCF and the WACC to estimate the firm value (Damodaran, 2010). The following equation provides formulation of FCF (Benninga, 2008), and we use weighted average cost of debt and equity as WACC (Brealey, 2012).

$$\begin{aligned}\text{Free cash flow} = {} & \text{net income after taxes} \\ & + \text{depreciation expense} \\ & + \text{after tax interest on debt} \\ & + \text{increase in current liabilities} \\ & - \text{capital expenditures} \\ & - \text{increase in current assets.}\end{aligned} \quad (2)$$

Terminal value estimates the value of the firm under the assumption of going concern that is the firm would continue the business to infinite future (Palepu, Healy, & Peek, 2013). The terminal value represents the future expectations estimated through the firm's return on equity. The present value of FCF accumulates into the stock of firm value. Every year new value adds through inflows and old value outflows. The model calculates the market price per share by dividing the firm value with the number of shares outstanding. The estimated market price per share feedbacks to the cost of equity next time around. Figure 5 presents the simplified version of the operationalization of the DCF.

4 | MODEL VALIDATION

The validity of results from a model depends on the validity of the structure and the model. The validity of the model is exhibited if the internal structure of the model conforms to the theoretical and empirical knowledge about the real system and depicts adequately the behavior that is relevant to the issue (Sterman, 2000). This ensures the structural validity of the model that the model is generating the right behavior for the right reasons. Given the model structure discussed above, we carried out direct structure tests that review validity of the model structure by direct comparison with knowledge about real system (Barlas, 1996; Senge & Forrester, 1980). Every equation of the model uses knowledge and theory about the real system to depict the organic relationships. To ensure that the model is dimensionally consistent, we applied dimensional consistency tests. Based on the tests' results, we can report that our model is structurally valid and

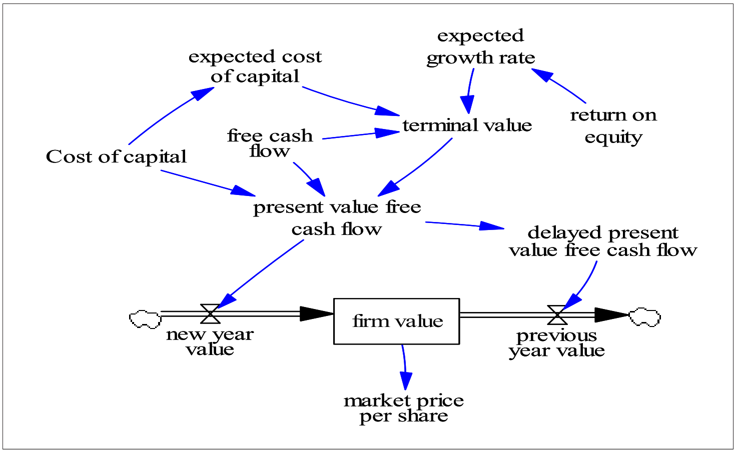

FIGURE 5 Simplified stock and flow diagram for valuation module [Colour figure can be viewed at wileyonlinelibrary.com]

dimensionally consistent. Extreme conditions tests assess the model behavior by assigning the selected parameters extreme values and comparing the simulated model behavior to the observed and/or expected behavior of the real system under similar extreme conditions. The results of extreme conditions test applied to certain parameters suggest that the model behavior is realistic under extreme conditions.

Figure 6 characterizes the reference mode for market price per share (the variable of interest) and the total debt as compared to the historical data. The results suggest that the model is replicating the behavior substantially and thus could be simulated into the future for policy and scenario analysis.

Behavior reproduction tests have been performed to further assess the model's ability to reproduce the behavior. Table 2 presents the R^2 (coefficient of determination), mean square error (MSE), root mean square percentage error (RMSPE), and Theil's inequality statistics (Theil, 1966) by decomposing MSE into bias (U^M), unequal variation (U^S), and unequal covariation (U^c) for total debt and market price per share. The R^2, RMSPE, and MSE indicates that the model structure is capable to mimic the underlying behavior pattern. Moreover, the decomposition of RMSPE wherein larger U^c in both cases indicates that the model is capturing the mean and the underlying trends of the data reasonably well and the error is only due to difference from point to point estimation (Sterman, 2000). Advocating utility of such models, researchers observe that forecasts from calibrated model are more reliable than from other approaches (Suryani et al., 2010).

5 | SCENARIOS AND POLICY DESIGN

The study designs capital structure policies and scenarios to test the impact of capital structure policies on the firm

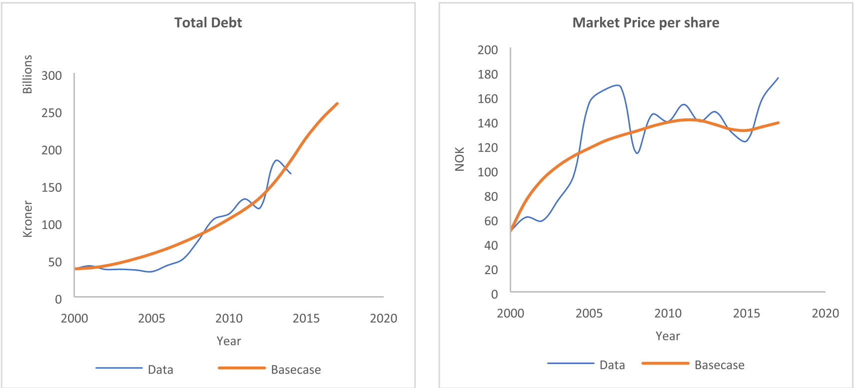

FIGURE 6 Reference mode and total debt, simulation and historical data [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Model fits to historical data (error analysis)

Variable	RMSPE	MSE (units)	U^m	U^S	U^C	R^2
Total debt	0.30	2.35E+20	0.07	0.38	0.55	0.92
Market price per share	0.23	5.56E+02	0.01	0.39	0.6	0.72

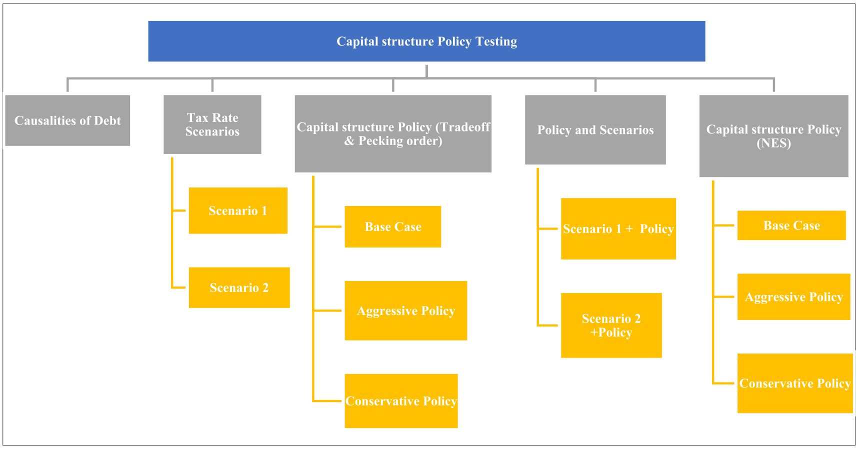

FIGURE 7 Capital structure policy analysis [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 3 Capital structure policy and scenarios

Capital structure policy	Policy variable	Policies
Aggressive policy	Debt fraction	75% debt
Base case	Debt fraction	55% debt
Conservative policy	Debt fraction	35% debt
Tax rate scenarios		Scenarios
Base case		68%
Scenario 1		Base case +5%
Scenario 2		Base case −5%

value. Considering the key role of tax deductibility of debt interest payments in financing choices (Graham, 1996; Fama & French, 1988), we designed tax rate scenarios to capture the uncertain alternative situations that might affect the outcomes of capital structure policy and the firm value. A profitable firm could benefit from increasing the level of debt to a point where marginal tax benefits start to decline; however, the evidence suggests that large and profitable firms use debt conservatively (Graham, 2000). For our case firm, taxes are important primarily because oil firms operating in Norway are subject to heavy petroleum and income taxation. We have designed capital structure policies by increasing and decreasing the percent debt financing with reference to the base case. We test these policies in isolation and then in combination with the tax rate scenarios to test their impact in different situations.

Considering the market push for the renewable energy and potential depletion of oil and gas reserves, the oil and gas firms are trying to diversify their investment portfolios. Our case firm is utilizing its offshore expertise in offshore wind energy and other sources of renewable energy such as solar energy. As such, we model NES explicitly to test if these new investments would change the results of capital structure policies' impact on the firm value. We have modelled the investments in NES based on the firm's goal to invest 100 billion kroner by 2030 so that 15%–20% of the firm's investments would be in NES by the end of 2030.[2] Therefore, it is interesting to investigate the impact of NES investments on the firm value and to identify which debt policy would be optimal in that case. We have made relevant assumptions based on the available predictions about this industry (InnoEnergy, 2017).Table 3 outlines the designed capital structure policies and tax rate scenarios.

The tree diagram in Figure 7 depicts the framework that we used for the purpose of capital structure policy testing under different scenarios. First, we test the causalities of debt by simulating the model through the predictions of each theory as depicted in Table 1 and examine the impact on the market price per share. Second, we simulate the model under three tax rate scenarios as

[2]https://www.equinor.com/en/magazine/transitioning-to-broad-energy-company.html

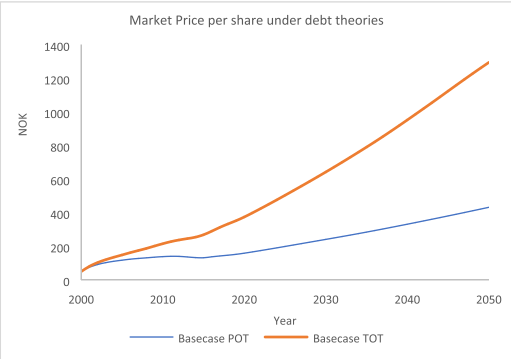

FIGURE 8 Causalities of debt (POT, TOT [Colour figure can be viewed at wileyonlinelibrary.com]

described in Table 3 to examine the impact on the market price per share. Third, we simulate the model under three capital structure policies as represented in Table 3. Fourth, we couple the policies with the tax scenarios to examine their impact. Finally, we add the NES explicitly to the model and test which capital structure policy would be beneficial in this case.

6 | RESULTS AND THEIR DISCUSSION

The results section provides the simulation outcomes from the model. Figure 6 demonstrates the reference mode for the market price per share, a representation of the firm value. Market price per share reflects the value that investors believe the firm is worth for per unit of ownership in the firm and is expected to incorporate all the publicly available information (Palepu et al., 2013). Therefore, we present the market price share behavior under all assumed capital structure policies and scenarios.

6.1 | Testing the theories (causalities of debt)

First, we examined the capital structure theories through their predicted causalities that we incorporated in the model. The simulation results demonstrate that POT's predicted effects portray the market price per share realistically (Figure 8). It is interesting to note that the data also indicate that the firm prefers internal finances to external finances[3] potentially following the POT. The simulation results indicate that POT outperforms TOT in this case to explain the capital structure of the firm.

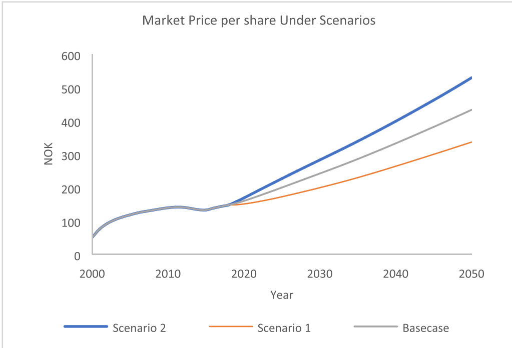

FIGURE 9 Market price per share under tax rate scenarios [Colour figure can be viewed at wileyonlinelibrary.com]

6.2 | Taxes

A key variable of interest in consideration of capital structure policy is the tax rate, which plays a significant role in determining the net income after taxes of the firm. Tax rate plays a major role in debt to equity tradeoff, as one of the key benefits is tax advantage of debt that interest expenses are tax deductible. The tax rate scenarios reveal (Figure 9) that increase in tax rate significantly decreases the firm value and vice versa. This emphasizes the importance of taxes for an oil firm. An increase in tax rate reduces the net income available for shareholders and reinvestment. Lesser amount of FCF is available that results in decrease in the firm value.

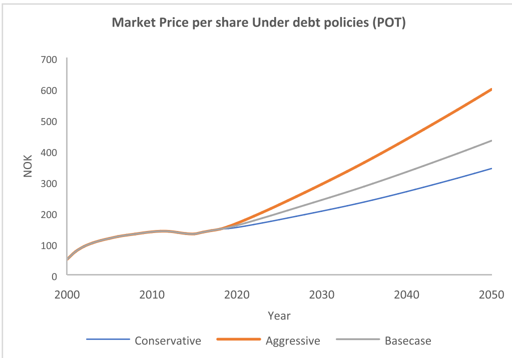

FIGURE 10 Market price per share under debt policies (POT) [Colour figure can be viewed at wileyonlinelibrary.com]

[3]https://www.equinor.com/en/investors/our-dividend/annual-reports-archive.html

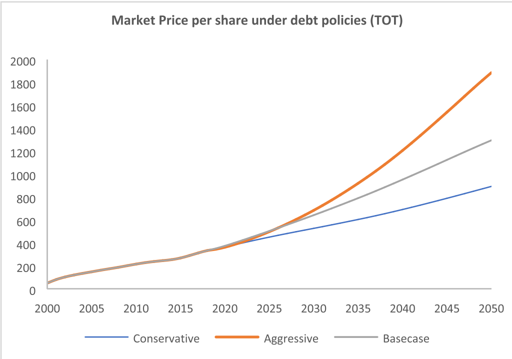

FIGURE 11 Market price per share under debt policies (TOT) [Colour figure can be viewed at wileyonlinelibrary.com]

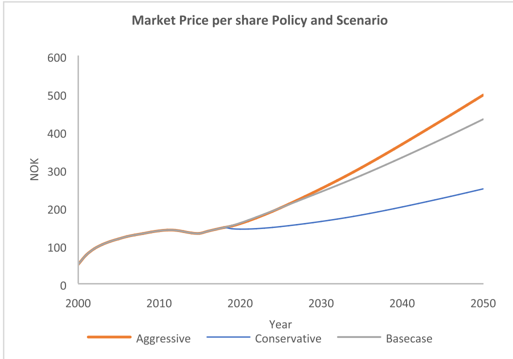

FIGURE 12 Market price per share under scenario 1 and debt policies [Colour figure can be viewed at wileyonlinelibrary.com]

6.3 | Capital structure policy

Capital structure policy has been analyzed by modeling explicitly the financing through two competing capital structure theories. The debt policy has been modeled in such a way that the desired capital budget is financed through debt first, then internal financing is the preference and external equity is the last choice. The results (Figure 10) demonstrate the market price per share behavior under the assumptions of POT. The debt policies discussed in Table 3 have been simulated to find the optimal policy for debt and equity mix. Simulation results demonstrate that as percentage of debt increase in the capital mix, the value is increased and vice versa. Aggressive capital structure policy maximizes the value whereas conservative capital structure policy performs substantially poor as compared to the base case.

The TOT has been investigated assuming debt as a first choice to finance the capital budget requirements. The results (Figure 11) demonstrate that aggressive capital structure policy increases the share price. However, an increase in the firm value is higher than that under POT. The reason is that under TOT debt is the most preferred source of financing, and thus, it is obtained in the first place making the total debt and percentage of debt in new financing higher. The tax advantage of debt leads to increase in FCF (see Equation 2) and decrease in WACC and consequently increasing the firm value. However, under the aggressive policy, the tradeoff becomes so risky that the debt payments are so huge that some of the payments would be outstanding even after using all internal profits to pay back the debt. Consequently, the firm would have to raise new equity to pay off the debt, which is a risky situation. Therefore, although the simulations results suggest higher firm value with high level of debt due to tax advantages of debt, there are limits to that. Even under the base case policy, internal profits are very low after making

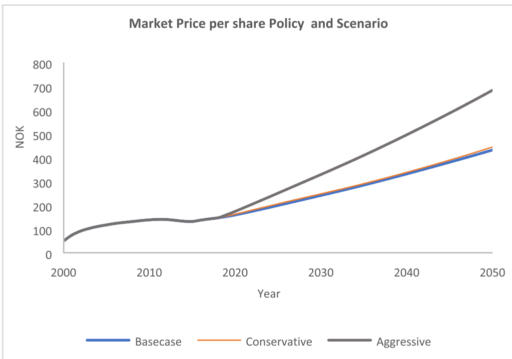

FIGURE 13 Market price per share under scenario 2 and debt policies [Colour figure can be viewed at wileyonlinelibrary.com]

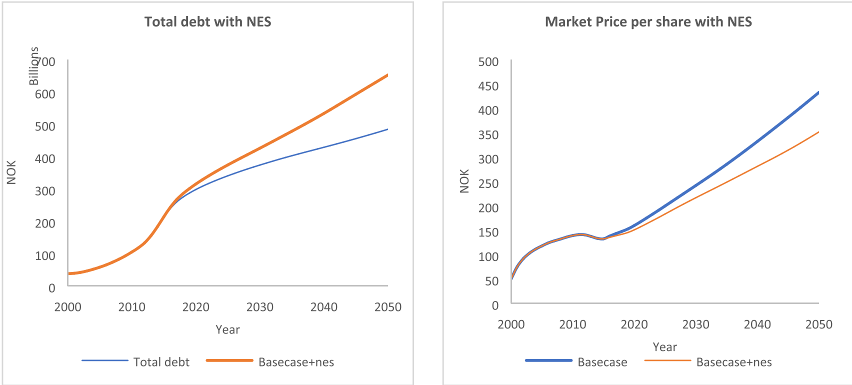

FIGURE 14 Reference mode and total debt with incorporated NES [Colour figure can be viewed at wileyonlinelibrary.com]

the debt payments. A firm does not want to reach a level of debt where they need to raise the money to pay back the debt.

The simulated outcomes (Figures 12 and 13) indicate multiple aspects of the firm's financial operations. Percent debt financing for new external financing for the firm varies over time between 35%–55%. One aspect could be the firm is having less debt in the capital structure mix than optimal. The firm is able to earn at a rate higher than its borrowing rate, which results in higher firm value as debt percentage increases (Ward & Price, 2006). Figure 1 demonstrates the simplified causal structure highlighting the benefits and costs of debt financing. Two major inputs from financial module to the valuation module are FCF and WACC, which are the two major elements of DCF valuation method (Janiszewski, 2011). The FCF are calculated from cash generated from internal operations of the firm accounted for all the expenses and investment needs. Debt financing influences cash through interest expense and debt payments. Interest expenses and debt payments increase as the level of debt increases. However, interest payments are tax deductible. Tax benefits of debt add to the firm value by having positive impact on the firm value. An increase in interest expenses reduces the taxes to the government and increases the cash available for shareholders (Brealey, Myers, Marcus, Wang, & Zhu, 2007). Alternatively, when debt payments increase, lesser internal finances are available for the firm and consequently the firm needs to generate cash through external financing. As the level of debt rises, the WACC is reduced as the cost of debt is lesser than the cost of equity. The FCF of the firm is discounted at a lower discount rate causing the firm value to increase. The results are supported by the agency cost theory as debt increases, agency costs reduce due to less cashflows available at manager's discretion and reducing the conflict between owners and managers and reducing the monitoring costs (Berger and Patti, 2006).

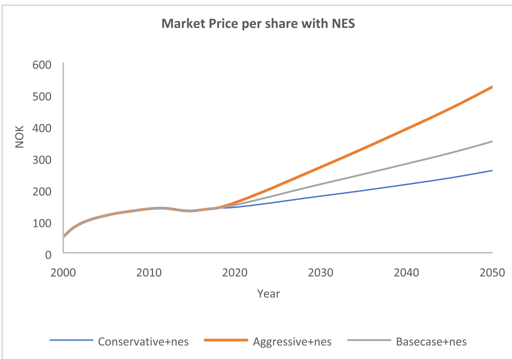

FIGURE 15 Reference mode and total debt, simulation and historical data [Colour figure can be viewed at wileyonlinelibrary.com]

6.4 | Policy and scenarios

We present the simulation results of the interaction of capital structure policies and tax rate scenarios in Figure 12. An increase in taxes has significant impact on the firm value. Aggressive policy underperforms base case policy in the early years of simulation period. This explains as the tax rate increases, the tax benefit of increased debt financing is compromised for the increased costs. However, around year 2025, aggressive policy yields the same market price per share as base case policy. After that, aggressive policy outperforms the base case policy and conservative policy. Capital structure policies under assumed tax rate scenarios reveal that market price per share is positively influenced by decreases in tax expenses (Figure 13). Aggressive policy proves out to be robust policy under all assumed tax rate scenarios. Even though the results emphasize the importance of tax rate and external environmental changes in the policy design, nevertheless, the results demonstrate that the firm should have relatively more debt in its capital structure to maximize the firm value per share whatever is its tax rate.

6.5 | New energy solutions

The above debt policy analysis was carried out before introducing the NES into the model. Figure 14 represents the market price per share and total debt after introducing the NES to the model. The value reduces as investment made in this diversification reduces the FCF over time.

As renewable energy production is not yet cost-effective, the FCF from NES are lesser than those generated through normal business operations causing the market price per share to decrease. To finance these higher investments, the firm needs more capital and consequently the total debt increases. In this case, we performed the debt policy analysis to identify better debt policy given additional investments into NES (Figure 15). The results indicate that higher debt increases the firm value in this case as well. This refers to the fact that firm can profit from debt benefits by increasing the debt ratio in financing NES even though NES yield FCF lesser than normal business operations. Aggressive debt policy proves out to be the best policy among assumed policies in all cases and scenarios.

The results are supported by the agency theory, which claims that by increasing the debt in the capital structure mix the value is enhanced (Jensen & Meckling, 1976). The firm can benefit from increased debt percentage for financing the capital requirements. However, tax scenarios also reveal that changes in some of the key financial variables could lead to different inferences. This means the benefits of increasing debt in capital structure mix need to be sizeable enough to increase the firm value to compensate the potential costs and risks associated with increased debt. Although debt is a cheaper source of finance as compared to equity, a firm cannot increase the debt ratio to the limits due to multiple reasons including the risk considerations. Especially for the case firm, debt repayments become a challenge as debt ratio is increased. That explains one reason as why the base case has lower level of debt. If external environment turns out to be the worst or the product market expectations do not turn out optimistic as expected, high ratio of debt could lead the firm into financial distress (Cao & Chen, 2012). Especially for Equinor, oil and gas prices are fluctuating in the short term and a very high ratio of debt could be risky for the firm if the price expectations do not meet up. The firm's policy is to keep the financial flexibility and thus prefer internal finances for investments. High funds from operations as compared to the debt ratio facilitate better rating by the rating agencies leading to lower WACC. Another vital perspective is limited natural resources. The firm's operational capacity is limited by the availability of natural resources. Oil and gas reserves are in place in a certain quantity in the Norwegian Continental Shelf and internationally. The firm's investment opportunity set is limited by the natural resources' availability that limits its financing choices as well. Therefore, the firm prefers to utilize its internal capital first to meet the capital requirements. However, our case firm would be better off by taking advantage of debt tax benefits if it wishes to diversify its business by expanding its investment opportunity set. Another reason could be strong net cash flows to the firm that effectively reduces the need to raise debt. All these factors explain some of the reasons for firm's conservative debt ratio. However, the simulation results suggest that increasing the debt ratio would add to the firm value as the firm is expected to earn at a rate higher than its WACC.

7 | CONCLUSION

The objective of this study is the capital structure policy analysis to maximize the firm value. For this purpose, the study develops a system dynamics-based simulation model of corporate planning activities for an oil firm integrating operational and financial variables. The model comprises of financial, production, and valuation modules. First two modules integrate production and financial activities of the firm to estimate the major financial variables, which feed into the valuation module that performs the firm valuation using DCF method. Extensive policy analysis has been performed to explore the influence of firm's capital structure policy on the firm value to identify the optimal policy. While doing so, the study reviewed and tested major capital structure theories. Various scenarios involving changes in taxes have been designed to investigate how changes in certain key financial variables would influence the firm value. The results for debt policy demonstrate that as percentage of debt increases in the capital structure mix, the firm value per share increases and vice versa. This is because of cost reduction as debt is cheap source of financing due to tax advantages of debt and equity is an expensive choice. The results for scenarios suggest that the lower rate of taxes is beneficial for the firm value. However, tax rate scenarios reveal that changes in key financial variables should be considered while devising the policy as they play a major role. The firm is operating in the oil and gas market where prices of oil and gas are fluctuating in the short term that making it highly risky to form expectations about future prices of oil and gas. Consequently, making a decision to finance such investment with a very high debt ratio would increase the firm's debt repayment requirements potentially consuming all its FCF and resultantly increasing its liquidity risk. Currently, the firm is very conservative in its debt policy; however, the results suggest that the firm can benefit from increased debt ratio in the capital structure mix to improve its firm value per share. The simulation results of capital structure theories suggest that POT outperforms TOT in enhancing the firm value in this case.

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APPENDIX

Behavior sensitivity test involves identifying the parameters to which the model is sensitive and determining if the sensitivity of the model to the parameter is realistic (Barlas, 1996). We report the results of the sensitivity tests parameters "time to develop", "average age of fixed assets", and "debt retirement time" in Figure 6. Time to develop is the time it takes for proved reserves to become developed making production possible. If time to develop is less (more), reserves would be developed quicker (slower) and production would be more (less). The results confirm the behavior pattern. The second parameter is average age of fixed assets which defines how quickly (slowly) fixed assets are depreciated. If fixed assets are depreciated quickly (slowly), there are less (more) available next time around. Debt retirement time has been investigated with different time periods and the total debt behavior is realistic. When time is less, accumulated debt is lesser and vice versa.

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Research Article

A System Dynamics Model Of Exchange Rate Determination And Forecasting

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Abstract

Objective: The objective of this paper is to develop a model of exchange rate determination and forecasting to provide reasonable forecasts for the exchange rate to facilitate long-term investments.

Design: The study develops the model using the system dynamics method. Grounded on the fundamental theories, the model incorporates nonlinear feedback relationships of interest rate, inflation, per capita income, terms of trade, and oil prices with the exchange rate.

Findings: The simulation results indicate the robustness of the model to mimic not only the long term past behavior of the exchange rate but also its ability to provide a reliable long-term forecast for the exchange rate. The model is portable and applies to any oil-exporting country after calibration.

Policy Implications: The study has practical implications for individuals, businesses, and the Government because they are all influenced by the exchange rate movements. Specifically, this model provides a useful tool for long term strategic financial planning of oil firms.

Originality: The study develops a model for exchange rate accounting for nonlinear feedback relationships among the variables.

Introduction

The exchange rate is one of the significant factors that may influence and is influenced by the economy of the country. It is one of the essential elements reflecting a country's economic health. The exchange rate movements influence the trade performance of many firms in any specific country and its balance of payments. The exchange rate is defined as the price of one currency in terms of another currency, determined by the demand and supply mechanism in the market. This demand and supply mechanism is a consequence of multiple factors of the economy. Specification of those factors that determine the exchange rate is still a challenge despite the vast amount of work done to explain the exchange rate volatility. This is evidenced by the presence of enormous theoretical models, and various modeling approaches (Meese & Rogoff, 1983) used to determine the exchange rate behavior. The monetary model of the exchange rate has been an essential part of exchange rate determination models, which relies on the fundamental variables of the economy to explain the exchange rate movements (Cerra & Saxena, 2010). Much empirical evidence is emerging due to advances in econometrics for testing the relationship between the exchange rate and the fundamental variables as predicted by the theoretical models. In the international finance literature, imperative theories, namely Purchasing Power Parity (PPP), International Fisher Effect (IFE), and Interest Rate Parity (IRP) are most widely used. These theories define international parity conditions that determine the exchange rate between two currencies. The PPP assumes that the price of an identical basket of goods in two countries is constant when measured in terms of common currency. Whereas IFE and IRP consider interest rate as a source of change between the currencies' exchange rates. Such use of international parity conditions to determine the exchange rate is labeled as the fundamental method that is expected to provide long-term trends rather than short-term predictions (J. Madura & Fox, 2011). It is because the exchange rate might deviate from its equilibrium level defined by PPP in the short run, but it is expected to revert to its mean in the long run (Dąbrowski, Papież, & Śmiech, 2014). Other methods of exchange rate determination are technical and market-based. These methods are linear.

Moreover, the empirical evidence is inconclusive (Öge Güney & Hasanov, 2014; Park & Park, 2013). It is ironic to note that these methods not only ignore the feedback processes but also do not utilize the fundamental causal structure put forward by the fundamental method. This might be one possible reason for the poor empirical performance of these models. This study is an endeavor to fill the gap by modeling the exchange rate through these fundamental theories using feedback loops and nonlinear relationships. The objective of this paper is to develop a system dynamics model of the exchange rate that embodies the structure that explains the relationship between exchange rate and the fundamental variables, enabling the replication of the past behavior and leading to reliable forecasts to facilitate the long term investment and financing decisions. First, the model is simulated to calibrate the historical exchange rate between Norwegian Kroner and the US dollar. Once the model can capture the long-term trends of exchange rate movements, the model is simulated to provide forecasts for the future and test various scenarios designed to assess the impact of changes in variables on the exchange rate.

The model developed in this study would provide forecasts for exchange rate movements from long term foreign investment and financing perspective for multinational companies generally and specifically for oil companies as it includes the impact of oil price fluctuations for an oil-exporting country. Since the Bretton Woods system ended in 1971, most of the countries followed the floating exchange rate policy, and exchange rate volatility has become inevitable(Kilicarslan, 2018). Exchange rate volatility is the change in the price of one currency in terms of another currency. Volatility is the movement of the price of currency around the balance value of exchange rate or short-term fluctuations from the long-term equilibrium trends of an exchange rate that leads to appreciation or depreciation of the currency(Oaikhenan & Aigheyisi, 2015). Appreciation or depreciation of the currency does significantly impact the profitability of foreign exchange transactions, relative prices of the country, foreign investment flows, including both direct and portfolio and stable economic growth

(Ajao, 2015; Martins, 2015). Changes in macroeconomic factors increase the uncertainty causing volatility in the exchange rate market. This uncertainty causes delays in investment decisions, negatively influencing economic growth through influencing investor confidence, capital, and trade flows (Oaikhenan & Aigheyisi, 2015). Thus, forecasting exchange rate movements is significant for making decisions regarding trade and capital flows, investments, and the economy. Exchange rate considerations are essential not only for trade volumes of a country but also for long term investments, the former appears on the current account balance whereas, the later on the capital account. Multinational companies undertake most of the foreign direct investment of the world, and the exchange rate plays an important role not only when the investments are made but also when payoff from these investments needs to be converted back to the local currency (Crowley & Lee, 2003).

In this article, the simple model of the exchange rate is developed, which accounts for the fundamental factors that play their role in exchange rate determination through demand and supply of currency. The study focuses on the structures generating the exchange rate trend between Norwegian kroner (NOK) and US dollar (USD) by using the system dynamics approach, based on interrelationship among inflation, interest rate, per capita income, terms of trade, oil prices, and exchange rate. The model operationalizes the PPP and IRP theories of the exchange rate to determine the exchange rate to provide empirical evidence if these fundamental models of exchange rate explain the exchange rate behavior. The model focuses on the Norwegian economy. Norway has allowed a free-floating exchange rate since 1992. Norway is an economy rich in natural resources, including petroleum, gas, hydropower, fish, and minerals. Thus, the exports of the country include these natural resources, mainly petroleum, gas, seafood, and shipping, with trade surplus historically in the trade balance. Oil and gas exports are almost half of the total exports of Norway[1]. Therefore, oil prices also play an important role in exchange rate determination. The economy is significantly influenced by the exchange rate movements due to dependence on exports from petroleum and other natural resources. This dependence also influences the per capita income of the country and terms of trade. Thus, an exchange rate model that develops a structure explaining the exchange rate movements is useful for developing an understanding of the exchange rate, specifically in the case of Norway. The study contains significance as it provides an exchange rate model based on fundamental macroeconomic factors. The factors are modeled in feedback and nonlinear relationships, thus making the relationship between the exchange rate and the factors more dynamic and close to the real world as opposed to the other statistical static models. The model provides a simple structure explaining the exchange rate movements, which makes it generic and possible to be used for other currencies as well. The forecasts generated by the model have implications for individuals, businesses, and the Government for their long-term decision making that involves the impact of the exchange rate.

The rest of the paper is organized as follows: Section 2 describes the variables and their relationships with the exchange rate. Section 3 discusses the structure of the system dynamics model. Section 4 provides the model calibration and scenario design. Section 5 discusses the implication of the results. Limitations and future research are given at the end

Literature Review

Fundamental Variables in Exchange Rate Determination

The study develops an explanatory model that incorporates the structural causes of the exchange rate behavior. This section discusses the macroeconomic factors modeled in a feedback relationship with the exchange rate as the exchange rate also does influence trade and other key macroeconomic variables of an economy.

[1] https://www.norskpetroleum.no/en/production-and-exports/exports-of-oil-and-gas/

Exchange rate

The exchange rate is one of the critical factors of a country's economic health, trade levels, and portfolio returns. The exchange rate represents the variable of interest aimed to be determined and forecasted through the causalities. The model incorporates the exchange rate for NOK per USD (NOK/USD) using a direct exchange rate quotation. Changes in exchange rate occur due to changes in demand and supply of the currencies (Jeff Madura, 2006). These changes in supply and demand of the currencies are due to various macroeconomic factors (Abbas, Iqbal, & Ayaz, 2012). Thus, the new exchange rate is determined at the equilibrium level, where the supply and demand of the currencies meet.

Interest rate: (International Fisher Effect, Interest Rate Parity)

Interest rate is defined as the rate that determines the charge on the use of money and reflects one of the critical determinants of the exchange rate. It is because the interest rate directly influences the demand and supply of the currency. As per IFE and IRP, the differential in interest rate leads to the difference in the forward exchange rate from the spot exchange rate (Perera, Silva, & Silva, 2018). Higher local interest rate promises a higher return on the local currency relative to other options and attracts more capital from individuals, investors, and foreign capital. Thus, higher local interest rate increases the demand for the currency and impact positively with the appreciation of the local currency and vice versa. The interest rate is used as a tool for monetary policy by the central banks due to its significant role in the supply and demand of the currency.

Inflation: (Purchasing Power Parity)

Purchasing power parity is one of the most controversial and prevalent theories of international financial management (Rogoff, 1996). The theory accounts for the relationship between exchange rate and inflation. The validity of the theory has implications for decision and policymakers of central banks, exchange rate markets, and multinational firms (Jiang, Jian, Liu, & Su, 2016). The implication is that if PPP holds, then nominal exchange rate fluctuations do not affect the trade flows. PPP assumes that the real exchange rate should return to an equilibrium level in the long run and should be mean-reverting (stationary) in the long run. If the real exchange rate is not stationary, it implies that there is no relationship between domestic and foreign prices and nominal exchange rate in the long run and invalidates the PPP hypothesis (Bahmani-Oskooee, Chang, Chen, & Tzeng, 2017). The theory implies that exchange rate adjustment is necessary for the purchasing power to be the same. Otherwise, consumers will shift purchases to wherever prices are lower until power is the same. Inflation is expected to hurt the home currency exchange rate. As inflation rises in a country, exports decline, and imports increase. This puts pressure on the country's currency, and the value of the currency declines (Kuttner & Posen, 2000). Thus, as per PPP, inflation would pressure to adjust the exchange rate until purchasing power becomes the same.

Per capita income

Per capita income influences and is influenced by the exchange rate movements. If the income of a foreign country rises, people would have more money to increase their spending, and imports of a foreign country would rise, resulting in appreciation of the local currency and vice versa.

Terms of trade (TOT)

The exchange rate plays a very significant role in the trade level of an economy. In the same way, exchange rate fluctuations are influenced by the imports and exports of the country as they impact the demand and supply of the currency. When there is an increase in exports, the demand for the local currency will increase, leading to an appreciation of the local currency. When imports increase, it negatively affects the domestic currency as people spend the money to import more goods for consumption. That increases the demand for foreign currency relative to domestic currency and results in deterioration of domestic currency.

TOT = foreign exports / imports …..(1)

Oil Prices

There has been evidence of the relationship between oil prices and the exchange rate in the literature (Kim & Jung, 2018; Reboredo, 2012). Oil prices play their role in exchange rate movements in the case of Norway as the country is an exporter of oil and gas, with oil and gas being a significant part of the exports. Theoretically, for an oil exporter, oil price shock transfers to the exchange rate through two primary channels. One is through terms of trade, and the other is through wealth effects (Bodenstein, Erceg, & Guerrieri, 2011). When oil prices increase, it positively influences the oil-exporting economy as international profits of the oil firms increase and demand the local currency increase to convert those profits back into local currency. Due to an increase in currency demand, local currency appreciates, and vice versa.

System Dynamics Model

System dynamics methodology is appropriate for modeling the exchange rate movements for multiple reasons. The model accounts for the feedback relationship among the fundamental factors and exchange rate. The Calibrated system dynamics model's forecasts are likely to be more reliable and informative than the other methods. Developing and testing the system dynamics model is an iterative process and includes five significant steps. The first step is problem articulation, which includes identifying the dynamic problem that needs to be solved and the critical variables involved and time horizon. The second step is dynamic hypothesis development that incorporates the details of the problem causing variables and causal loop diagram that incorporates the significant variables and relationships of the variables involved. The third step is the formulation that involves the model building. The relationships need to be defined as per theory and which have real-life meaning such as stocks, flows, auxiliary, parameters such as initial conditions and constants. The fourth step is testing the behavior of the system related to the purpose of the model. When the model is generating the right behavior for the right reasons, there comes the last step of policy formulation and evaluation where various policies or scenarios could be tested and evaluated. But the modeler does not necessarily need to follow these steps linearly and could move to any step forward or back during the modeling process (J. Sterman, 2000). System dynamics modeling allows for the inclusion of nonlinear behavior of the variables.

The purpose is to develop an exchange rate model to determine the exchange rate through fundamental causal variables. Exchange rate fluctuations are a complex phenomenon, and building a simplified explanatory model that replicates the long-term behavior is a challenging task. The model includes the fundamental factors that are expected to play their role in exchange rate fluctuations. Figure 1 summarizes the causal structure of the model. The exchange rate is represented as NOK/ USD. Thus, an increase in exchange rate refers to the depreciation of Norwegian kroner and vice versa. Reinforcing loop (R1) represents the role of expectations in the determination of future exchange rates. Expectations in the market are formed on the previous trends of the exchange rate.

Reinforcing loop (R2) demonstrates the feedback relationship between inflation and exchange rate. Exchange rate depreciation leads to an increase in inflation. An increase in inflation leads to depreciation of the exchange rate next time around. Reinforcing loop (R3) indicates the relationship between exports and exchange rates. Depreciation of the exchange rate impacts exports positively. It is because the products of Norway become cheaper for foreign countries when NOK depreciates. An increase in exports has a positive impact on the economy, and the exchange rate appreciates. When exports increases, the demand for NOK increases and results in an appreciation of NOK. Balancing loop (B1) represents the feedback relationship between the interest rate and exchange rate. When the exchange rate depreciates, interest rate increase to attract more capital as the interest rate is used as a tool to control the currency demand and supply. The inflow of capital has a positive influence on the exchange rate. Balancing loop (B2) accounts for the relationship between imports and the exchange rate. Depreciation of the exchange rate leads to a decrease in imports as they become expensive in terms of local currency. A decrease in imports leads to exchange rate appreciation. High per capita income indicates the overall strength of the country's economy and has a positive influence on the exchange rate leading to an appreciation of the local exchange rate. When there is an increase in oil prices, it leads to an appreciation of Norwegian kroner and vice versa. Given this feedback structure, the model is simulated to analyze the exchange rate behavior.

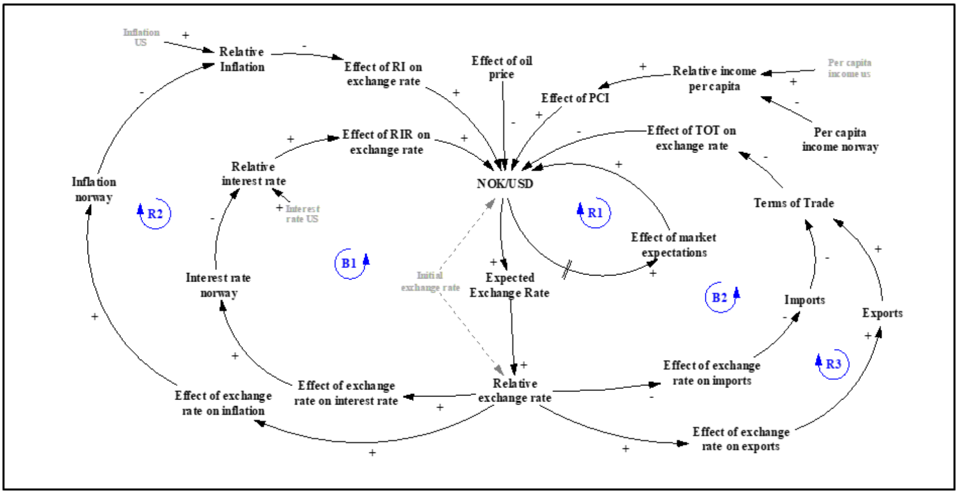

Figure 1 - Feedback structure of exchange rate module

Assumptions and initial values

Developing a simplified exchange rate model that can replicate the past behavior reasonably and provide reliable forecasts requires some assumptions about the model boundary and other elements. Therefore, assumptions are made to make this simplification.

- Only currency NOK is explored in terms of USD. The model does not take into account the interaction of the currency with any other currencies or economies. Thus, the model focuses on a single economy.
- The fundamental variables having the most significant impact theoretically and being the fundamental are included in the model.
- The initial values and historical data for the variables are obtained from secondary statistical resources such as OECD Data[2] and World Bank data[3] etc. The model initializes from 1995 and for the future is simulated until the year 2045.

Model Calibration and Scenario design

The model is used to calibrate the historical exchange rate and then produce the forecasts for the future. As per the system dynamics' rule, the structure of the model should be able to replicate the behavior of the variable

[2] https://data.oecd.org/

https://www.inflation.eu/

[3] https://data.worldbank.org/

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being explored for the right reasons. The model has been validated during the development process, and validation tests reveal that the model performs reasonably for these tests. Figure 2 represents the simulated exchange rate behavior in 1995. The simulation outcome reveals that the model is able to capture the long-term trend of the exchange rate reasonably. To further validate the results, statistical significance tests are applied to validate the behavior prediction accuracy of the exchange rate model. Error analysis includes Root Mean Square Percent Error (RMSPE) and Theil inequality tests (J. D. Sterman, 1984). RMSPE estimates the normalized error magnitude, and MSE is a measure of total error between historical and simulated results. Theil inequality is a decomposition of these estimated errors into bias (Um), unequal variation (US), and unequal covariation (UC). Table 1 reports the figures from error decomposition and Theil inequality tests. The results reveal RMSPE of only 10%, and further decomposition reveals that error is 6% due to bias .03% due to unequal variation and 86% due to unequal covariation. A more substantial portion of unequal covariation reveals that the model is capturing the historical trend, and there is only a diversion point by point(J. D. Sterman, 1984).

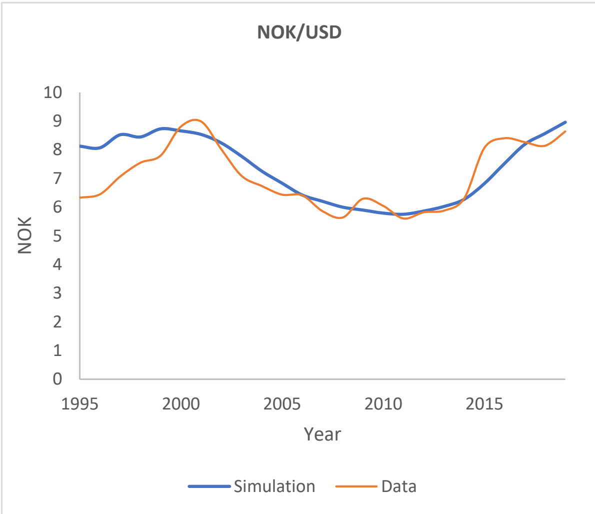

Figure 2 - Exchange rate behavior compared to exchange rate data

Table 1 - Error Analysis

Variable	RMSPE	MSE (units)	U^m	U^S	U^C
NOK/USD	0.108	5.58E-01	0.134	0.003	0.862

Scenario Design

The system dynamics model includes the critical relationships in feedback structure and makes it meaningful and useful to test various scenarios for the future to comprehend and estimate the impact of changes in the exchange rate and other variables of interest (Suryani, Chou, Hartono, & Chen, 2010). Scenarios have been designed to estimate how would the change in macroeconomic variables influence the exchange rate and, in turn, how the exchange rate would influence these macroeconomic variables (Table 2).

Table 1 - Scenarios

Scenarios	Variable	Change
Higher	Interest Rate	2.5%
Base case	Interest Rate	2%
Lower	Interest Rate	1.5%
Higher	Inflation	3.1%
Base case	Inflation	2.1%
Lower	Inflation	1.1%
Increase	Oil prices	+$10
Base case	Oil prices	$25
Decrease	Oil prices	-$10

Scenarios for interest rate and inflation of Norway have been designed and tested to analyze how would any percentage change in one of the variables impact the expected exchange rate. The base case interest rate in 2019 is around 2%; a higher case scenario assumes an interest rate of 2.5%- and lower-case scenario assumes an interest rate of 1.5%. For inflation, base case inflation was around 2.1% in 2019. In a higher inflation scenario, 1% higher inflation is assumed, and in lower inflation cases, 1% lower inflation is assumed. Due to the significance of oil prices in the Norwegian economy and exchange rate, oil price scenarios have also been analyzed to test how would any change in oil prices influence the exchange rate. In 2019, the base case assumed $25 per barrel. For higher oil prices, a $10 increase is assumed, and for lower oil prices $10 decrease is assumed.

Results

Simulation results illustrate the behavior of the variables based on the relationships as predicted by the theory. The simulation result from the base case for reference mode (NOK/USD) is given in Figure 2. Now, the model is simulated into the future to forecast the exchange rate behavior until the year 2045 under the base case scenario, assuming the current trends extrapolate into the future. Figure 3 demonstrates the exchange rate of forecasted behavior.

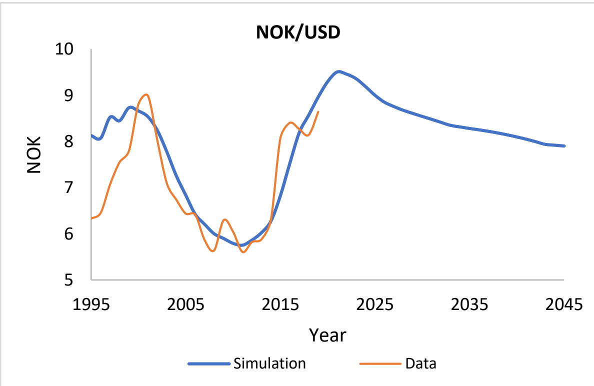

Figure 3 - Exchange rate behavior assuming Base case scenario

Assuming the current trends of significant macroeconomic variables, the exchange rate depreciates to 9.5 NOK/USD in the year 2021. It then starts to appreciate slowly until it reaches 7.9 NOK/USD by the end of the simulation period.

Now the model is simulated to test the scenarios. Figure 4 represents the exchange rate behavior under the assumed interest rate scenarios. The interest rate is the critical variable of interest rate parity theory. The interest rate and exchange rate have a feedback relationship. An increase in local interest rates leads to an appreciation of the exchange rate due to increased demand for the local currency and vice versa. As per the simulation results, a 0.05% increase in interest rate leads to an appreciation of Norwegian currency from 9.2 NOK/USD in 2020 to 8.4 NOK/USD in 2021 and 7.28 NOK/USD in 2045 assuming all other factors as per the base case. As per the lower interest rate scenario, a 0.05% decrease in local interest rate leads to depreciation of Norwegian currency from 9.2 NOK/USD in 2020 to 9.8 NOK/USD in 2021 and 9.03 NOK/USD in 2045.

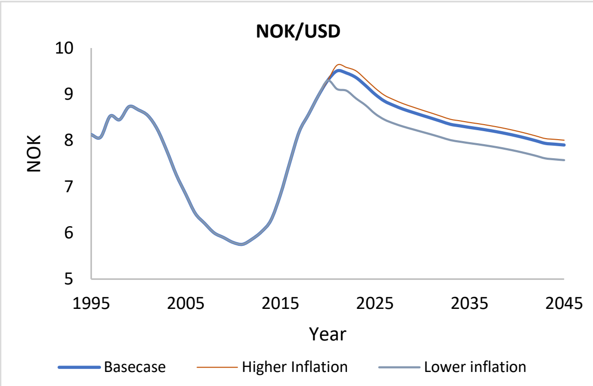

Figure 4 - Exchange rate under interest rate scenarios

Then, the model is simulated to analyze the inflation scenarios. Figure 5 characterizes the exchange rate under inflation scenarios. Inflation is the critical variable of PPP theory impacting the exchange rate. Exchange rates and inflation have a feedback relationship. An increase in local inflation levels leads to the depreciation of the local currency and vice versa. The simulation results reveal that assuming a 1% increase in inflation in the Norwegian economy leads to depreciation of NOK from 9.2 NOK/USD in 2020 to 9.63 NOK/USD in 2021 assuming all other factors remaining same. Lower inflation scenario (-1% than the basecase) reveals an appreciation from 9.2 NOK/USD in 2020 to 9.1 NOK/USD in 2021. This confirms the hypothesis that relative prices of a basket of goods play their role in the determination of the exchange rate.

Finally, the model is tested for changes in oil prices. Figure 6 embodies the exchange rate behavior under oil price scenarios. When there is an increase in oil prices, NOK appreciates, and vice versa. Assuming a $10 increase in oil prices from the basecase reveals an appreciation of the exchange rate from 9.2 NOK/USD in 2020 to 9.13 NOK/USD in 2021, given all other factors as per base case and by the end of the simulation period it reaches 7.60 NOK/USD. Under lower oil price scenario, which assumes a $10 decrease in oil prices, the local currency depreciates from 9.2 NOK/USD in 2020 to 9.92 NOK/USD in 2021. It stabilizes until it

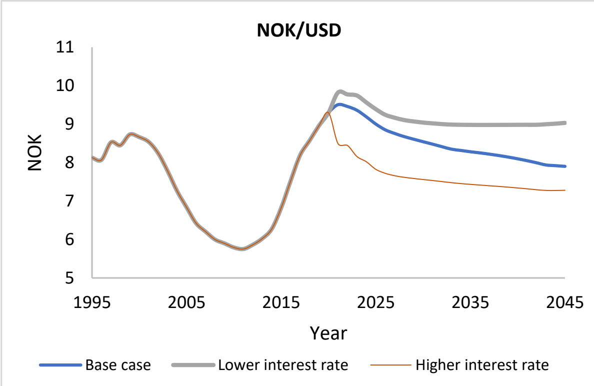

Figure 5 - Exchange rate under inflation scenarios

appreciates to 8.21 in the year 2045. As the country is an exporter of oil, the exchange rate is influenced by the changes in oil prices.

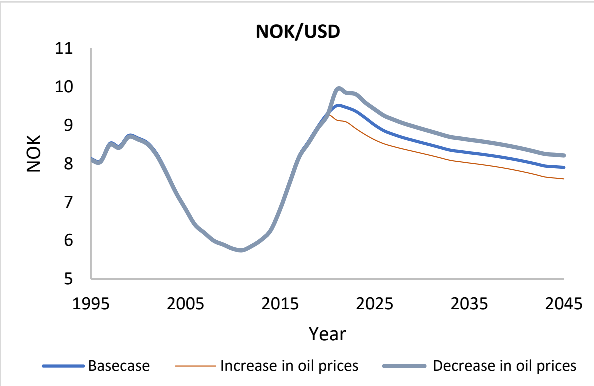

Figure 6 - Exchange rate under oil price scenarios

The simulation results reveal the behavior of the exchange rate is influenced by the key macroeconomic variables as predicted by the theory. Fundamental macroeconomic variables influence the exchange rate and thus can provide long term forecasts for the exchange rate. The study provides empirical evidence on the validity of the PPP and IRP in the determination of the exchange rate.

Conclusion

The objective of this paper is to develop a system dynamics model based on fundamental macroeconomic variables to determine and forecast the exchange rate. Feedback and nonlinear relationships among the interest rate, inflation, oil prices, terms of trade, per capita income, and terms of trade are modeled to calibrate the exchange rate behavior. The simulation results reveal that the variables, as per their predicted relationships by the theory, can replicate reasonable long-term exchange rate behavior. However, some short-term variations might be caused by some other factors or noises. Then, the model is simulated into the future to provide forecasts for the future from long term investments' perspective as the forecasting exchange rate is significant before making long term international investments. Then, some scenarios, including critical variables such as interest rate, inflation, and oil prices, are tested to analyze how would the changes in these critical variables influence the exchange rate. An increase in Norwegian inflation results in the depreciation of NOK. Whereas, an increase in interest rate has a positive influence and leads to the appreciation of the exchange rate. Oil price shocks impact the NOK, and an increase in oil prices is definite in the case of NOK as the country is an exporter of oil. The model explains and provides a simplified and generic model of the exchange rate determination based on fundamental macroeconomic variables.

The exchange rate is a significant economic variable. The study provides a simplified simulation-based model for the exchange rate for better understanding and forecasting of the exchange rate from a long term perspective based on fundamental theories. The study has practical implications for individuals, businesses, and the Government because they are all influenced by the exchange rate movements. The study has implications for investors accurately as based on the predicted exchange rate; they can hedge their exchange rate risk. The study also has implications for monetary policies as the study elaborates on the relationship of two primary monetary policy tools, interest rate, and inflation with the exchange rate.

Limitations and Future Research

The study has certain limitations. The study relies on fundamental variables only to forecast the exchange rate. The exchange rate model could further include other models of exchange rate determination and make a comparison to better forecast the exchange rate and get insights. The model could also be extended to include further economies.

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Conflicts of Interest: The authors declare no conflict of interest.

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Appendixes

Model Documentation

Model documentation includes model equations and their explanation. The system dynamics model used in this dissertation was built as a step wise process, adding blocks for every article. Article 1 discusses the base model and the investment policy, article 2 integrates the capital structure policy into the model, article 3 integrates the dividend policy into the model. Article 4 is based on an exchange rate module. Article 5 is based upon the comprehensive model and integrates the model developed for article 3 and 4.
Thus, these equations describe the comprehensive model (article 5) which integrates all the previous versions of the models used for individual articles (1,2,3,4).

Time Unit	Year
Initial Time	2000
Final Time	2050
Reported Time Interval	1
Time Step	0.03125

1. Accounts Payable = INTEG (credit Purchases – payments, INITIAL ACCOUNTS PAYABLE)
   Units: NOK

This stock accumulates accounts payable for the case firm, that represent the current liabilities. Accounts payable stock represent the accumulated outstanding payables, the firm must pay. Accounts payable are reported on balance sheet. Any changes in accounts payable, increase or decrease from previous accounting year, appear on cash flow statement.

2. Accounts Receivable = INTEG (credit sales – cash collections, INITIAL ACCOUNTS RECEIVABLE)
   Units: NOK

This stock represents the sum of amount the firm has yet to receive from customers for delivering the commodities. Accounts receivable represent the accumulated amount the firm has to receive and appear on the balance sheet as current assets. As the case firm do not report separately their accounts receivable, the model assumes sales as credit sales, as an inflow to the accounts receivable.

3. After tax interest on debt = Interest Expenses * (1- Tax Rate)
   Units: NOK/year

This variable represents the cost of debt after tax, calculated by subtracting the income tax savings from the interest expense, as interest expenses are tax deductible. This variable is used to calculate free cash flows and cost of debt.

4. Agency costs = sales/ total assets
   Units: 1/year

Agency costs arise when there is conflict between the principal (shareholders) and the agents (management). The proxy for agency costs used in the model is asset utilization ratio, calculated as annual sales divided by the total assets. The ratio measures as how efficiently the managers deploy assets to generate sales. The ratio is inversely related to the agency costs. An increase in sales to asset ratio compared to base case means decrease in agency costs as the managers have been efficient in their decision making on behalf of principals. Agency costs play their role in capital structure policy decision in the model and represent agency theory.

5. Assets growth rate = (Fixed assets / Delayed fixed assets)-1
   Units: Dmnl

This variable represents growth in fixed assets from the previous year. This ratio play role in capital structure decision in the model.

6. Average age of fixed assets = 12
   Units: Year

Average age of fixed assets is a parameter for calculating the depreciation expense from fixed assets. It represents, on average, the time in years used for depreciating the fixed assets for the firm in the model.

7. Average asset growth rate = SMOOTH (assets growth rate, smoothing time for financial variables)
   Units = Dmnl

This variable averages the year-to-year growth in total assets. This average is used to form the impact of assets growth on capital structure decision in the model.

8. Average collection period = 0.11
   Units: Year

This parameter indicates the time between the day when credit sale is made and the day when purchaser pays for it. This parameter indicates the time in which firms credit sales are converted to cash, and thus represents the management practices in cash collections.

9. Average payment period = 0.37
   Units: Year

This parameter estimates the time between the day when the firm purchases credit supplies or services and the day when the firm makes payment for that. This is an important indicator of firm's creditworthiness and cashflows are influenced by this.

10. Averaged value = SMOOTH (cumulative production ratio, smoothing time for financial variables)
    Units: Dmnl

This variable averages the cumulative production ratio to model the impact of cumulative production on production costs.

11. Benchmark agency costs = 0.5
    Units: Dmnl/year

This parameter sets up benchmark to estimate relative agency costs. The parameter is used to normalize the agency costs to model their impact on capital structure decision.

12. Benchmark profitability = 0.05
    Units: Dmnl/year

This parameter is used to normalize profitability ratio. Profitability ratio play its role in the capital structure decision and the dividend payout decision.

13. Book Value per Share = Total equity/ Common stocks
    Units: NOK/share

This variable calculates the per share net asset value of the firm. Firm´s total Equity is divided by the outstanding total number of shares. Book value per share is used to calculate the market to book ratio, which is a proxy for investment opportunities and plays role in dividend payout decision.

14. Capacity equipment lifetime = 20
    Units: Year

This parameter represents the average life time of capacity of equipment, used to generate energy through new energy solution, primarily windmills etc.

15. Capacity in process = INTEG (ordering new capacity- installations ,INITIAL CAPACITY IN PROCESS)
    Units: boe (barrels of oil equivalent) /year

This stock represents the accumulated capacity of the equipment in process, which will be developed after certain delay time, to extract oil and gas (such as plants, oil extractors etc).

16. Capacity of equipment = INTEG(installations- depreciation , INITIAL CAPACITY OF EQUIPMENT)
    Units: Boe/year

This stock represents the developed and ready to extract equipment capacity. The maximum of oil and liquids that firm can extract from the seabed or ground depends on this capacity, given the amount of developed reserves.

17. Capital expenditure NES = desired capital budget NES
    Units: NOK/year

This variable represents the capital expenditure for new energy solutions (NES), which is assumed to be the wind energy in the model for simplification. Therefore, the model assumes wind energy in NES.

18. Capital expenditures =(internal financing+ new debt+ new equity)- capital expenditure NES
    Units: NOK/year

This variable represents the capital expenditure, investments, by the firm except for NES which is estimated separately.

19. Capital structure decision = 0.55
    Units: Dmnl

This parameter represents the capital structure decision, the percentage of debt in external financing in the model.

20. Cash = INTEG (cash inflow- cash outflow, INITIAL CASH)
    Units: NOK

This stock represents the accumulation of cash overtime. Cash is represented on balance sheet, being current asset.

21. Cash collections = accounts receivable/ average collection period
    Units: NOK/year

This outflow represents the receipt of cash from outstanding accounts receivables.

22. Cash inflow = cash collections+ cash inflow from financing+ NES sales

Units: NOK/year

This inflow to the stock of cash represents all the cash inflows to the firm during the year. Cash inflows and outflows represent cash flow statement on an aggregated level.

23. Cash inflow from financing = new debt+ new equity issued
    Units: NOK/year

This variable represents the financing generated from external sources, debt and equity, to meet the needs for desired capital budget.

24. Cash outflow = cash outflow from financing+ operating expenses+ income tax expense+ capital expenditures+ cost of goods sold*(1- credit purchase fraction)+ payments+ capital expenditure nes+ production cost NES
    Units: NOK/year

This outflow accounts for all the cash outflows from the stock of Cash during the year.

25. Cash outflow from financing = debt payments+ total dividends+ interest expenses
    Units: NOK/year

This variable accounts for all the cash outflow to pay out the cost of capital generated from external sources. This variable represents accounts on cash flow statement.

26. Change in exchange rate = (" NOK/USD"- expected exchange rate)/ time horizon TF
    Units: NOK/USD/year

This inflow to the expected exchange rate stock calculates the change in exchange rate to account for the major patterns of growth in exchange rate.

27. Change in PPC = (" NOK/USD"- PPC)/ time horizon TF
    Units: NOK/USD/year)

This inflow is used to smooth the raw value of exchange rate to generate the perceived present condition (stock). This inflow is part of trend function structure modelled explicitly in the model.

28. Change in RC = (PPC- RC)/ time horizon TF
    Units: NOK/USD/year)

Change in reference condition (RC) is the inflow to the stock of reference condition (RC), to compare the perceived present condition (PPC) with past values of exchange rate, to determine the pattern of change in behaviour.

29. Change in trend = (indicated trend- perceived trend)/ time to perceive trend
    Units: Dmnl /year/year

Change in trend is the inflow to the Perceived trend stock, which smoothes the difference between indicated trend and perceived trend.

30. Common stocks = INTEG (issuance of stock, INITIAL COMMON STOCKS)
    Units: Share

This stock represents the total number of stocks outstanding accumulated over the years.

31. Cost fraction = 0.75
    Units: Dmnl

This parameter is used to estimate the cost of goods sold for the firm for all the other activities except for oil and gas production.

32. Cost of capital = (total equity/(total equity+ total debt))* cost of equity+(total debt/(total debt+ total equity))*(interest expenses*(1- tax rate)/ total debt)
    Units: Dmnl/year

Cost of capital is calculated from weighted average cost of equity and debt, whereas cost of debt is after tax as interest expenses are tax deductible.

33. Cost of equity = (dividend per share*((1+ growth rate))/ market price per share)+ expected growth rate
    Units: Dmnl/year

Cost of equity is calculated using the dividend growth model. The cost is calculated by dividing the expected dividends with current market price per share. The cost of equity also accounts for the expected growth rate.

34. Cost of goods sold = cost of goods sold for oil and gas+ manufacture marketing cost
    Units: NOK/year

This variable represents the total cost of goods sold for the firm including cost of goods sold for oil and gas and manufacturing and marketing cost (the cost which accounts for all the rest of operations by firm).

35. Cost of goods sold for oil and gas = production oil and gas* production cost per unit
    Units: NOK/year

This variable accounts for the cost of goods sold for oil and gas calculated every year.

36. Credit purchase fraction = 0.6
    Units: Dmnl

This parameter determines the amount of credit purchases out of total cost of goods sold. This represents firm's policy as how many supplies or equipment is purchased on credit to enable production and sales.

37. Credit purchases = credit purchase fraction* cost of goods sold
    Units: NOK/year

This inflow to the stock of accounts payable represents the outstanding payments per year.

38. Credit Sales = sales
    Units: NOK/year

All the sales by the firm are considered on credit initially. Cash is received when cash is collected from accounts receivable.

39. Cumulative production = INTEG(production oil and gas, 359869000.0)
    Units: Boe

This stock accumulates the total oil and gas production by the firm over the years.

40. Cumulative production ratio = (cumulative production/ developed reserves)
    Units: Dmnl

This ratio is used to estimate the impact of accumulated production on production cost per unit. As, oil and gas reserves are natural resources and finite, as total production increases, remaining reserves become costlier to extract. Thus, this ratio is used to model this non-linear impact on production cost per unit.

41. Cumulative world capacity NES = INTEG (growth in NES, INITIAL CUMULATIVE WORLD CAPACITY NES)
Units: KWH

As new energy solutions are in development phase now, this stock represents the estimated total world capacity for wind energy.

42. Debt payments = (total debt/ debt retirement time)
Units: NOK/year

This outflow represents the debt payment made from total debt depending on debt retirement time.

43. Debt policy outcome = capital structure decision* percent debt financing
Units: Dmnl

This variable represents the final outcome for capital structure decision.

44. Debt retirement time = 10
Units: Year

This variable represents the average maturity time of long-term debt of Equinor over the years.

45. Debt to equity ratio = total debt/ total equity
Units: Dmnl

This ratio measures the total debt divided by total equity and represents as how much of the assets the firm is financing through debt as compared to equity.

46. Delayed dividend per share = DELAY FIXED (dividend per share, 1 , dividend per share)
Units: NOK/Share/year

This variable delays dividend per share by 1 year to calculate the growth in dividend per share to calculate the cost of equity.

47. Delayed dividends = DELAY FIXED (total dividends, 1 , total dividends)
Units: NOK/year

This variable represents the total dividends delayed by one time period to model the impact of dividends on debt.

48. Delayed equity = DELAY FIXED (total equity, 1 , total equity)
Units: NOK

This variable represents the delayed equity used to estimate the effect of past dividends on debt.

49. Delayed fixed assets = DELAY FIXED (fixed assets, 1 , fixed assets)
Units: NOK

Delayed fixed assets delays the fixed assets by one time period to estimate the growth in fixed assets.

50. Delayed present value free cash flow = DELAY FIXED (present value free cash flow, 1 , present value free cash flow)
Units: NOK

This variable delays the PVFCF by one time period (year) to form the outflow from the total firm value.

51. Depletion = production oil and gas
    Units: Boe/year

The oil and liquids extracted from developed reserves represent production and the developed reserves are reduced by the same amount, because natural resources are finite. Thus, the production of oil and gas represents depletion as well.

52. Depreciation = capacity of equipment/ Equipment lifetime
    Units: Boe/year/year

This outflow represents the depreciation of equipment every year.

53. Depreciation expense = (fixed assets/ average age of fixed assets)
    Units: NOK/year

This outflow represents the depreciation expense, the amount that accounts for reduction in value of assets over time due to aging, or wear and tear.

54. Depreciation NES = NES energy capacity/ capacity equipment lifetime
    Units: KWH/year

This outflow represents the depreciation of New energy solutions capacity equipment every year.

55. Desired capital budget = desired capital budget oil+ desired capital budget NES
    Units: NOK/year

This variable represents the total desired budget for the firm including oil and gas and new energy solutions.

56. Desired capital budget NES = IF THEN ELSE(Time>2015, effect of cum prod ratio on new capital expenditure* desired capital budget oil, 0)
    Units: NOK/year

This variable represents the desired capital budget for new energy solutions. NES is added to the model in year 2015 as this is relatively new to the firm as well and currently in developing phase. Effect of cumulative production ratio is a non-linear formulations which determines the fraction of total desired capital budget to be spent on NES. Desired capital budget NES increases overtime as per firm's future commitment to the NES is increasing.

57. Desired capital budget oil = (Max (0, desired new production capacity* production cost per unit))
    Units: (NOK/year)

This variable represents the desired capital budget for oil and gas, which is maximum of 0 or desired production capacity multiplied by production cost per unit. Desired capital budget cannot be negative; therefore Max function has been used in formulation.

58. Desired new production capacity = IF THEN ELSE (max(((desired production capacity- developed reserves)/ time to adjust production capacity),0)>0 ,((desired production capacity- developed reserves)/ time to adjust production capacity) , depreciation* employment time)
    Units: Boe/year

This variable represents the desired new production capacity for oil and gas. If the difference of desired production capacity and developed reserves divided by time to adjust production capacity is greater than zero, then it is desired new production capacity. Otherwise, desired new production capacity would only replace depreciation per year. This means, if profits are high, firm would invest to increase production, otherwise only account for maintenance of current capacity.

59. Desired production capacity = (Max(developed reserves, developed reserves* effect of expected profit on desired capacity))
    Units: Boe

This variable calculates if the firm wants to invest to increase the current production capacity or only maintain the current capacity based on effect of expected profit on desired capacity.

60. Developed reserves = INTEG (new developed reserves- depletion, INITIAL DEVELOPED RESERVES)
    Units: Boe

This stock represents the quantity of developed reserves expected to be recovered from the area during the concession or contract period. Oil and gas production is subject to availability of developed reserves and required capacity.

61. Dividend per share = total dividends/ common stocks
    Units: NOK/year/share

This variable represents the dividend per share paid out to shareholders every year.

62. Dividend policy = 0.4
    Units: Dmnl

This parameter represents the dividend payout decision. This percentage determines the dividend paid out to shareholders every year in the model.

63. Effect of agency costs on debt financing = WITH LOOKUP (Relative Agency Costs, ([(0,0)-(5,1.5)],(0,1.3),(1,1.2),(2,1.1),(3,1),(4,0.9),(5,0.8)))
    Units: Dmnl

This outlook function models the effect of agency costs on capital structure decision. The inverse effect relationship of agency costs and debt financing is modelled as predicted by the agency cost theory of corporate finance. Relative agency costs have been calculated by dividing agency costs with benchmark agency costs.

64. Effect of asset growth on debt = WITH LOOKUP (average asset growth rate, ([(0,0)-(0.15,2)],(0,1.1),(0.05,1.15),(0.1,1.2),(0.15,1.3)))
    Units: Dmnl

This lookup function models the effect of growth in fixed assets on capital structure decision. The literature suggests that growth in assets is positively associated with percentage of debt.

65. Effect of cum prod ratio on new capital expenditure = WITH LOOK UP (Cumulative Production Ratio, ([(0,0)-(20,3)], (0,0.55),(0.5,1.2),(1,1.6),(1.5,1.7),(3,1.75),(5,1.75),(20,1.75))
    Units: Dmnl

This lookup accounts for the impact of cumulative production ratio on new capital expenditure for NES capacity building. As per the current trend towards the NES globally, increase in cumulative production ratio for oil and gas has positive effect relationship with Capital expenditure for NES. With Equinor's commitment to net zero emissions by 2050, one of the steps is to grow in NES along with working on reducing emissions from oil and gas. This look up estimates the positive effect relationship.

66. Effect of cumulative production ratio on cost = WITH LOOKUP (Averaged value, ([(0,0)-(20,3)],(0,0.55),(0.5,1.2),(1,1.6),(1.5,1.7),(3,1.75),(5,1.75),(20,1.75))
    Units: Dmnl

This lookup represents the effect of cumulative production ratio on production cost per unit. As the production from an oil well increases, every new barrel of oil becomes more expensive to extract.

67. Effect of debt to equity ratio on debt financing = WITH LOOKUP (debt to equity ratio, ([(0,0)-(1,1)],(0,0.8),(0.1,0.7),(0.3,0.65),(0.5,0.6),(0.8,0.6),(1,0.5)))
Units: Dmnl

This lookup accounts for the effect of debt-to-equity ratio on capital structure decision. As the percentage of debt increases in debt to equity ratio, the firm has to be considerate next time to raise the percentage of debt, as it would increase the financial risk of the firm. This effect relationship is modelled in this look up function.

68. Effect of debt to equity ratio on payout ratio = WITH LOOK UP (relative debt to equity ratio, ([(0,0)-(1,2)],(0.00917431,1.3),(0.17737,1.2),(0.363914,1.1),(0.562691,1),(0.730887,0.868421),(0.877676,0.701754),(0.990826,0.561404),(1,0.5)))
Units: Dmnl

This lookup function accounts for the effect of debt-to-equity ratio on dividend payout decision. As Equinor prefers internal financing to external financing, if the firm needs more debt, the dividend payout is also less due to need of financing.

69. Effect of exchange rate on exports = WITH LOOK UP (Relative exchange rate, ([(0.5,0.6)-(2,1.5)],(0.5,1.15),(1.08257,1.1),(2,0.95)))
Units: Dmnl

This lookup function establishes the feedback relationship between exchange rate and exports. When NOK depreciates, it becomes cheaper and exports of the country increase. This effect relationship is represented in this table.

70. Effect of exchange rate on imports = WITH LOOKUP (Relative exchange rate, ([(0.5,0.6)-(2,1.5)],(0.5,1.15),(1.08257,1.1),(2,0.95)))
Units: Dmnl

This lookup function models the effect relationship of exchange rate on imports. As domestic currency depreciates, imports become expensive for the economy and thus exchange rate has a negative impact on imports and vice versa.

71. Effect of exchange rate on inflation = Relative exchange rate^ elasticity of exchange rate to inflation
Units: Dmnl

This variable represents the effect relationship of exchange rate with inflation by estimating the elasticity between exchange rate and inflation. If domestic currency depreciates, it is expected to increase the inflation in the country.

72. Effect of exchange rate on interest rate = Relative exchange rate^ elasticity of exchange rate to interest rate
Units: Dmnl

The feedback effect relationship between exchange rate and interest rate is modelled through elasticity. Although the effect of exchange rate on interest rate is very nominal, when exchange rate depreciates, interest rate is expected to increase to increase the demand for the currency, and bring the exchange rate back to equilibrium as predicted by the interest rate parity theory.

73. Effect of expected profit on desired capacity = WITH LOOKUP (Expected profit margin, ([(0,0)-(15,10)],(0,0),(4.5,0.5),(5,1),(6.33028,2),(7.70642,3),(9,4.5),(9.77064,5.1),(10.3211,5.8),(10.9174,6.5),(11.5,8),(11.8807,8.5),(13.0734,8.5),(14.8624,8.5)))
Units: Dmnl

This look up function accounts for the effect relationship of expected profit margin on desired capacity. If the expected profit margin is high, the firm would have higher desired capacity and vice versa.

74. Effect of investment opportunities on payout ratio = WITH LOOKUP (Relative market to book ratio, ([(0,0)-(10,10)], (0.122324,2),(2.47706,1.5),(4.74006,1),(6.66667,0.5),(10,0.2)))
Units: Dmnl

This variable represents the effect relationship between investment opportunities availability and the dividend payout decision.

75. Effect of market expectations = 1+ perceived trend* time horizon TF
Units : Dmnl

This variable estimates the effect of market expectations on exchange rate through trend function modelled explicitly. Trend function is used to estimate forecasts based on previous trend (Sterman, 2000).

76. Effect of oil prices on exchange rate = WITH LOOKUP (Relative oil prices, ([(0,0.7)-(5,2)], (0.0458716,1.25), (0.672783,1.2), (1.25382,1.13), (1.85015,1.07), (2.49235,1), (3.19572,0.9), (4.08257,0.8), (5,0.75)))
Units: Dmnl

This variable represents the feedback relationship of oil and gas prices and exchange rate. In Norwegian economy, oil and gas prices play role in determining the exchange rate as this sector is one of the largest sectors of the economy. When prices increase, domestic currency appreciates and vice versa.

77.Effect of oil revenue on sales = WITH LOOKUP(Relative revenue, ([(0,0)-(15,3)],(0.0672783,2.274), (2.15291,2.22368), (2.69113,1.97368), (3.36391,1.52632), (4.6422,0.934211),(6.12232,0.592105),(7.83792,0.460526), (11,0.447368),(15,0.43)))
Units: Dmnl

This variable represents the relationship of oil and gas revenue to the revenue of the firm from the rest of the operations such as marketing etc.

77. Effect of past dividend on debt = WITH LOOKUP(Relative past dividend, ([(0.01,0.8)-(1.5,2)],(0.01,0.942105),(0.1,1),(0.262691,1.11579),(0.5,1.2),(1.5,1.3)))
Units: Dmnl

This variable represents the effect of past dividends on capital structure decision. When the firm pays out higher dividends, more capital is required from debt financing to meet the capital requirements.

78. Effect of PCI = WITH LOOKUP (Relative income per capita, ([(0,0.7)-(3,2)], (0.0458716,1),(1.30275,0.95),(1.82569,0.9),(2.25688,0.85),(3,0.75)))
Units: Dmnl

This variable represents the effect of per capita income (PCI) on exchange rate as predicted by fundamental theories of exchange rate. When PCI increase, people have more money to spend, and imports increase. Exchange rate depreciates as the domestic money supply increase.

79. Effect of production on per capita income = WITH LOOKUP (Relative production, ([(0,0)-(10,10)], (0.0917431,0.6),(0.948012,1.05263),(1.92661,2.14912),(2.9052,2.5),(4.52599,2.6),(6.91131,2.7),(9.84709,2.8)))
Units: Dmnl

This variable represents the effect of oil and gas production on per capital income of Norway. Being the major sector in Norway, production of oil and gas does impact the economy and per capital income. When the sector is growing and production increases, it has positive effect on per capita income and vice versa.

80. Effect of profitability on debt = WITH LOOKUP (Relative profitability, ([(1,0)-(15,1.2)],(1,1.15),(3,1.1),(5,1.1),(7,1.05),(10,0.9),(12,0.8),(15,0.7)))
Units: Dmnl

This variable represents the effect relationship of profitability (net income before taxes/total assets) on capital structure decision. Profitability is negatively related to debt as with an increase in net income, firm needs to raise less debt to meet the capital requirements.

81. Effect of relative profitability on payout ratio = WITH LOOKUP (Relative profitability, ([(0,0)-(15,3)],(0.122324,0.570175),(2.75229,0.605263),(5.77982,0.710526),(8.2263,0.815789),(9.90826,0.934211),(15,0.95)))
Units: Dmnl

This variable captures the effect relationship of profitability on dividend payout decision. Profitability has positive relationship with payout ratio as with increase in profits the firm has more money to payout.

82. Effect of reserves on value = WITH LOOKUP (Relative reserves, ([(0,0)-(6,2)], (0,0),(0.5,0.2),(1,1),(6,1.1)))
Units: Dmnl

This lookup accounts for the effect of reserves availability on firm value. As developed reserves increase, they have positive impact on value of the firm.

83. Effect of return on equity on payout ratio = WITH LOOKUP (Relative ROE, ([(0,0)-(1,1)],(0.00917431,0.742105),(0.0030581,0.742105),(0.186544,0.757895),(0.446483,0.786842),(0.672783,0.8),(0.990826,0.8),(1,0.8))
Units: Dmnl

This variable represents the effect relationship of return on equity on payout decision. Return on equity has positive effect relationship with dividend payout decision as when the firm is earning more on equity, more profits can be distributed to the shareholders.

84. Effect of RI on exchange rate = WITH LOOKUP (Relative inflation, ([(0,0.9)-(2.5,2.5)],(0.0122324,0.925439),(0.385321,0.944737),(0.850153,0.97),(1.19878,0.997368),(1.49235,1.01579),(1.98777,1.05),(2.2,1.07),(2.5,1.08)))
Units: Dmnl

This variable represents the feedback relationship between inflation and exchange rate. When inflation in Norway is higher relative to US, NOK depreciates and vice versa.

85. Effect of RIR on exchange rate = WITH LOOK UP (Relative interest rate, ([(0,0) -(2,1.5)], (0.0122324,1.19737), (0.397554,1.18), (0.617737,1.11842), (0.770642,1.05), (0.911315,1), (1.26605,0.7), (1.62691,0.7),(2,0.7))
Units: Dmnl

This variable represents the feedback relationship between interest rate and exchange rate. When interest rate in Norway increases relative to US, higher interest rate attracts more capital into the economy and increase demand for NOK currency, resulting in appreciation of NOK and vice versa.

86. Effect of TOT on exchange rate = WITH LOOKUP (TOT, ([(0,0)-(2.2,2)], (0.0244648,1.05), (0.489297,1),(0.856269,0.98),(1.34557,0.95),(1.70642,0.93),(2,0.91),(2.2,0.9)))
Units: Dmnl

This variable represents the feedback relationship between Terms of Trade (Exports/Imports) and exchange rate. When TOT of a country is higher, it means exports are higher than imports, and demand for the home currency increase. This leads to appreciation of the home currency and vice versa.

87. Elasticity of exchange rate to inflation = 0.01
Units: Dmnl

This parameter represents the amount of change in inflation due to a change in exchange rate.

88. Elasticity of exchange rate to interest rate = 0.01
Units: Dmnl

This parameter estimates the effect of change in exchange rate on interest rate.

89. Employment time = 1
Units: Year

This parameter is used to normalize the variables.

90. Energy cost per unit = (energy production cost)* learning curve
Units: NOK/KWH

This variable estimates the cost of wind energy in kroner per kilowatt hours.

91. Energy price = 0.3
Units: NOK/KWH

This parameter represents the price of energy in kroner per kilowatt hours.

92. Energy production cost = 1.428
Units: NOK/KWH

This parameter represents the cost of producing NES energy in Kroner per kilowatt hours.

93. Equipment lifetime = 28
Units: Year

This parameter represents the average lifetime of equipment for extraction of oil and gas from developed reserves.

94. Expected cost of capital = SMOOTH (cost of capital, smoothing time for financial variables)
Unit: Dmnl/year

This variable represents the expected cost of capital to forecasts the future firm value. Expected cost of capital is forecasted by smoothing cost of capital for historic periods.

95. Expected exchange rate = INTEG(change in exchange rate, INITIAL EXCHANGE RATE
Units: NOK/USD

This stock calculates the expected exchange rate, provides a smoothed forecast of exchange rate based on the historic exchange rate.

96. Expected free cash flow = SMOOTH (free cash flow* employment time, smoothing time for financial variables)*(1+ expected growth rate)
Units: NOK/year

This variable provides expected free cash flows, by smoothing free cash flows for smoothing time for financial variables while accounting for the expected growth.

97. Expected growth rate = SMOOTH(return on equity*(1- payout ratio), smoothing time for financial variables)
Units: Dmnl/year

Expected growth rate is calculated by using sustainable growth rate formula used to calculate long term growth in corporate finance. The sustainable growth rate is calculated by multiplying the retention ratio by return on equity. The calculated growth rate is smoothed to estimate the expected growth rate.

98. Expected profit margin = SMOOTHI (realized price/ production cost per unit, smoothing time for financial variables, realized price/ production cost per unit)
Units: Dmnl

Expected profit margin is estimated based on the smoothed ratio between the price and production cost per barrel.

99. Exports = initial exports*((1+ growth rate in exports)^ growth time)* effect of exchange rate on exports
Units: USD/year

This variable represents the total exports of Norway calculated through the growth rate in exports and the effect of exchange rate on exports.

100. External financing needs = Max(0, desired capital budget- internal financing)
Units: NOK/year

This variable represents the needs for external financing from the difference between the desired capital budget and internal financing available withing the firm.

101. Firm value = INTEG(new year value- old year value, INITIAL FIRM VALUE)
Units: NOK

This stock represents the total firm value in kroner (NOK). Change in value every year is calculated through inflow, new year value, and outflow, old year value.

102. Fixed assets = INTEG(New fixed assets- depreciation expense , INITIAL FIXED ASSETS)
Units: NOK

This stock represents the total fixed assets of the firm over the years. Fixed assets stock increases with increases in investments in new fixed assets and decreases with depreciation of assets.

103. Free cash flow = (Net income after taxes+ depreciation expense+ after tax interest on debt+ increase in liabilities)- capital expenditures- increase in assets- capital expenditure nes
Units: NOK/year

This variable represents the free cash flows, the cash left after paying for all the costs and expenses and capital expenditures. Free cash flows have been calculated using formula from Beninga, (2008). All the non-cash expenses are added back to the net income after taxes. And expenses and capital expenditures are deducted to calculate the free cash flows.

104. Gross profit = (sales- cost of goods sold)+ gross profit loss NES
Units: NOK/year

This variable represents the gross profit for the firm after subtracting the cost of goods sold. This includes gross profit from oil and gas operations and gross profit or loss from NES (new energy solutions) operations.

105. Gross profit loss NES = NES sales- production cost NES
Units: NOK/year

Gross profit/loss NES represents the gross profit from NES operations, subtracting the cost of goods sold for NES from NES sales.

106. Growth in cumulative world capacity NES = 0.05
Units: Dmnl/year

This parameter estimates the growth in New energy solutions world-wide, estimated from the trends towards environmentally friendly solutions for energy.

107. Growth in inflation norway = WITH LOOKUP(Time/ employment time, ([(2000,-0.5)-(2050,0.5)], (2000,-0.2),(2004.59,-0.1),(2010.24,-0.03),(2014.53,-0.00877193),(2016.97,- 0.00438596), (2018.65, -0.00438596), (2029.82,-0.01), (2050,-0.008)))
Units: Dmnl

This variable represents the annual growth rate in inflation in Norway.

108. Growth in inflation us = WITH LOOKUP (Time/ employment time, ([(2000,-0.3)-(2050,0.5)],(2000,-0.2),(2003.21,-0.100877),(2005.05,-0.0263158),(2006.27,-0.00877193),(2010.24,-0.0175439), (2013.76,-0.0368421),(2029.97,-0.02),(2050,-0.01)))
Units: Dmnl

This variable represents the annual growth rate in inflation in US.

109. Growth in interest rate Norway = WITH LOOKUP (Time/ employment time, ([(2000,-1)-(2050,1)], (2000,-0.01),(2001.88,-0.02),(2007.7,-0.03),(2022,-0.06),(2050,-0.07)))
Units: Dmnl

This variable represents the annual growth rate in interest rate in Norway. The growth has been estimated from historical trend of interest rate.

110. Growth in interest rate US = WITH LOOKUP (Time/ employment time, ([(2000,-1)-(2050,1)],(2000,-0.001),(2001.54,-0.01),(2004.62,-0.03),(2009.24,-0.032),(2032.87,-0.036),(2050,-0.036)))
Units: Dmnl

This variable represents the annual growth rate in interest rate in US. The growth has been estimated from trend in actual interest rate.

111. Growth in NES = cumulative world capacity NES* growth in cumulative world capacity NES
Units: KWH/year

This inflow to the stock of cumulative world capacity NES represents the growth in NES capacity based on stock of NES capacity and the growth in capacity measured per year.

112. Growth in PCI US = 0.02
Units: Dmnl

This parameter represents the growth rate in US Per Capita Income (PCI).

113. Growth rate = (dividend per share/ delayed dividend per share)-1
Units: Dmnl

This variable represents growth rate estimated through dividend growth model formulation to calculate the cost of equity of the firm.

114. Growth rate in exports = WITH LOOKUP (Time/ employment time, ([(2000,0)-(2050,0.5)],(2000,0),(2003,0.02),(2005.05,0.04),(2007.53,0.07),(2015.9,0.03),(2050,0.01)))
Units: Dmnl

This variable represents the growth rate in exports of Norway.

115. Growth rate in imports = WITH LOOKUP (Time/ employment time, ([(2000,0)-(2050,0.5)],(2000,0.001),(2003,0.02),(2005.5,0.05),(2007.53,0.07),(2020.49,0.04),(2050,0.01)))
Units: Dmnl

This variable represents the growth rate in imports of Norway.

116. Growth time = WITH LOOKUP (Time/ employment time, ([(1999,0)-(2050,60)],(2000,1),(2001,2),(2002,3),(2003,4),(2004,5),(2005,6),(2006,7),(2007,8),(2008,9),(2009,10),(2010,11),(2011,12),(2012,13),(2013,14),(2014,15),(2015,16),(2016,17),(2017,18),(2018,19),(2019,20),(2020,21),(2021,22),(2022,23),(2023,24),(2024,25),(2025,26),(2026,27),(2027,28),(2028,29),(2029,30),(2030,31),(2031,32),(2032,33),(2033,34),(2034,35),(2035,36),(2036,37),(2037,38),(2038,39),(2039,40),(2040,41),(2041,42),(2042,43),(2043,44),(2044,45),(2045.17,46),(2046,47),(2047,48),(2048,49),(2049,50),(2050,51)))
Units: Dmnl

This variable is used to represent the number of years for calculating growth per year in macroeconomic determinants of exchange rate, representing the initial simulation year as time period 1 to the end of the period as 51.

117. Imports = (initial imports*((1+ growth rate in imports)^ growth time)* effect of exchange rate on imports)
Units: USD/year

This variable represents the total imports of US per year in USD calculated from growth rate and effect of exchange rate on imports.

118. Income tax expense = tax rate* net income before taxes
Units: NOK/year

This variable represents the income tax expense for the firm. The expense is calculated from net income and tax rate.

119. Increase in assets = (Credit Sales- Cash collections)
Units: NOK/year

This increase in current assets represent the cash needed for inventories and accounts receivables when sales increase. Although this is not considered as expense for tax purposes but drains cash and is subtracted when calculating free cash flows (Beninga, 2008). This increase in current assets is calculated from accounts receivable's inflows and outflows.

120. Increase in liabilities = (Credit purchases- Payments)
Units: NOK/year

Increase in current liabilities when it is related with sales, provides cash to the firm indirectly and is added to the free cash flow calculation (Beninga, 2008). This increase in current liabilities is calculated through account payables' inflows and outflows.

121. Indicated trend = ((PPC- RC)/ RC)/ time horizon TF
Units: Dmnl/year

Indicated trend represents the difference between the PPC (perceived present condition of exchange rate) and RC (reference condition of exchange rate) and this difference is a fraction of RC and divided by Time horizon TF. This variable provides the fractional rate of change in exchange rate (Sterman, 2000).

122. Inflation norway = ((initial inflation norway*((1+ growth in inflation norway)^ growth time))* effect of exchange rate on inflation)
Units: Percent/year

This variable represents inflation in Norway per year calculated from growth rate and effect of exchange rate on inflation.

123. Inflation US = initial inflation us*((1+ growth in inflation us)^ growth time)*(1/ effect of exchange rate on inflation)
Units: Percent/year

This variable represents the Inflation in US per year, calculated from growth in inflation and effect of exchange rate on inflation. Reciprocal for effect is used as exchange rate is used as NOK/USD. Thus, this effect formulation would be opposite for USD.

124. Initial accounts payable = 2.672e+010
Units: NOK

This constant represents the initial value for accounts payable stock.

125. Initial accounts receivable = 2.0355e+010
Units: NOK

This constant represents the initial value for accounts receivable stock.

126. Initial capacity = IF THEN ELSE (Time=2016, 2.22154e+008 , 0)
Units: KWH

This variable defines the initial capacity of NES in kilowatt hours. As NES is introduced in 2016 in the model, initial capacity is set zero otherwise.

127. Initial capacity in process = 1e+008
Units: Boe/year

This constant represents the initial value for capacity in process for oil and gas.

128. Initial capacity of equipment = 3.59869e+008
Units: Boe/year

This constant represents the initial capacity for equipment in place for oil and gas production.
Description: Estimated from actual production

129. Initial Cash = 3.01e+009
Units: NOK

This constant represents the initial cash for Cash stock.

130. Initial common stocks = 1.976e+009
Units: Share

This constant represents the initial value for common stocks measured as number of outstanding shares of the firm.

131. Initial cumulative world capacity NES = 7.58055e+008
Units: KWH

This constant represents the initial capacity of cumulative world capacity NES.

132. Initial debt = 3.7862e+010
Units: NOK

This constant represents the initial value of total debt of the firm.

133. Initial debt to equity ratio = INITIAL(debt to equity ratio)
Units: Dmnl

This constant represents the initial debt to equity ratio to calculate the relative debt to equity ratio.

134. Initial developed reserves = INITIAL(2.677e+009)
Units: Boe

This constant represents the initial number of developed reserves measured in barrel of oil equivalent.

135. Initial exchange rate = 8
Units: NOK/USD

This constant represents the initial value of exchange rate for NOK/USD.

136. Initial exports = 7.81106e+010
Units: USD/year

This constant represents initial value for exports of Norway.

137. Initial firm value = 9.88e+010
Units: NOK

This constant represents the initial value for the firm value estimated from market price per share and number of outstanding stocks.

138. Initial fixed assets = 1.02697e+011
Units: NOK

This constant represents the initial value for total fixed assets of the firm.

139. Initial imports = 4.94759e+010
Units: USD/year

This constant represents the initial value for imports of Norway.

140. Initial inflation Norway = 0.0297
Units: Percent/year

This constant represents the initial inflation in Norway measured in percentage per year.

141. Initial inflation US = 0.0339
Units: Percent/year

This variable defines the initial inflation in US measured as percent per year.

142. Initial interest rate US= 6.02917
Units: Percent/year

This constant represents the initial interest rate for US measured in percent per year.

143. Initial interest rate Norway = 6.21833
Units: Percent/year

This constant represents the initial interest rate in Norway measured in percent per year.

144. Initial market to book ratio = INITIAL(market to book ratio)
Units: Dmnl

This constant represents the initial market to book ratio.

145. Initial oil prices = 30.26
Units: USD/Boe

This constant represents the initial price for oil measured in USD per barrel of oil equivalent.

146. Initial per capita Norway = 38146.7
Units: USD/year

This constant represents the initial per capita income in Norway measured in USD per year.

147. Initial per capita US = 36334.9
Units: USD/year

This constant represents initial per capita income in US measured in USD per year.

148. Initial PPC = PPC
Units: NOK/USD

This constant represents initial perceived present condition (PPC) for exchange rate.

149. Initial production = INITIAL (production oil and gas)
Units: Boe/year

This constant represents the initial oil and gas production per year measured in barrels of oil equivalent (Boe).

150. Initial production cost = 27
Units: NOK/Boe

This constant represents the initial production cost for producing one barrel of oil equivalent measured in Norwegian kroner. Production cost per boe is calculated as the total operating expenses upstream for the last four quarters divided by the production volumes (Mboe/day multiplied by no.of days) for the corresponding period.

151. Initial Proved Reserves = INITIAL (4.317e+009)
Units: BOE

This constant represents the initial volume of proved reserves, measured in barrels of oil equivalent.

152. Initial Return on equity = INITIAL(Return on equity)
Units: Dmnl/year

This constant represents the initial value for return on equity.

153. Initial revenue = INITIAL (Oil and gas revenue)
Units: NOK/year

This constant represents the initial oil and gas revenue measured in Norwegian kroner per year.

154. Initial Total Equity = 6.148e+010
Units: NOK

This constant represents the initial value of total equity for the firm in Norwegian kroner.

155. Initial Trend = 0.01
Units: Dmnl/Year

This constant represents the initial trend to the stock of perceived trend for exchange rate.

156. Installation cost = 21
Units: NOK/KWH

This constant represents the estimated installation cost in kroner per kilowatt hours for NES.

157. Installations = (Capacity in process/ time to develop)
Units: Boe/year/year

This flow represents an outflow from Capacity in process stock (for oil and gas) and inflow to the capacity of equipment stock. Time to develop defines the delay which is involved in developing the capacity of equipment to extract oil and liquids from the reserves.

158. Interest Expenses = Total Debt* Interest Rate
Units: NOK/year

This variable represents the interest expense for the firm determined by the total debt and interest rate.

159. Interest rate = risk free interest rate*(1+ growth in interest rate Norway)+ risk premium of debt
Units: 1/Year

This variable defines the interest rate, cost of debt to the firm. This rate is determined as risk free interest rate accounted for the growth in interest rate of Norway. Risk premium of debt is also added to the cost which is determined by the riskiness of the firm.
This cost is from realized interest rate from historical data of the firm.

160. Interest rate Norway = ((initial interest rate Norway*((1+ growth in interest rate Norway) ^ growth time) * effect of exchange rate on interest rate))
Units: Percent/year

This variable defines the interest rate in Norway calculated from initial interest rate and growth in interest rate given the effect of exchange rate on interest rate.

161. Interest rate US = initial interest rate*((1+ growth in interest rate us)^ growth time)*(1/ effect of exchange rate on interest rate)
Units: Percent/year

This variable defines the interest rate in US calculated from initial interest rate, growth in US interest rate and accounting for the effect of exchange rate on interest rate.

162. Internal Financing = Retained income- Debt payments
Units: NOK/year

This variable defines the internal financing available within the firm generated from internal profitable operations.

163. Investment fraction = 0.65
Units: DMNL

This constant defines the fraction for dividing total investment into oil reserves and equipment capacity.

164. Issuance of Stock = New Equity/ Market price per share
Units: Share/year

This inflow represents the issuance of new shares for raising equity.

165. Learning curve = WITH LOOKUP (Relative cumulative world capacity NES, ([(0.9,0)-(15,1)],(1,1),(2,0.8),(2.5,0.7),(3,0.6),(4,0.5),(15,0.5)))
Units: DMNL

This look up function incorporates the learning curve for NES with assumption that as the world is focusing on NES, costs would reduce as expertise would increase. Thus, with increase in world cumulative capacity for NES, energy cost for the firm would also reduce.

166. Manufacture marketing cost = Manufacturing and marketing sales* cost fraction
Units: NOK/year

This variable represents the cost of goods sold for the firm except for oil and gas and NES (which are endogenized in the model).

167. Manufacturing and Marketing sales = oil and gas revenue* effect of oil revenue on sales
Units: NOK/Year

This variable represents the rest of the revenue to the firm except for oil and gas revenue.

168. Market price oil = " NOK/USD"* oil price in dollars
Units: NOK/BOE

This variable represents the market price for oil in Norwegian Kroner per barrel of oil equivalent.

169. Market price per share = max(firm value/ common stocks, 0)
Units: NOK/share

This variable represents the reference mode, the variable which represents the value of the firm. Market price per share is calculated as total firm value divided by the total number of outstanding shares.

170. Market to book ratio = Market price per share/ Book Value per Share
Units: Dmnl

This ratio evaluates the current price of business represented through market price per share, to the book value per share of the business. This ratio compares the market value of the firm to its book value.

171. NES Energy Capacity = INTEG (New capacity- Depreciation NES, INITIAL CAPACITY)
Units: KWH

This stock represents the total capacity for NES by the firm.

172. NES Sales = energy price* power production
Units: NOK/Year

This variable represents the sales for NES energy by the firm determined by the production and market price for NES.

173. Net income after taxes = Net income before taxes- Income tax expense
Units: NOK/Year

This variable represents the profit of the firm after paying all the costs, expenses, and taxes.

174. Net income before taxes = Operating income- Interest expenses
Units: NOK/Year

This variable represents the net income of the firm before paying the taxes, calculated by subtracting the interest expenses from operating income.

175. New capacity = new production capacity NES
Units: KWH/Year

This inflow represents the addition of new production capacity to the stock of NES energy capacity.

176. New Debt = Debt policy outcome* External financing needs
Units: NOK/year

This inflow to the stock of total debt represents the debt borrowed every year.

177. New Developed Reserves = Proved Reserves/ Time to develop)
Units: BOE/Year

This flow represents the outflow from the proved reserves and inflow to the developed reserves stock. This represents the transition from proved reserves to the developed reserves delayed by the time to develop.

178. New equity = (1- debt policy outcome)* external financing needs
Units: NOK/Year

This variable represents the new equity issued every year to meet the capital requirements.

179. New equity issued = New Equity
Units: NOK/Year

This inflow to the stock of total equity represents the new equity added to the total equity of the firm every year.

180. New Fixed Assets = Capital expenditures+ Capital expenditure NES
Units: NOK/Year

This inflow represents the new fixed assets of the firm per year calculated from total capital expenditure per year.

181. New Production Capacity NES = Capital expenditure NES/(Energy Cost per unit+ Installation cost)
Units: KWH/Year

This variable represents the new production capacity NES measured in Kilowatt hours per year. New capacity is defined by the total capital expenditure NES divided by the total cost to produce the unit kilowatt hours, including energy cost and installation cost.

182. New Production Capacity = Desired new production capacity*(Capital Expenditures/Desired Capital Budget Oil)
Units: BOE/Year

This variable represents the new production capacity determined from the desired new production capacity and percentage of availability of capital expenditure out of desired capital budget.

183. New Year Value = Present Value Free Cash Flow/ Employment Time
Units: NOK/year

This inflow represents the new year value added to the firm value stock.

184. NOK/USD = (Initial exchange rate* effect of RIR on exchange rate* Effect of PCI* effect of RI on exchange rate* effect of market expectations* effect of TOT on exchange rate* effect of oil prices on exchange rate)
Units: NOK/USD

This variable represents the exchange rate, NOK (Norwegian kroner) per USD (united states dollars).

185. Oil and Gas Revenue = Production Oil and Gas* Smoothed Price
Units: NOK/Year

This variable represents the revenue from oil and gas production, given the realized oil and gas prices.

186. Oil Exploration = New production capacity*(investment fraction)
Units: BOE/Year

This variable represents the inflow to the stock of proved reserves. The added capacity is defined by the investment percentage out of capital expenditure to be spent on exploration and the new production capacity.

187. Oil Price in dollars = WITH LOOKUP (Time/ employment time, ([(2000,0)-(2050,200)], (2000,27.6),(2001,23.12),(2002,24.36),(2003,28.1),(2004,36.05),(2005,50.59),(2006,61),(2007,69.04),(2008,94.1),(2009,60.86),(2010,77.38),(2011,107.46),(2012,109.45),(2013,105.87),(2014,96.29),(2015,49.49),(2016,40.68),(2017,52.51),(2018,71),(2019.27,64.3),(2020,39),(2021,65),(2050,60)))
Units: USD/BOE

This lookup function represents the oil price in USD per year.

188. Old Year Value = delayed present value free cash flow/ employment time
Units: NOK/Year

This outflow represents the old year value of the firm calculated from one-year delayed PVFCF.

189. Operating Expenses = Sales* Operating Expenses Fraction
Units: NOK/Year

This variable represents the operating expenses of the firm estimated as percentage of sales. Percentage is estimated from the historic data of operating expenses.

190. Operating expenses fraction = 0.12
Units: DMNL

This constant represents the percentage of operating expenses.

191. Operating Income = Gross Profit- Operating Expenses- Depreciation Expense
Units: NOK/Year

This variable represents the operating income calculated by subtracting the operating expenses and depreciation expense from gross profit.

192. Ordering New Capacity = (New production capacity/ ordering time)*(1- investment fraction)
Units: BOE/Year/Year

This inflow to the stock of capacity in process is determined from new production capacity delayed by the ordering time, given the capital expenditure spent on capacity.

193. Ordering Time = 5
Units: Year

This parameter represents the ordering time for ordering new capacity.

194. Past Dividend = Delayed Dividends / Delayed equity
Units: DMNL/Year

This variable calculates the ratio between dividends from previous period and equity from previous period to estimate the effect of this ratio on capital structure decision. If the firm pay out higher dividend as compared to previous period, the firm would need more debt in capital structure mix to meet the capital requirements.

195. Past Dividend benchmark = 0.1
Units: DMNL/Year

This constant represents benchmark to calculate relative past dividend to normalize the ratio.

196. Payments = Accounts Payable/ Average Payment Period
Units: NOK/Year

This outflow represents the payments for accounts payable by the firm based on credit practices of the firm estimated through average payment period.

197. Payout Ratio = Dividend Policy*(effect of return on equity on payout ratio* effect of investment opportunities on pay-out ratio* effect of debt to equity ratio on pay-out ratio* effect of relative profitability on pay-out ratio)
Units: Dmnl

This variable represents the payout decision by the firm. This percentage is based on previous dividend policy and effects of key financial indicator including return on equity, investment opportunities, debt to equity ratio and profitability on pay-out ratio.

198. Per Capita Income Norway = Initial Per Capita Norway* effect of production on per capita income
Units: USD/Year

This variable represents the per capita income in Norway calculated from initial per capita income and effect of oil and gas production on per capita income.

199. Per Capita Income US = Initial Per Capita US*((1+ growth in pci us)^ growth time)
Units: USD/Year

This variable represents per capita income in US estimated from initial per capita income and growth in PCI.

200. Perceived Trend = INTEG (Change in trend, INITIAL TREND)
Units: DMNL/Year

This stock represents the perceived trend, expected rate of change in exchange rate.

201. Percent Debt Financing = (effect of profitability on debt)*(effect of debt to equity ratio on debt financing)*(effect of asset growth on debt)*(effect of past dividend on debt)*(effect of agency costs on debt financing)+((1/ effect of profitability on debt)*(1/ effect of debt to equity ratio on debt financing)*(1/ effect of asset growth on debt)*(1/ effect of past dividend on debt))* effect of agency costs on debt financing*0
Units: DMNL

This variable represents the percentage of debt financing in external financing calculated from effects of profitability, debt to equity ratio, asset growth, past dividend and agency cost on debt. The second part of equation which is currently switched off (for base case) has been used to test the theories of debt.

202. Power Production = NES energy capacity/ capacity equipment lifetime
Units: KWH/Year

This variable represents the energy production from NES by the firm per year conditioned by the NES capacity and equipment lifetime.

203. PPC = INTEG (Change in PPC, INITIAL EXCHANGE RATE /(1.0+(Time horizon TF* INITIAL TREND))
Units: NOK/USD

This stock for perceived present condition represents the smoothed value of exchange rate, using first order smoothing.

204. Present Value Free Cash Flow = (Free Cash Flow/(1+ Cost of Capital))+ Terminal Value
Units: NOK

Present value free cash flow represents the present value of stream of cash flows the firm is expected to produce. PVFCF is calculated from PVFCF and terminal value of the firm.

205. Production Cost NES = Power Production* Energy Cost Per Unit
Units: NOK/Year

This variable represents the cost of goods sold for NES.

206. Production Cost per unit = (Initial production cost* effect of cumulative production ratio on cost)
Units: NOK/BOE

This variable represents the production cost per unit for producing one barrel of oil equivalent per year. The cost is estimated from initial production cost and effect of cumulative production ratio on cost.

207. Production oil and gas = MIN(Developed reserves/ production time, capacity of equipment)
Units: BOE/Year

This variable represents the oil and gas production from developed reserves given the production time, where capacity of equipment is the prerequisite. Thus, given the available developed reserves and capacity, production is determined through production time.

208. Production time = 6
Units: Year

This constant represents the average production time on an aggregate level for the firm.

209. Profitability = Net Income Before Taxes/ Total assets
Units: DMNL/Year

This variable represents the profitability ratio, calculated from net income before taxes divided by total assets. This ratio estimates how efficiently the firm utilizes assets to generate net income.

210. Proved Reserves = INTEG(Oil Exploration- New Developed Reserves, INITIAL PROVED RESERVES
Units: BOE

This stock represents the aggregated proved stocks for the firm. Proved reserves are defined as: which require the use of a price based on a 12-month average for reserve estimation, and which are based on existing economic conditions and operating methods and with a high degree of confidence (at least 90% probability) that the quantities will be recovered (Definition by Equinor).

211. RC = INTEG(Change in RC, INITIAL PPC/(1.0+(Time horizon TF * INITIAL TREND))
Units: NOK/USD

This stock for reference condition (RC) is determined by the smoothing of perceived present condition.

212. Realized Percentage = IF THEN ELSE(Time<2005,1, 0.8)
Units: DMNL

This variable defines the percentage for actual realized price for oil and gas, received by the firm.

213. Realized Price = market price oil* realized percentage
Units: NOK/BOE

This variable defines the realized price received by the firm. The reason being that the market price for oil reported globally is a rounded figure, that might slightly vary as the reported price is averaged yearly. Another reason is the model uses average price for oil and gas as production is also merged. Thus, the realized price is the actual oil and gas price received by the firm estimated from the oil and gas revenue and oil and gas production of the firm per year.

214. Realizing Time = 2
Units: Year

This constant represents the time to smooth the realized price to account for the delays in receipt of revenues.

215. Relative Agency Costs = agency costs/ benchmark agency costs
Units: DMNL

This variable defines the relative agency costs to normalize the agency costs through benchmark agency costs. The variable is used to determine the effect of agency costs on debt.

216. Relative Cumulative World Capacity NES = Cumulative world capacity NES/ initial cumulative world capacity NES
Units: Dmnl

This variable calculates the cumulative world capacity for NES relative to its initial value.

217. Relative Debt to Equity Ratio = Debt to Equity Ratio/ Initial Debt to Equity Ratio
Units: Dmnl

This variable represents the debt-to-equity ratio relative to its initial. Relative debt to equity ratio is calculated to normalize the debt-to-equity ratio to estimate the effect relationship with capital structure and dividend pay-out decisions.

218. Relative exchange rate = expected exchange rate/ initial exchange rate

Units: Dmnl

This variable represents expected exchange rate relative to initial exchange rate. Relative exchange rate is calculated to normalize the expected exchange rate to estimate the effect relationship with other macroeconomic variables such as exports, imports, inflation and interest rate.

219. Relative Income Per Capita = Per Capita Income Norway/ Per capita Income US
Units: Dmnl

This variable represents the per capita income Norway relative to per capita income of US. The relative income per capita is calculated to estimate the effect relationship of both countries' per capita income with exchange rate between NOK and USD.

220. Relative Inflation = Inflation Norway/ Inflation US
Units: Dmnl

This variable represents the inflation in Norway relative to inflation in US.

221. Relative Interest Rate = Interest Rate Norway/ Interest Rate US
Units: Dmnl

This variable represents the interest rate in Norway relative to interest rate in US.

222. Relative market to book ratio = market to book ratio/ initial market to book ratio
Units: Dmnl

This variable represents the market to book ratio relative to its initial value.

223. Relative Oil Prices = (Oil Price in dollars/ Initial Oil Prices)
Units: Dmnl

This variable represents the oil prices in dollars relative to initial oil prices.

224. Relative Past Dividend = Past Dividend/ Past Dividend benchmark
Units: Dmnl

This variable represents the past dividend ratio relative to benchmark past dividend.

225. Relative Production = Production Oil and Gas/ Initial Production
Units: Dmnl

This variable represents oil and gas production relative to initial oil and gas production.

226. Relative Profitability = Profitability/ Benchmark Profitability
Units: Dmnl

This variable represents profitability relative to benchmark profitability.

227. Relative Reserves = Developed Reserves/ Initial Reserves
Units: Dmnl

This variable represents developed reserves relative to initial value of developed reserves.

228. Relative Revenue = Oil and Gas Revenue/ Initial Revenue
Units: Dmnl

This variable represents oil and gas revenue relative to its initial value.

229. Relative ROE = Return on Equity/ Initial Return on Equity
Units: Dmnl

This variable represents return on equity relative to its initial value.

230. Retained Income = (net income after taxes- total dividends)
Units: NOK/Year

This variable represents the retained income per year after paying dividends from net income after taxes.

231. Return on Equity = Net Income After Taxes/ Total Equity
Units: Dmnl/Year

This variable represents the return on equity, an indicator of financial performance of the firm measured by dividing the net income after taxes by total equity.

232. Risk free interest rate = 0.025
Units: Dmnl/Year

This constant represents the risk-free interest rate.

233. Risk premium of debt = WITH LOOKUP (Debt to Equity Ratio, ([(0,0)-(2,0.1)], (0,0.01), (0.5,0.012),(0.75,0.015),(1,0.02),(1.25,0.022),(1.5,0.025),(1.75,0.03),(2,0.04)))
Units: Dmnl/Year

This variable accounts for the default risk premium of the firm which adds to the interest rate paid by the firm on debt. This cost exists to compensate the debtholders against the risk of default by the firm. Risk premium of debt is added to the risk free interest rate to calculate the interest rate paid by the firm.

234. Sales = Oil and gas revenue+ Manufacturing and marketing sales
Units: NOK/Year

Sales are a submission of oil and gas revenue and the rest of the operations of the firm summarized into manufacturing and marketing sales.

235. Smoothed Price = SMOOTH (realized price, realizing time)
Units: NOK/BOE

This variable is formulated to smooth oil and gas prices to account for the time delays and the actual oil and gas prices received by the firm as compared to quoted market prices globally.

236. Smoothing time for financial variables = 6
Units: Year

This constant represents the time used for smoothing the financial variables in the model to generate smoothed output, trying to minimize noises in data.

237. Tax Rate = 0.68
Units: DMNL

This constant represents the tax rate, rate used to calculate the tax payments by the firm. Standard income tax as per 2019 is 22% in Norway. Special tax rate on income generated from petroleum and related operations is taxed at additional 56% rate in Norway, making a 78% marginal tax rate on income. This rate is estimated given the tax payments by the firm.

238. Terminal Value = (Expected free cash flow/ Expected cost of capital)* effect of reserves on value
Units: NOK

This variable estimates the value of the firm beyond the forecasted period, based on assumptions taken, in the future forever. The free cash flows are estimated using perpetual growth method which estimates the future cash flows (perpetuity) based on the present free cash flows of the firm.

239. Time to adjust production capacity = 13
Units: Year

This constant accounts for the time delay for investing in new production capacity.

240. Time to Develop = 9
Units: Year

This constant accounts for the time delay from exploration of reserves to development and capacity building for extraction of oil and gas from reserves.

241. Time to Perceive Trend = 5
Units: Year

This constant represents the time to perceive trend for exchange rate, a parameter used in expectation formation for exchange rate, modelled through Trend function explicitly.

242. Time Horizon TF = 1
Units: Year

Time horizon Trend Function represents the constant that accounts for time required to perceive present condition, and time horizon for the reference condition, used in Trend function modelled explicitly to generate the expected rate of change in exchange rate.

243. TOT = Exports/ Imports
Units: DMNL

This variable calculates Terms of Trade (TOT) as a ratio between exports and imports of Norway. The ratio provides a measure of total price of exports as compared to total price of imports. TOT influence and are influenced by the exchange rate fluctuations.

244. Total Assets = Fixed Assets+ Cash+ Accounts Receivable
Units: NOK

This variable represents the total assets of the firm including the current and fixed assets.

245. Total debt = INTEG (New Debt- Debt Payments, INITIAL DEBT)
Units: NOK

The stock for total debt represents the liabilities and includes long term debt and short-term debt. The inflow is new debt and outflow is debt payments. This stock is used as Plug-in for initializing balance sheet in balance.

246. Total dividends = net income after taxes* pay-out ratio
Units: NOK/Year

This variable represents the total dividends paid by the firm per year as per the dividend payout policy.

247. Total Equity = INTEG (New equity issued+ Retained Income, INITIAL TOTAL EQUITY)
Units: NOK

The stock for total equity represents the total equity of the firm which includes both common stock and additional paid in capital. The inflow is the new equity issued and retained earnings.

Data

Historical Data used for Model Calibration and Initialization

This section represents the data that has been used to initialize and calibrate the model for Article 1,2,3, and 5.

Time	*firm value*	*market price per share*	*NOK/USD*	*inflation us*	*inflation norway*	*market price per share*
2000	9,88E+10	50	7,7	0,0339	0,0297	50
2001	1,3261E+11	61,25	8,8	0,0155	0,021	61,25
2002	1,2617E+11	58,25	7,97	0,0238	0,027	58,25
2003	1,6202E+11	74,8	7,08	0,0188	0,0063	74,8
2004	2,0555E+11	94,9	6,74	0,0326	0,0112	94,9
2005	3,3503E+11	154,75	6,45	0,0342	0,0184	154,75
2006	4,432E+11	165,65	6,42	0,0254	0,0217	165,65
2007	5,3445E+11	167,75	5,86	0,0408	0,0283	167,75
2008	3,6245E+11	113,8	5,63	0,0119	0,0218	113,8
2009	4,6265E+11	145,35	6,3	0,0272	0,0202	145,35
2010	4,4389E+11	139,5	6,05	0,015	0,0275	139,5
2011	4,8828E+11	153,45	5,61	0,0296	0,02	153,45
2012	4,4407E+11	139,6	5,82	0,0174	0,0139	139,6
2013	4,6905E+11	147,5	5,8	0,015	0,0201	147,5
2014	4,1721E+11	131,2	6,3	0,0076	0,0207	131,2
2015	3,933E+11	123,7	8,07	0,0073	0,0233	123,7
2016	5,0609E+11	158,4	8,4	0,0207	0,0347	158,4
2017	5,7255E+11	175,2	8,2	0,0211	0,0163	175,2
2018	6,1115E+11	183,75	8,14	0,0191	0,0349	183,75
2019	5,8371E+11	175,5	8,79	0,0229	0,0137	175,5
2020	4,9042E+11	147,45	9,5	0,0124	0,0129	147,45

Time	*foreign imports*	*interest rate us*	*interest rate norway*	*oil price*	*Common stocks*
2000	3,3902E+10	6,029167	6,218333	30,26	1976000000,00
2001	3,3242E+10	5,0175	6,236667	25,9	2165000000,00
2002	3,5589E+10	4,610833	6,384167	26,17	2166000000,00
2003	4,1126E+10	4,015	5,045	31,01	2166000000,00

2004	5,0038E+10	4,274167	4,368333	41,25	2166000000,00
2005	5,7015E+10	4,29	3,745833	56,44	2165000000,00
2006	6,528E+10	4,791667	4,076667	66	2675500000,00
2007	8,1596E+10	4,629167	4,774167	72,26	3186000000,00
2008	9,2623E+10	3,666667	4,458333	99,06	3185000000,00
2009	6,982E+10	3,256667	3,998333	61,73	3183000000,00
2010	7,7757E+10	3,214167	3,528333	79,39	3182000000,00
2011	9,1803E+10	2,785833	3,135	94,88	3182000000,00
2012	8,8355E+10	1,8025	2,101667	94,05	3181000000,00
2013	9,1904E+10	2,350833	2,5775	97,98	3180000000,00
2014	9,0733E+10	2,540833	2,515	93,17	3179959000,00
2015	8,0945E+10	2,135833	1,565	48,66	3179443000,00
2016	7,5565E+10	1,841667	1,331667	43,29	3195000000,00
2017	8,4846E+10	2,33	1,6375	50,88	3268000000
2018	1642500000	2,91	1,87	64,94	3326000000,00
2019			1,49	56,98	3326000000,00
2020			0,82	30	3326000000,00

Time	*Per capita income norway*	*per capita income us*	*exports*	*imports*	*foreign imports*
2000	38146,72	36334,909	7,8111E+10	4,9476E+10	3,3902E+10
2001	38549,589	37133,243	7,7803E+10	4,8844E+10	3,3242E+10
2002	43061,15	38023,161	7,9043E+10	5,3236E+10	3,5589E+10
2003	50111,654	39496,486	9,0329E+10	6,1073E+10	4,1126E+10
2004	57570,269	41712,801	1,0843E+11	7,3339E+10	5,0038E+10
2005	66775,394	44114,748	1,3322E+11	8,3872E+10	5,7015E+10
2006	74114,697	46298,731	1,5367E+11	9,5254E+10	6,528E+10
2007	85170,862	47975,968	1,7368E+11	1,1963E+11	8,1596E+10
2008	97007,942	48382,558	2,1432E+11	1,3455E+11	9,2623E+10
2009	80067,177	47099,98	1,5221E+11	1,052E+11	6,982E+10
2010	87770,267	47450,318	1,7057E+11	1,2011E+11	7,7757E+10
2011	100711,225	49883,114	2,0572E+11	1,3877E+11	9,1803E+10
2012	101668,171	51603,497	2,0635E+11	1,4026E+11	8,8355E+10
2013	103059,248	53106,91	2,0394E+11	1,4795E+11	9,1904E+10
2014	97199,919	55032,958	1,9321E+11	1,4877E+11	9,0733E+10
2015	74521,57	56803,472	1,4548E+11	1,2362E+11	8,0945E+10
2016	70941,525	57904,202	1,3037E+11	1,2433E+11	7,5565E+10
2017	75704,24	59927,93	1,4432E+11	1,3041E+11	8,4846E+10
2018	81807,198	62641,014	1,6633E+11	1,4111E+11	1642500000

Time	*production oil and gas*	*Free Cash Flow*	*Realized Price*	*foreign exports*	*Oil price in dollars*	*market price oil*
2000	366825000	3,946E+10	222,753536	5,8195E+10	27,6	243,174106
2001	367555000	2,2524E+10	199,343559	5,6095E+10	23,12	207,818282
2002	392010000	6116000000	167,535457	5,7594E+10	24,36	195,296678
2003	394200000	8722000000	177,746203	6,8075E+10	28,1	199,281659
2004	403690000	7007000000	210,070081	8,4725E+10	36,05	242,927612
2005	426685000	2,4861E+10	275,271457	1,0243E+11	50,59	325,635941
2006	414275000	4,3416E+10	342,365172	1,2266E+11	61	391,218803
2007	629260000	4,2135E+10	348,68379	1,2925E+11	69,04	404,635362
2008	702625000	4,4004E+10	423,573436	1,6543E+11	94,1	530,777919
2009	716130000	5006000000	307,739534	1,1558E+11	60,86	383,060265
2010	689120000	1,68E+10	356,035909	1,3015E+11	77,38	467,753047
2011	675250000	3,39E+10	478,604367	1,5946E+11	107,46	602,38143
2012	731460000	3,32E+10	459,010892	1,5658E+11	109,45	637,048099
2013	708100000	-2E+09	446,817546	1,4762E+11	105,87	622,475264
2014	703355000	3608000000	380,177862	1,4979E+11	96,29	607,02333
2015	719415000	-3,157E+09	288,9848	1,1213E+11	49,49	399,255032
2016	721970000	-1,57E+10	229,601784	9,2796E+10	40,68	341,917841
2017	759200000	3900000000	294,610643	1,0608E+11	52,51	434,169536

Time	*Sales*	*Depreciation expense*	*Total Dividends*	*Debt Payments*	*New Debt*	*book value per share*
2000	2,2983E+11	1,5739E+10	1702000000	1,3258E+10	1191000000	25,2747976
2001	2,3171E+11	1,8058E+10	5668000000	4548000000	9609000000	23,9140878
2002	2,4218E+11	1,6844E+10	6169000000	4831000000	5396000000	26,323638
2003	2,4853E+11	1,6276E+10	6282000000	2774000000	3206000000	32,3979686
2004	3,0376E+11	1,7456E+10	6390000000	6574000000	4599000000	39,2566944
2005	3,8465E+11	2,0962E+10	1,1481E+10	3187000000	422000000	49,2581986
2006	5,1896E+11	2,0962E+10	1,7756E+10	2270000000	97000000	62,7295833
2007	5,2167E+11	3,945E+10	2,5694E+10	2876000000	1723000000	55,6418707
2008	6,5198E+11	4,2996E+10	2,7082E+10	2864000000	2596000000	67,2147567
2009	4,6252E+11	5,383E+10	2,3085E+10	4905000000	4,6318E+10	62,3056865
2010	5,2695E+11	5,0694E+10	1,91E+10	3300000000	1,56E+10	68,9817725
2011	6,456E+11	5,135E+10	1,99E+10	7400000000	1,01E+10	87,6492772
2012	7,043E+11	6,05E+10	2,07E+10	1,22E+10	1,31E+10	100,345803
2013	6,166E+11	7,24E+10	2,15E+10	7300000000	6,28E+10	111,792453

Time	*Net Income after taxes*	*Gross profit*	*Operating Income*	*interest expenses*	*Income Tax Expense*
2000	1,6637E+10	1,1036E+11	5,9991E+10	2035000000	4,0456E+10
2001	1,7733E+10	1,0556E+11	5,6154E+10	2713000000	3,8486E+10
2002	1,6999E+10	9,4279E+10	4,3102E+10	1952000000	3,4336E+10

2003	1,6843E+10	9,8882E+10	4,2891E+10	877000000	2,7447E+10
2004	2,5421E+10	1,1558E+11	6,5107E+10	317000000	4,5425E+10
2005	3,1495E+10	1,5393E+11	9,5043E+10	539000000	6,0036E+10
2006	5,1847E+10	2,6937E+11	1,6616E+11	1756000000	1,1939E+11
2007	4,4641E+10	2,6127E+11	1,372E+11	1489000000	1,0217E+11
2008	4,327E+10	3,228E+11	1,9883E+11	1534000000	1,372E+11
2009	1,7715E+10	2,5665E+11	1,2167E+11	3431000000	9,7195E+10
2010	3,7647E+10	2,6951E+11	1,3726E+11	435000000	9,9179E+10
2011	7,8443E+10	3,2599E+11	2,1178E+11	6555000000	1,354E+11
2012	6,95E+10	3,398E+11	2,066E+11	1700000000	1,372E+11
2013	3,92E+10	3,097E+11	1,555E+11	100000000	9,92E+10

Time	*Net Income Before Taxes*	*New Equity Issued*	*total debt*	*fixed Assets*	*Accounts Receivable*
2000	5,7093E+10	0	3,7862E+10	1,027E+11	2,0366E+10
2001	5,6219E+10	1,289E+10	4,1795E+10	1,265E+11	2,7739E+10
2002	5,1335E+10	0	3,7128E+10	1,2238E+11	3,395E+10
2003	4,429E+10	0	3,7278E+10	1,2653E+11	3,0192E+10
2004	7,0846E+10	0	3,6189E+10	1,5292E+11	3,1736E+10
2005	9,1531E+10	0	3,4093E+10	1,8067E+11	4,2816E+10
2006	1,7124E+11	-1,012E+09	4,2317E+10	2,2951E+11	5,6097E+10
2007	1,4681E+11	-217000000	5,054E+10	2,7835E+11	6,9378E+10
2008	1,8047E+11	-308000000	7,5301E+10	3,2984E+11	6,1083E+10
2009	1,1491E+11	-343000000	1,0411E+11	3,4252E+11	5,4829E+10
2010	1,3683E+11	0	1,115E+11	3,516E+11	7,59E+10
2011	2,1384E+11	0	1,314E+11	4,076E+11	9,56E+10
2012	2,067E+11	0	1,194E+11	4,391E+11	6,56E+10
2013	1,384E+11	0	1,826E+11	4,874E+11	8,18E+10

Time	*Cash*	*Production cost per unit*	*Retained Earnings*	*Proved reserves*	*Developed reserves*
2000	3,01E+09	26,95	4,5003E+10	4317000000	2677000000
2001	4395000000	26,25	6682000000	4277000000	2737000000
2002	6702000000	25,01	1,7355E+10	4267000000	2722000000
2003	7316000000	22,4	2,7627E+10	4264000000	2751000000
2004	5028000000	23,3	4,6153E+10	4289000000	2654000000
2005	7025000000	22,2	6,5401E+10	4295000000	2682000000
2006	1,2645E+10	27,3	9,685E+10	5152500000	3506500000
2007	1,8264E+10	30,95	1,283E+11	6010000000	4331000000
2008	1,8638E+10	34,6	1,6525E+11	5584000000	4229000000
2009	2,3508E+10	35	1,4948E+11	5408000000	4113000000
2010	2,74E+10	38	1,705E+11	5325000000	3975000000

2011	4,92E+10	42	2,302E+11	5426000000	3827000000
2012	6,29E+10	42	2,706E+11	5422000000	3737000000
2013	8,3E+10	44	2,845E+11	5600000000	3711000000

Time	*Operating Expenses*	*oil and gas revenue*	*Manufacturing and Marketing sales*	*Manufacture Marketing cost*	*Total Equity*
2000	2,8883E+10	8,0162E+10	1,4967E+11	1,0958E+11	4,9943E+10
2001	2,9422E+10	7,3348E+10	1,5836E+11	1,165E+11	5,1774E+10
2002	2,8308E+10	6,5549E+10	1,7663E+11	1,3809E+11	5,7017E+10
2003	2,6651E+10	6,9474E+10	1,7905E+11	1,4081E+11	7,0174E+10
2004	2,735E+10	8,3815E+10	2,1994E+11	1,7877E+11	8,503E+10
2005	3,0243E+10	1,1719E+11	2,6747E+11	2,2125E+11	1,0664E+11
2006	4,4801E+10	1,4161E+11	3,7735E+11	2,3828E+11	1,6783E+11
2007	6,0318E+10	2,208E+11	3,0087E+11	2,3434E+11	1,7728E+11
2008	5,9349E+10	2,651E+11	3,8688E+11	3,0487E+11	2,1408E+11
2009	5,6974E+10	2,005E+11	2,6202E+11	1,8081E+11	1,9832E+11
2010	5,767E+10	2,217E+11	3,0525E+11	2,3125E+11	2,195E+11
2011	6,0419E+10	2,823E+11	3,633E+11	2,9124E+11	2,789E+11
2012	4,52E+10	3,009E+11	4,034E+11	3,3378E+11	3,192E+11
2013	5,61E+10	2,841E+11	3,325E+11	2,7574E+11	3,555E+11

Time	*Dividend per share*	*Payout Ratio*	*cost of goods sold for oil and gas*	*Retained Income*	*Changes in Working Capital*
2000	0,86133603	0,10536742	9885933750	-3,817E+10	2,0464E+10
2001	2,61801386	0,32867498	9648318750	1,0564E+10	6409000000
2002	2,84810711	0,36619969	9804170100	1,0164E+10	-642000000
2003	2,90027701	0,37948532	8830080000	1,3435E+10	-2,901E+09
2004	2,9501385	0,25646171	9405977000	1,2974E+10	-5,736E+09
2005	5,30300231	0,37360885	9472407000	3,1557E+10	8853000000
2006	8,27785548	0,34735998	1,131E+10	1,7011E+10	-1,2E+11
2007	8,06465788	0,58268324	2,6051E+10	2,018E+10	-9,317E+10
2008	8,50298273	0,62595632	2,4311E+10	-787000000	-1,373E+11
2009	7,25259189	1,26057992	2,5065E+10	1,8182E+10	-9,958E+10
2010	6,00251414	0,50154929	2,6187E+10	5,8087E+10	-1,05E+11
2011	6,25589437	0,25257974	2,8361E+10	4,82E+10	-1,114E+11
2012	6,50943396	0,30043541	3,0721E+10	1,75E+10	-1,226E+11
2013	6,76313306	0,54020101	3,1156E+10		-1,092E+11

Time	*Paid Up Capital*	*Cash outflow from financing*	*cash inflow from financing*	*after tax interest on debt*	*Accounts Payable*

2000	4,32E+10	1,6995E+10	1191000000	651200000	2,672E+10
2001	4,3202E+10	1,2929E+10	2,2499E+10	868160000	2,1134E+10
2002	4,3202E+10	1,2952E+10	5396000000	624640000	2,5252E+10
2003	4,3202E+10	9933000000	3206000000	280640000	2,4091E+10
2004	4,2747E+10	1,3281E+10	4599000000	101440000	2,4903E+10
2005	4,2779E+10	1,5207E+10	422000000	172480000	3,2284E+10
2006	4,6061E+10	2,1782E+10	-915000000	561920000	5,5595E+10
2007	4,9342E+10	3,0059E+10	1506000000	476480000	6,4624E+10
2008	4,9422E+10	3,148E+10	2288000000	490880000	2,3045E+10
2009	4,9704E+10	3,1421E+10	4,5975E+10	1097920000	4,0128E+10
2010	4,88E+10	2,2835E+10	1,56E+10	139200000	7,37E+10
2011	4,87E+10	3,3855E+10	1,01E+10	2097600000	6,1801E+10
2012	4,86E+10	3,46E+10	1,31E+10	544000000	5,51E+10
2013	4,83E+10	2,89E+10	6,28E+10	32000000	6,02E+10

Time	*Capital Expenditures*	*Cost of goods sold*	*Cash from Financing Activities*	*Cash from Investing Activities*	*Cash from Operating Activities*
2000	1,7292E+10	119469000000	3,516E+10	1,6014E+10	5,6752E+10
2001	1,6649E+10	126153000000	3,147E+10	1,2838E+10	3,9173E+10
2002	1,7907E+10	147899000000	4631000000	1,6756E+10	2,4023E+10
2003	2,2075E+10	149645000000	7862000000	2,3198E+10	3,0797E+10
2004	3,18E+10	188179000000	9055000000	3,1959E+10	3,8807E+10
2005	3,1389E+10	230721000000	1,6514E+10	3,7664E+10	5,625E+10
2006	4,5177E+10	249593000000	3,1378E+10	5,7175E+10	8,8593E+10
2007	5,1791E+10	260396000000	7908000000	7,5112E+10	9,3926E+10
2008	5,8529E+10	329182000000	1,7029E+10	8,5837E+10	1,0253E+11
2009	6,8046E+10	205870000000	-1,129E+10	7,5095E+10	7,3052E+10
2010	6,84E+10	257436000000	800000000	7,93E+10	8,52E+10
2011	8,51E+10	319605000000	1,27E+10	8,49E+10	1,19E+11
2012	9,48E+10	364500000000	1,82E+10	9,66E+10	1,28E+11
2013	1,033E+11	306900000000	-2,66E+10	1,104E+11	1,013E+11

Data For Exchange rate Module (Article 4)
Following tables provide used for calibrating and in initializing the exchange rate module (article 4).

Time	*NOK/USD*	*inflation us*	*inflation norway*	*oil price*	*interest rate us*
1995	6,33	2,54	2,11	18,42	6,58
1996	6,45	3,32	1,78	22,16	6,43

1997	7,07	1,7	2,33	20,61	6,3
1998	7,55	1,61	2,41	14,39	5,26
1999	7,8	2,68	2,77	19,31	5,63
2000	8,810656	3,39	2,97	30,26	6,029167
2001	8,98868	1,55	2,1	25,9	5,0175
2002	8,017105	2,38	2,7	26,17	4,610833
2003	7,091874	1,88	0,63	31,01	4,015
2004	6,73863	3,26	1,12	41,25	4,274167
2005	6,436765	3,42	1,84	56,44	4,29
2006	6,413423	2,54	2,17	66	4,791667
2007	5,860883	4,08	2,83	72,26	4,629167
2008	5,640573	1,19	2,18	99,06	3,666667
2009	6,294122	2,72	2,02	61,73	3,256667
2010	6,044883	1,5	2,75	79,39	3,214167
2011	5,605634	2,96	2	94,88	2,785833
2012	5,8204486	1,74	1,39	94,05	1,8025
2013	5,879619	1,5	2,01	97,98	2,350833
2014	6,304116	0,76	2,07	93,17	2,540833
2015	8,067388	0,73	2,33	48,66	2,135833
2016	8,40506	2,07	3,47	43,29	1,841667
2017	8,268321	2,11	1,63	50,88	2,33
2018	8,142717	1,91	3,49	64,94	2,91
2019	8,642747	2,68	2,77	56,98	0

Time	*interest rate norway*	*Per capita income norway*	*per capita income us*	*exports*	*imports*
1995	7,42	34875,7043	28690,876	5,6058E+10	4,6848E+10
1996	6,77	37321,9742	29967,713	6,49E+10	5,0544E+10
1997	5,88	36629,0309	31549,139	6,5083E+10	5,196E+10
1998	5,4	34788,3599	32853,67	5,643E+10	5,3647E+10
1999	5,49	36371,051	34513,56	6,2488E+10	5,086E+10
2000	6,218333	38146,72	36334,909	7,8111E+10	4,9476E+10
2001	6,236667	38549,589	37133,243	7,7803E+10	4,8844E+10
2002	6,384167	43061,15	38023,161	7,9043E+10	5,3236E+10
2003	5,045	50111,654	39496,486	9,0329E+10	6,1073E+10
2004	4,368333	57570,269	41712,801	1,0843E+11	7,3339E+10
2005	3,745833	66775,394	44114,748	1,3322E+11	8,3872E+10
2006	4,076667	74114,697	46298,731	1,5367E+11	9,5254E+10
2007	4,774167	85170,862	47975,968	1,7368E+11	1,1963E+11
2008	4,458333	97007,942	48382,558	2,1432E+11	1,3455E+11
2009	3,998333	80067,177	47099,98	1,5221E+11	1,052E+11
2010	3,528333	87770,267	47450,318	1,7057E+11	1,2011E+11
2011	3,135	100711,225	49883,114	2,0572E+11	1,3877E+11

2012	2,101667	101668,171	51603,497	2,0635E+11	1,4026E+11
2013	2,5775	103059,248	53106,91	2,0394E+11	1,4795E+11
2014	2,515	97199,919	55032,958	1,9321E+11	1,4877E+11
2015	1,565	74521,57	56803,472	1,4548E+11	1,2362E+11
2016	1,331667	70941,525	57904,202	1,3037E+11	1,2433E+11
2017	1,6375	75704,24	59927,93	1,4432E+11	1,3041E+11
2018	1,87	81807,198	62641,014	1,6633E+11	1,4111E+11

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