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

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Abstract

Exchange rate volatility is a vital issue in international finance due to its effect on the value of the firm, depending on firm's exposure to the exchange rate risk. However, this impact is not clear in literature as evidence is mixed. This article analyses the impact of exchange rate fluctuations on firm value. A system dynamics-based corporate planning model has been developed that incorporates the modules for financial and physical processes, firm valuation and exchange rate determination. Simulation results reveal that a stronger home currency leads to an increase in market price per share of the firm and vice versa. The results provide counter intuitive evidence on the impact of exchange rate on firm value and provide nonlinear feedback loop-based explanation. The study fills the gap in literature by incorporating a systemic approach in the strategic planning process to assess the composite impact of parameter changes on key variables.

KEYWORDS

corporate finance, exchange rate, firm valuation, system dynamics, systematic approach

1 | INTRODUCTION

Creating and maximizing the firm value is the ultimate objective of any firm and fundamental debate in corporate finance (Brealey et al., 2011; Copeland et al., 2000). This objective requires consideration of organic relationships of multiple aspects of the firm while operating in an international environment. Foreign exchange risk is one such vital issue (Madura & Fox, 2011) that has become gradually more important in international financial management since the end of the fixed exchange rate regime in 1973 (Ihsan et al., 2018). The economic theory postulates that change in exchange rate not only affect the current profitability and the market value of the firms having revenues/costs/assets/liabilities in foreign currencies but also can influence the market expectations about future cash flows and consequently the firm value (Flota, 2014). The changes in exchange rate influence the firm value through transaction, translation and economic exposures that international firms generally have (Choi & Prasad, 1995). However, the impact of exchange rate movements on firm value is not clear in the literature (Bartov & Bodnar, 1994). Although some report economically sizeable impact of exchange rate movements on firm value, yet these movements do not explain larger variation in firm valuation (Doidge et al., 2006).

The theory explains that a weak home currency (decline in a country's exchange rate) is favourable for the economy in the short-term as it makes the country's exports cheaper for foreign countries, consequently country's exports and income increase. Alternatively, the inverse is true for country's imports making imports costlier resulting into increased expenses (Kappler et al., 2013). However, a longer span of weak home currency is detrimental to the economy of the country. Similarly, the firm level impact of exchange rate exposure is complex to identify and determine because of the interplay of variety of different financial and operational elements over time. Consequently, depreciation in home currency's exchange rate is not always beneficial for exporting firms due to firm specific characteristics such as financial strategies and operating profiles. This necessitates the firm level structural analysis to investigate the impact of exchange rate movements on firm value. Therefore, this study focuses on analysis of one firm by developing a system dynamics model for an energy firm focusing on exchange rate and firm valuation dynamics. For this purpose, the research question is as follows: How do the exchange rate fluctuations caused by macro determinants affect the value of an oil-exporting firm?

To answer this research question, we use system dynamics method that allows integration of accumulation processes, feedback relationships and nonlinear interactions among the feedback loops (Sterman, 2000). Earlier articles addressed the firm valuation with reference to investment policy and oil price impact (Khan et al., 2020a) and impact of capital structure policy on firm value (Khan et al., 2020b). Another article develops a stand-alone model for exchange rate determination and forecasting using system dynamics method (Khan, 2020). This study is a step further and integrates the models developed for these studies to explore the impact of exchange rate movements on the firm value.

The case oil firm in this study is Equinor, an international energy company headquartered in Norway. The firm is primarily an oil and gas company with investments in renewable energy as well. Risk of the companies operating in oil industry is high due to the volatile nature of oil prices in the short run, whereas investments are long term and irreversible (Dixit & Pindyck, 1994). Thus, sustaining the firm value requires decision making while accounting for all the relevant variables and their nonlinear interactions over time considering short- versus long-term trade-offs. This makes system dynamics a natural choice to model the physical and financial structure grounded on the relevant theories and to simulate it to investigate the impact of critical variables on firm value.

The study entails significance for the following unique contributions to the literature. First, the study represents an operational corporate planning model for an energy firm, which includes financial as well as physical processes, while accounting for the non-linear feedback relationships and accumulation processes in the system, to mimic the real-world system realistically. The study operationalizes the central corporate finance and international finance theories of firm valuation and exchange rate determination in detail through system dynamics. The model can easily be replicated and utilized for policy and scenario analysis for any other firm after appropriate customization, such as amending the physical processes of that firm in the model, and thus fills the gap for the need of a systematic approach, which accounts for the various corporate functions of the firm in the strategic planning process.

Second, the study incorporates a comprehensive model to assess the impact of parameter changes compositely on the crucial factors. This allows for assessment of impact on all the factors of interest, avoiding the problem of mitigating or excluding the potential impact on multiple factors, which often leads to the failure of achievement of desired results in the strategic planning process.

Third, the study provides empirical evidence and explanation on how changes in exchange rate impact the firm value by providing the results that are counter intuitive and highlight the need to consider the whole process as how the changes in exchange rate would be transferred through the policy decisions by the firm, to determine the value of the firm. The study also discusses the impact of macroeconomic strategic policy variables' changes on the firm value through exchange rate. Such as the study maps the route as how the change in interest rate as an economic policy would have impact on the firm value of an internationally operating firm. This aspect of considering the comprehensive processes to draw the relationships is often overlooked while considering the impact of exchange rate on firm value.

Lastly, the analysis performed in the study has implications for managers and decision makers to assess the impact of their decisions on all the operational areas of the firm together. The feedback loops represent the causal relationships of financial, physical and external variables in a systematic way. For example, the role of changes in interest rate reveals that interest rate influences exchange rate and the changes in exchange rate influence the interest rate. Normally, such systematic approach is not very frequently addressed in the international finance and corporate finance literature.

The rest of the paper is organized as follows: System dynamics model provides details on the developed model. Data sources and model validation section provide details on data sources, validation and calibration. Scenario

design section provides detail of each scenario assumed and formation of combinations. Results section represents the simulation results of the scenarios and conclusion summarizes the findings and implications.

2 | SYSTEM DYNAMICS MODEL

This system dynamics-based comprehensive corporate planning model incorporates multiple decision variables in multiple vital balancing and reinforcing loops that interact to determine the dynamic behaviour over time. The model structure includes three modules. The financial module includes integrated financial statements of the firm namely, balance sheet, income statement and cash flow statement and the major financial decision variables such as investment decision, capital structure decision and dividend pay-out decision. The production module depicts the physical stocks and flows of the firm and operationalizes the physical processes of oil and gas production, and renewable energy production processes. The integrated and interdependent structures of the physical operations and the consequent financial co-flows of the firm provide the foundation to perform the valuation. The valuation module uses discounted cash flow (DCF) valuation method to generate the firm value (Ivanovska et al., 2014). Please see Khan et al. (2020a, 2020b) for detailed description of the base model. Finally, the exchange rate module determines and forecasts the exchange rate Khan (2020). We use this exchange rate module and integrate it into the base model to analyse the impact of exchange rate on firm value. The model calibrates the historical behaviour from year 2000; the year of listing of Equinor on stock market; and simulates it into the future until 2050. Figure 1 demonstrates the details each module is containing for performing the firm valuation.

Figure 2 depicts causal loop diagram involving major feedback loops of the model, characterizing the impact of exchange rate on firm value through internal processes of the firm. Basic processes of the firm represented include investment, production and financing of investments through internal and external sources (investment, production and exchange rate loop). Please note that exchange rate comes into play through influencing the oil prices to determine the revenues. Following energy market's conventional price quotations, we use USD for oil and gas prices and the convert it to Norwegian kroner.

As the firm under study is an oil firm, the investments include capital into exploring the oil and gas reserves and developing the proved reserves for production. Desired capital budget represents the amount the firm wants to invest depending on the capital availability. Desired capital budget decision is based on expected oil prices. When the expectation for oil prices is positive, desired capital budget is higher and vice versa. There are major delays involved in the processes from determining the desired capital budget to having the new production capacity in place. Capital expenditure characterizes the investments, which, after a certain time delay, lead to production capacity and developed reserves. When the reserves are developed, oil and gas production is possible through extraction of oil and gas.

Oil and gas being one of the major exports of Norway, and the case firm being the largest player in Norwegian oil and gas industry, with the Government being the major shareholder, the production by the firm affects the per capita income of Norway. Therefore, in our postulation the oil and gas production of the firm will affect the per capita income of Norway (Investment production and exchange rate loop). This means that increase in oil and gas production and export will have positive impact on balance of payments of Norway and will increase the per capita income of Norway strengthening NOK. Fluctuations in exchange rate influence the oil and gas prices received by the case firm in NOK.

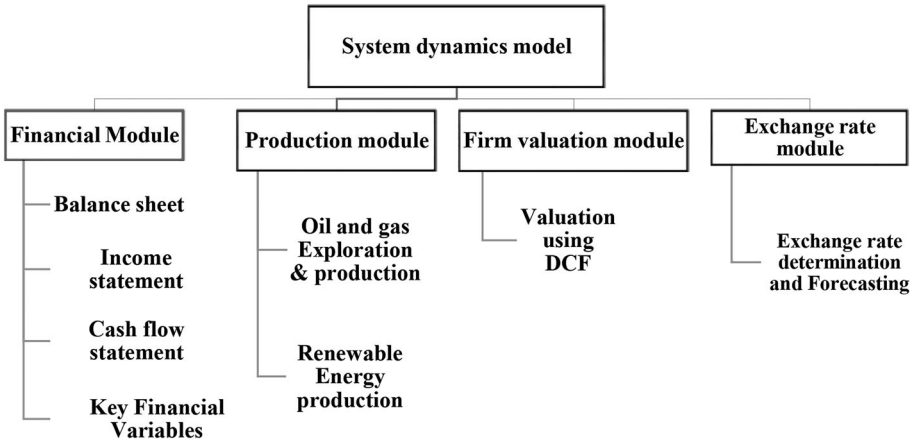


FIGURE 1 Description of modules in system dynamics model

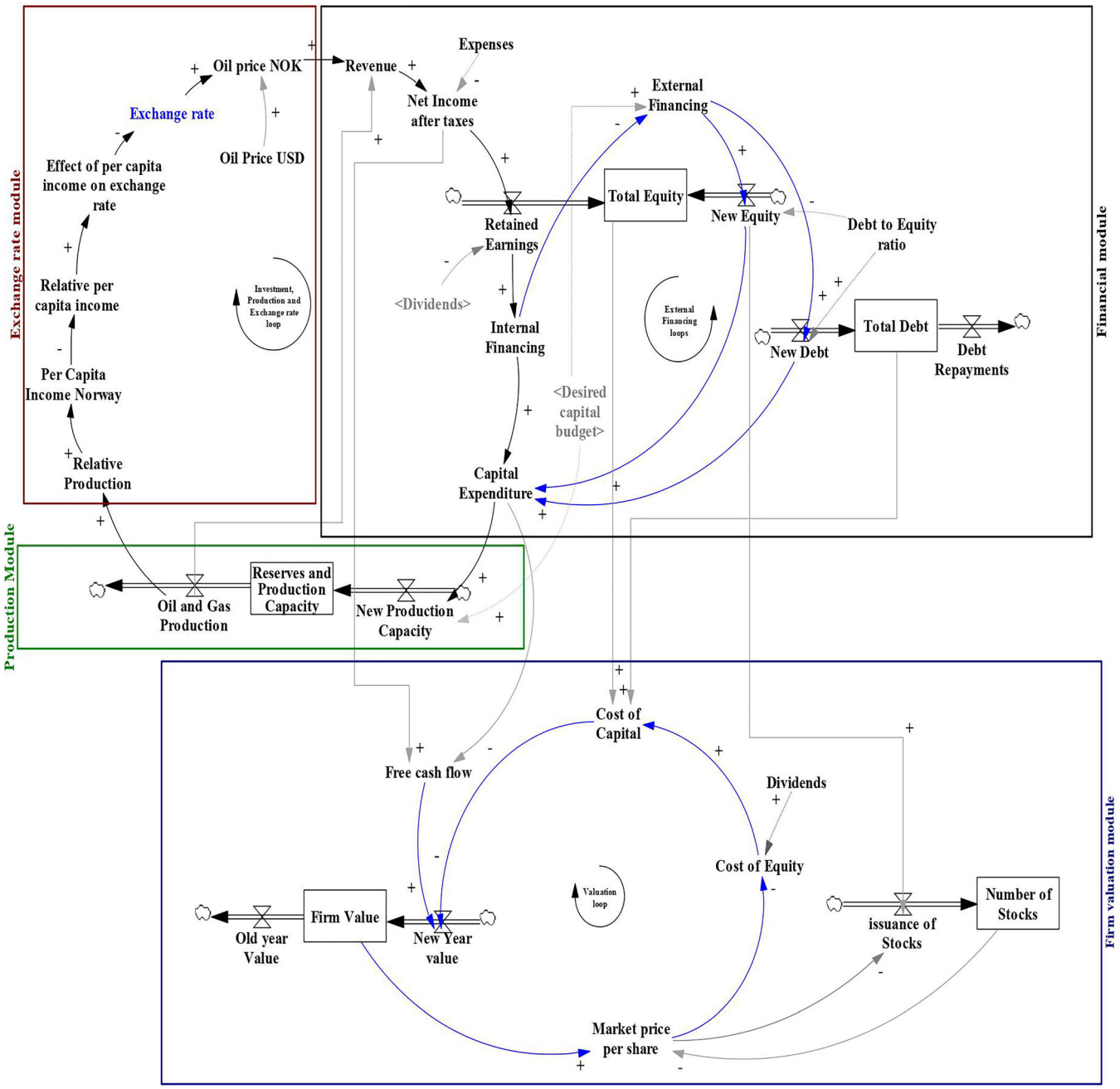


FIGURE 2 Causal loop diagram representing the major loops of the model [Colour figure can be viewed at wileyonlinelibrary.com]

Revenue of the firm is determined by the oil and gas production and oil and gas prices in the simulation model. The model calculates net income, after deduction of costs for all the production and operating and administrative expenses, which the firm can retain and reinvest or pay out as dividend (internal financing). These equations are following standard corporate accounting conventions.

The data of the firm on financing policy clearly indicate its first preference of internal finances; this means our case firm follows the pecking order theory of financing (Khan et al., 2020b) that we use for grounding our capital budget structure. Specifically, we formulate that the firm finances remaining capital budget (remaining after internal financing) through debt and equity according to the debt-to-equity ratio. The firm uses this acquired capital to make actual investments next time around. Internal financing characterizes the mechanism that investments made now from the available cash shall reduce the internal finances available for investments next period. External financing loop incorporates the new debt and equity issuance depending on the capital structure policy of the firm. If there are less internal finances available for the desired capital budget, the firm

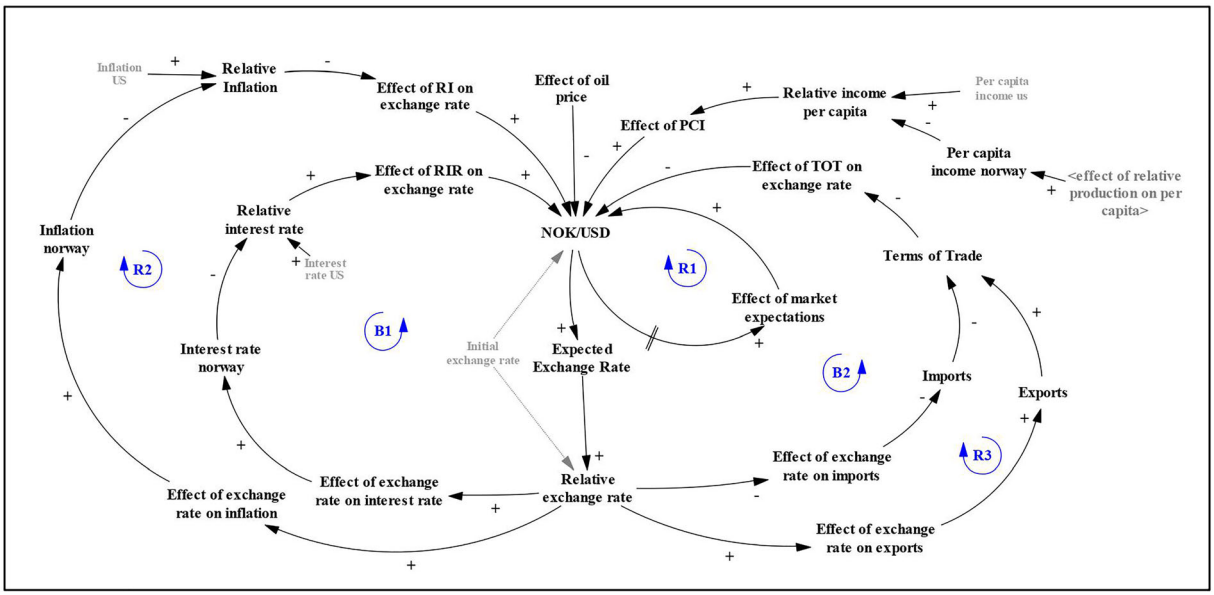
need more external financing and vice versa (equity financing loop and debt financing loop). These capital expenditures create the production capacity that determine the level of operations of the firm, the revenues in turn determine the cash flows available for future investments based on market price of oil and gas.

Given these processes of the firm, valuation is performed to determine the per share value of the firm, namely, market price per share (Valuation loop).

Valuation of the firm is performed through free cash flows and cost of capital (Valuation loop). The DCF theory grounds on the premise that value of a firm today is the present value of its expected future cash flows discounted by the weighted average cost of capital (WACC), which represents an aggregated cost of firm's finances (Tiwana et al., 2007). Firm value stock represents the total value of the firm. Market price per share is calculated from total firm value and number of outstanding shares. Cost of equity influences the discount rate (cost of capital) for valuation and is influenced by the market price of firm.

2.1 | Exchange rate module

The fluctuations in currency markets make forecasting exchange rate a challenging and difficult task for multinational firms and managers (Hu et al., 1999). The study provides a module for exchange rate determination and forecasting grounded in the fundamental theories of exchange rate determination and intertwining them in feedback loops based on system dynamics. Purchasing power parity claims that equilibrium exchange rate is determined by the ratio between the price of same basket of goods or services in two countries (Taylor & Mark, 2004). Interest rate parity theory claims that under equilibrium exchange rate, interest returns on deposits equal when measured in terms of home currency, characterized by no arbitrage condition (Dąbrowski et al., 2014). Figure 3 represents the major balancing and reinforcing feedback loops (Khan, 2020) that play their role in exchange rate determination. Balancing loop (B1) indicates the relationship of interest rate and exchange rate. Higher comparative interest rate increases the demand for the home currency and thus exchange rate appreciates. Appreciation in exchange rate positively influences the economy and bringing reduction in interest rate. Terms of trade (imports and exports) also affect exchange rate. Weak home currency positively influences exports as they become cheaper for the other countries, and increased exports lead to increase in demand for home currency strengthening its value against foreign currency (R3). Alternatively, weak home currency negatively influences the imports as they become expensive for locals and consequently reducing the imports resulting in reduction in demand for foreign currency to influence positively the home currency (B2). Moreover, reinforcing loop (R2) accounts for the relationship between inflation and exchange rate. An increase in inflation in the country will make the local products



Source: (Khan, 2020)

FIGURE 3 Exchange rate module [Colour figure can be viewed at wileyonlinelibrary.com]

costlier resulting into reduced exports and increased imports that increases demand for foreign currency and supply of home currency resulting in depreciation in the exchange rate (Kuttner & Posen, 2001), which leads to further increase in inflation. Finally, we formulate market expectations based on the past trend in exchange rate (R1). We integrate this exchange rate module into our base model of firm valuation to assess and forecast the impact of exchange rate volatility on the value of the case firm.

2.2 | Exchange rate and firm value

Exchange rate volatility is a crucial issue in international finance due to its effect on value of the firm depending on firm's exposure to the exchange rate risk (Choi, 1986). The complexity arises from the interaction of various factors involved. Exchange rate exposure of firm is the degree to which firm's cash flows are sensitive to unanticipated changes in exchange rate. Involvement of firms in international operations through sales and/or purchase of products/materials/services, purchase and/or sales of assets, raising debt and/or equity and receiving/making payments thereof exposes them to exchange rate risk. The sensitivity of corporate cash flows to the changes in exchange rate suggests that the firm value is subject to exchange rate risk. We observe mixed empirical evidence on the exchange rate risk and firm value relationships (Agyei-Ampomah et al., 2013; Dominguez & Tesar, 2006; Hutson & O'Driscoll, 2010; Mozumder et al., 2015). Many empirical studies found negative impact of exchange rate uncertainty on cash flows and firm value (Fraser & Pantzalis, 2004; Muller & Verschoor, 2006; Šimáková, 2017). Some studies found no impact of exchange rate risk on firm value (Bartov & Bodnar, 1994; Marston, 2001). Therefore, we consider it important to use alternative method system dynamics that allows the integration of processes in a realistic way to address this question.

3 | DATA SOURCES AND MODEL VALIDATION

3.1 | Data sources

The system dynamics model in this study is developed based on GAAP (generally accepted accounting principles), standard corporate finance literature (Benninga, 2008; Lyneis, 1980; Yamaguchi, 2003) and system dynamics principles (Sterman, 2000). The model has been developed using Vensim software. The model has been calibrated using data for Equinor. Secondary sources of data such as annual reports, other sources of information about Equinor (e.g., website), information about oil and gas reserves of Norway, information about oil and gas production processes in general has been utilized to estimate the parameters and model the processes. Table 1 summarizes some of the parameters and their respective values used in the model.

3.2 | Model calibration and validation

To ensure reliability of the results, we performed a variety of different validity tests on the model such as unit consistency test, structure validity tests and behaviour validation tests (Barlas, 1989). The model was validated at every stage. The tests confirm the technical soundness of the model, the equations have real life meaning and the model is mimicking historically observed behaviours reasonably well for the right reasons. Moreover, we calibrated the model to enhance reliability of the simulated outcomes. Figure 4 represents historical simulation behaviour for exchange rate and the market price per share.

Simulation results reveal that model is replicating the historical behaviour reasonably (Figure 4). To further validate the results, we have performed theil inequality test and RMPSE (root mean square percent erro) to test the goodness of fit of the model (Sterman, 2000). The results (Table 2) reveal that exchange rate and market price per

TABLE 1 Parameters and their estimated values

Variable name	Value	Source of data
Time to perceive trend (exchange rate)	5 years	Estimated
Capital structure decision	55%	Annual reports and calibration
Elasticity of inflation to exchange rate	0.01	Historical data and calibration
Dividend Policy	40%	Annual reports and calibration
Growth in cumulative world capacity NES (new energy solutions)	0.05/year	Estimated
Equipment lifetime	28 years	Annual reports and estimation
Adjustment time for production capacity	13 years	Estimated
Tax rate	68%	Annual reports

share has RMSPE of 8% and 22%, respectively. A major portion of magnitude of this error is decomposed into bias 57% and unequal covariation 36% for exchange rate, whereas, for market price per share, major portion is decomposed into unequal covariation of 68% and unequal variation of 31%. For firm value and production, RMSPE is 25% and 12%, respectively, and magnitude of this error is majorly decomposed into unequal covariation of 97% and 90%, respectively. This represents that the simulated behaviour is capturing reasonably the historic trend but diverges point by point (Qureshi & Pedercini, 2010).

4 | SCENARIO DESIGN

We develop different scenarios for the parameters of exchange rate determination to test their potential impact on the firm value (Table 3). As a base case, we assume historical trends to continue for these parameters. We then develop different scenarios as what would be the behaviour of exchange rate and ultimately our variable of interest, market price per share, if these parameters including oil prices, terms of trade (TOT), interest rate and inflation move in any direction away from their base value in 2020. We assume three scenarios for each of the parameter namely: higher, base case and lower. The base case represents business as usual scenario, (historic trend), whereas higher and lower scenarios assume higher and lower value for the parameter than the business as usual into the future (Table 3).

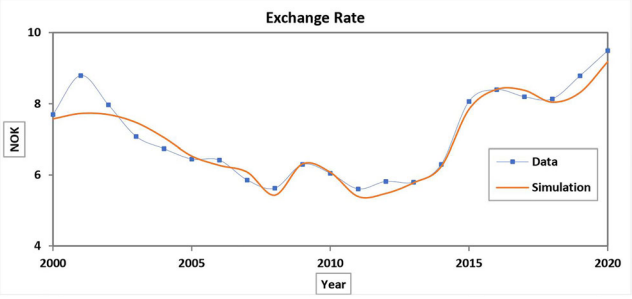


FIGURE 4 Exchange rate and market price per share data and simulation [Colour figure can be viewed at wileyonlinelibrary.com]

After testing these scenarios in isolation, we organize these scenarios into two major categories of oil price scenarios to simulate their combinations, namely higher oil prices and lower oil prices. We report three major scenarios for each category of oil price scenarios that maximize the firm value.

5 | RESULTS

5.1 | Forecasting

We simulate the validated and calibrated model for 30 years into the future and observe that it is capable to reproduce the historical behaviour reasonably (Figure 5). We observe an upward trend for market price per share and a stabilizing trend for exchange rate.

5.2 | Scenarios results

This section represents the simulation results of various scenarios to gain insights into the potential impact of changes in one of the parameters on the exchange rate and the firm value. The model assumes that exchange rate influences the revenue. For the same number of USDs received for oil and gas sales, a strong USD will be able to buy more NOK generating higher NOK revenue for the firm. Further, to simplify the model assumes home currency denomination of the operational expenditure and debt as the firm is Norway based with major portion of operations in Norway. This is a limitation of the model, and we warrant reasonable care to interpret the results. However, we note that as the model is based on feedback loops and complex interrelations, costs are also influenced by the fluctuations and play their role in firm valuation.

5.2.1 | Interest rate and inflation scenarios

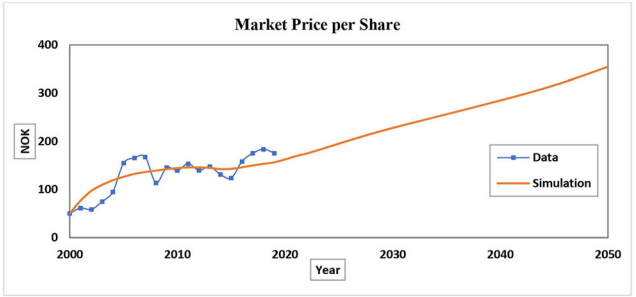
Interest rate and inflation are fundamental macroeconomic variables to manage the economy that also have implications for demand and supply of home currency

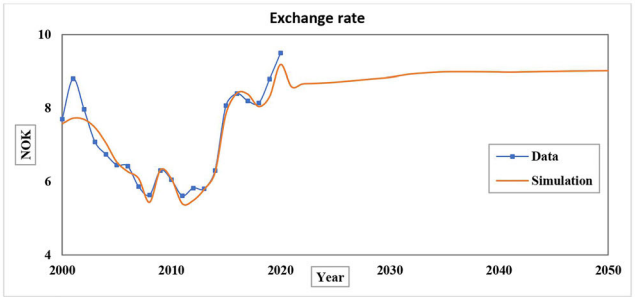
TABLE 2 Error analysis (Theil Inequality test)

Variable	RMSPE (%)	MSE (units)	$U^{(M)}$Bias	$U^{(S)}$ unequal variation	$U^{(C)}$ unequal covariation
Exchange rate	0.084	2.32E−01	0.572	0.067	0.361
Production	0.129	7.89E+15	0.029	0.062	0.909
Market price per share	0.220	4.64E+02	0.001	0.311	0.688
Firm value	0.255	7.19E+21	0.019	0.003	0.978

Scenarios	Description	Assumed parameter	
Interest Rate Scenarios	Higher	Interest rate	1.86% + 1%
	Base case	Interest rate	1.86%
	Lower	Interest rate	1.86% − 1%
Inflation Scenarios	Higher	Inflation	2.67% + 1%
	Base case	Inflation	2.67%
	Lower	Inflation	2.67% − 1%
Terms of Trade (TOT) Scenarios	Higher	TOT	1.2 + 0.5
	Base case	TOT	1.2
	Lower	TOT	1.2–0.5
Oil Price Scenarios	Higher	Oil prices	$65 + $10 per barrel
	Base case	Oil prices	$ 65/barrel
	Lower	Oil prices	$65 − $10 per barrel

TABLE 3 Description of parameters and their assumed scenarios





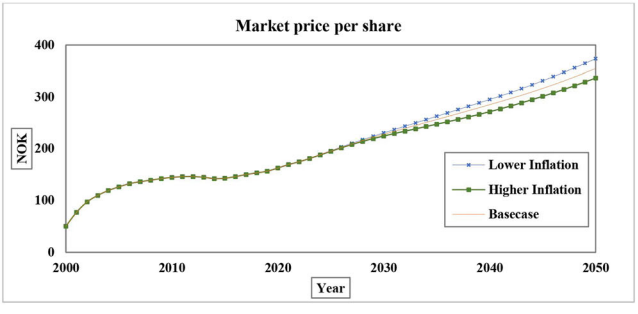
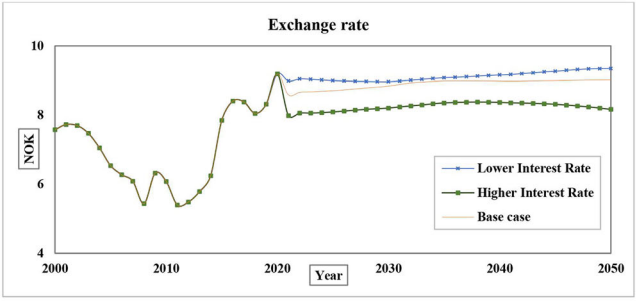
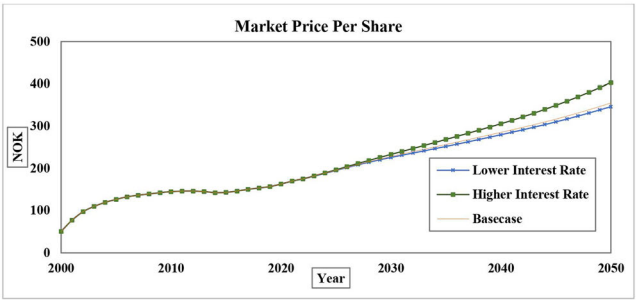


FIGURE 5 Exchange rate and market price per share behaviour [Colour figure can be viewed at wileyonlinelibrary.com]





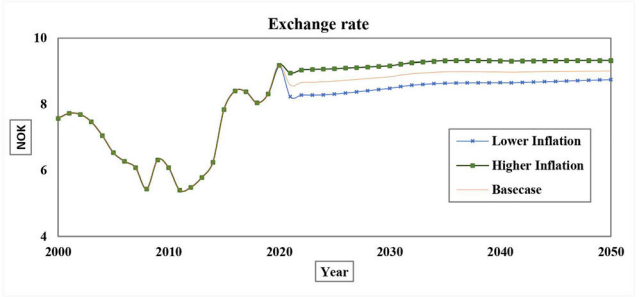


FIGURE 6 Exchange rate and market price per share under Interest rate and Inflation Scenarios [Colour figure can be viewed at wileyonlinelibrary.com]

affecting its exchange rate (Figure 6). Simulation results show that decrease (increase) in interest rate leads to weak (strong) NOK due to decrease (increase) in its demand, whereas increase (decrease) in inflation leads to weak (strong) NOK. A weak NOK negatively influences market price per share and a strong NOK positively influences the market price per share.

5.2.2 | TOT scenarios

We simulate the scenarios for terms of trade (TOT) to investigate the potential impact of any change in exports/imports in any direction on the exchange rate and the firm value. The simulation results (Figure 7) reveal that favourable TOT (exports>imports) strengthens NOK due to increase in demand for NOK and vice versa. Appreciation of NOK increases the market price per share as discount rates decrease.

5.2.3 | Oil price scenarios

Further, we simulate various combinations of these parameters under two major categories of oil prices—expectations for higher oil prices and expectations for lower oil prices. We present the results for three scenarios that produce the highest market price per share for each category (Figures 8 and 9). Tables 4 and 5 report the details for combinations of these scenarios with ranking that describes the best outcome. The results reveal that higher oil prices with base case interest rate yield the highest market price per share and outperform the base case. Whereas testing the lower oil prices scenario in combination with other scenarios reveals that lower oil prices along with higher interest rate yield the highest market price per share.

The simulation results reveal that appreciation of NOK leads to higher share price as compared to the base case, although appreciation of NOK leads to reduction in the firm's profits. Further, appreciation of NOK yields higher share price as compared to depreciation of NOK. We provide a plausible explanation to this counter intuitive result through the nonlinear feedback relationships among the factors. We ground our explanation in the interplay of organic non-linear relationships of the

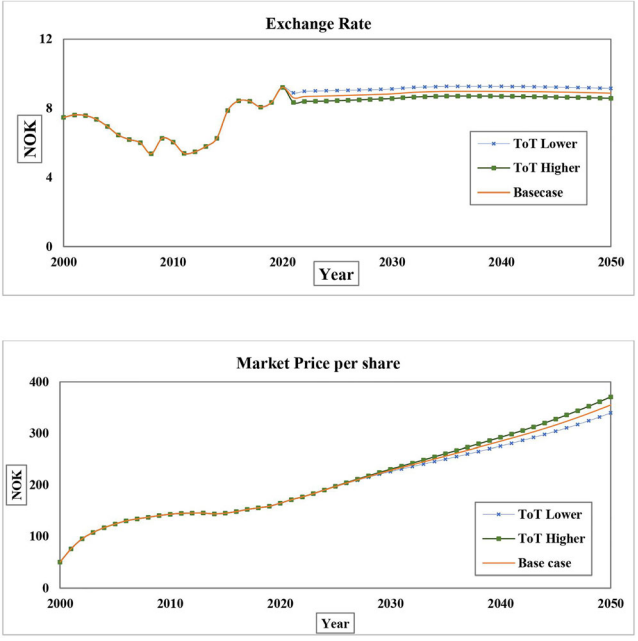


FIGURE 7 Exchange rate and market price per share under to T Scenarios [Colour figure can be viewed at wileyonlinelibrary.com]

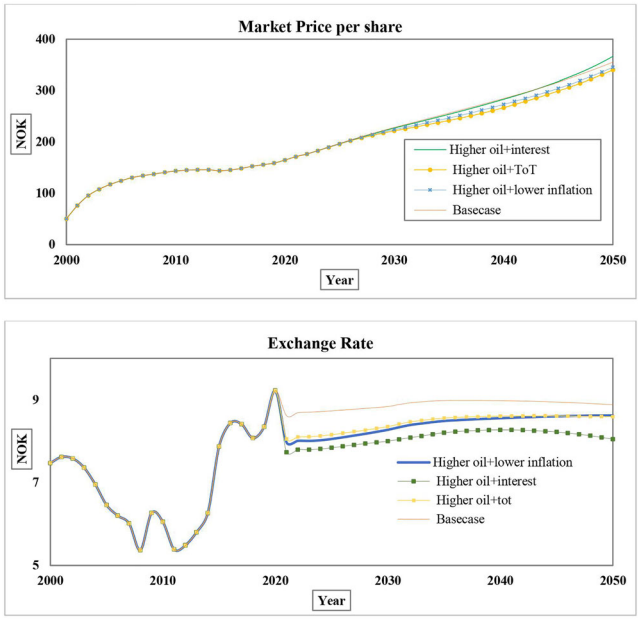


FIGURE 8 Exchange rate and market price per share under combinations of scenarios assuming higher oil prices [Colour figure can be viewed at wileyonlinelibrary.com]

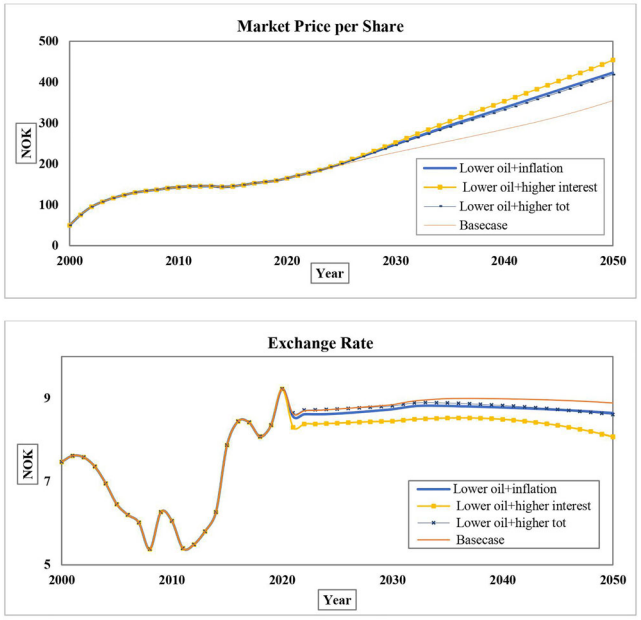


FIGURE 9 Exchanges rate and market price per share under combinations of scenarios assuming lower oil prices [Colour figure can be viewed at wileyonlinelibrary.com]

Scenario	Oil prices	ToT	Interest rate	Inflation rate
1	High	High	Base case	Base case
2	High	Low	Base case	Low
3	High	Base case	High	Base case

TABLE 4 Best scenarios combinations assuming higher oil prices

Scenario	Oil prices	ToT	Interest rate	Inflation rate
1	Low	Base case	High	Base case
2	Low	Low	Base case	Low
3	Low	High	Base case	Base case

TABLE 5 Best scenarios combinations assuming lower oil prices

investment decision in the model. First, as the profit margin increases, the firm has the motivation and the means to increase the capital expenditure. Increase in capital expenditure reduces the cash flows that yields lower share price as cash flows are the major pillar in DCF valuation. Second, increased investments lead to need for increased external financing leading to increase in the cost of capital at the same time, the second major pillar in DCF valuation. The discount rate increases through increased cost of capital and higher discount rate supresses the market price per share. External financing involves debt and equity, and equity issuance increases the number of shares issued. Increase in number of shares issued reduces the market price per share (as total value is divided by the number of shares; Figure 4). This not only emphasizes the role of balancing mechanism in the model but also advocates strength of system dynamics method to bring forth a result that challenges the commonly held postulates based on linear thinking in isolation completely ignoring the feedback loop perspective. We argue that this is a significant contribution of this study that adds to the postulations of very popular fundamental theories of exchange rate determination (PPP and IRP). Although our study validates the exchange rate behaviour as predicted by these theories, however, the impact on the firm value is counter intuitive. For transferring the impact of exchange rate fluctuations onto the firm value, operations and policies of the firm come into play. Such as, although the revenue is increasing and so do the investments but at the same time, costs are also increasing. This refers to the fact that the company cannot expand infinitely and increase the firm value. However, the firm performs better in appreciation of NOK scenario where the firm is investing moderately and overall, the Norwegian economy is strong.

6 | CONCLUSION

The study investigates the dynamics of firm valuation with focus on exchange rate fluctuations. Firm valuation is analysed through developing a comprehensive system dynamics model that incorporates financial and physical processes of the firm. The model represents the complex nonlinear relationships of the main variables. The study demonstrates that how changes in the fundamental parameters of exchange rate determination influence the exchange rate and how these exchange rate fluctuations affect the firm value. Increase in interest rate would lead to appreciation of NOK and increase in market price per share. Decrease in inflation appreciates NOK and increases the market price per share. Increase in terms of trade ratio leads to appreciation of NOK and increase in market price per share. Testing of combinations for higher and lower oil price expectations with other parameters reveals that base case interest rate along with higher oil prices and lower oil prices along with higher interest rate increase the market price per share. The policy implication of this result is that Norwegian government has interest rate as a tool to mitigate the exchange rate risk on the firm value of the case firm.

The study has implications for policy makers on firm level as well as economy level. Any change on economy level such as a change in interest rate does have implications not only for the overall economy but also significantly for any single internationally operating firm in the country. Thus, these companies not only need adequate understanding of the organic interrelationships of variety of relevant parameters while forecasting the exchange rates but also actively hedge their foreign exchange exposure.

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