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EFFECT OF GREEN TECHNOLOGY INVESTMENT ON CRUDE OIL INVENTORY SYSTEM - A CASE STUDY BASED ON ONGC DATA

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Abstract: The carbon footprints are increasing in the environment at an alarming rate mainly due to unplanned human activities. The world's population will continue to grow at a rapid pace in the future. As a result, our future generations may find it difficult to live on this planet in a healthy manner. The world's developed and developing countries began to investigate various methods for reducing their carbon footprint. However, it will not be sustainable if it is also not economically viable. In this scenario, maintaining a good profit for businesses while reducing their carbon footprint necessitates a pragmatic strategy. In this article, we will try to find a way out that will provide us with a practical solution. We will simulate the profitability of an upstream oil manufacturer that has invested heavily in green technologies. Under a carbon tax system, we will use the production-inventory model. This system assumes that capital investment in green technology can reduce emissions, and increase profits. We used data from the Oil and Natural Gas Corporation of India, available in its annual reports. As a matter of fact, the Oil and Natural Gas Corporation of India accounts for 70% of crude oil production in India and is a major player in India's upstream oil companies. The results were quite encouraging, with deviations between expected and actual values being less than 10%.

The findings also led us to believe that the excise duty and the pollution control tax levied in India can be regarded as a Green Tax or Carbon Tax. We used a published research model to find the optimal solution.

Keywords: Crude Oil, Carbon Emission, Inventory model, Green Technology, Profit Simulation, ONGC.

MSC: 35Q49.

1. INTRODUCTION

One of the most important sources of energy for human civilization is crude oil. It has significant contributions to the advancement of modern human civilization. However, this comes at a high cost. Many crude oil-related wars have occurred in modern human history. Humans, on the other hand, are largely on the losing side in the real war of environmental depletion. Numerous studies have been carried out on the environmental depletion caused by fossil fuel related activities. Carbon emissions is a significant issue associated with crude oil consumption. Human activities have resulted in a increase in carbon emissions, which are continuing to rise. About 15-40% of GHG emissions occur during the production, transportation, and refining of various crude oil products [1]. There are numerous latent activities that contribute to such massive GHG emissions. Crude oil storage and distribution require a specific temperature to be maintained; otherwise, the crude oil will evaporate. The machines must use a lot of power to maintain a certain temperature, which has a long-term impact on the carbon footprint.

The main issue with GHG emissions is the heat-trapping properties of carbon and methane gas. The heat trapped by them raises the temperature, resulting in climate change. In fact, methane is 25 times more effective than carbon dioxide at trapping heat in the atmosphere. Furthermore, methane concentrations in the atmosphere have more than doubled over the last two centuries. According to the Green House Bulletin, the greatest increase in Methane concentration occurred in 2021 [2]. Thus, both carbon dioxide and methane gas are the problems for the environment.

There is a major issue if we focus solely on reducing GHG emissions. In such a particular instance, the profitability of business organisations may suffer. The profitability of business organisations is just as important as reducing GHG emissions in the environment. As a result, there is a risk that the policies implemented will not last long enough to impact a positive change in society. There are several methods for simulating profitability and emission levels. We can, for example, simulate the amount of emissions by taking the path of chemistry [3]. Alternatively, we can simulate profitability using macroeconomics [4]. We must use mathematical inventory analysis concepts to simulate both profitability and the amount of emissions at the same time. Several inventory models have been developed to investigate both carbon emissions and business profitability.

In order to ensure a better future for humanity, governments around the world have decided to levy a carbon tax (Green Tax) on carbon-intensive companies. In

India, the carbon tax is not explicitly implemented. However, coal is subject to a carbon tax because it is thought to deplete the environment [5]. In practise, the excise duty is equivalent to the Carbon Tax in India. To the best of our knowledge, almost no literature on carbon taxes in India exists. Because India is the world's second most populous country, Carbon taxes must be implemented to reduce carbon emissions.

Singh and Deswal's work discusses the implementation of a carbon tax in the form of an excise tax in India [6, 7]. However, no other work has been completed in relation to the implementation of the Green Tax, etc. till date. There are a large number of businesses and factories that are the primary source of carbon emissions. So, with the profitability of Indian firms in mind, the challenge has been taken in the current study by simulating profits and emissions at the same time. Thus, in our current study, the crude oil industry has been chosen to consider both profitability and carbon emission reduction.

Maintaining a good profit while reducing emissions is a critical aspect of sustainable finance. Otherwise, the model cannot be sustained for an extended period of time. The focus may be given on inventory models for maximising profit by minimising costs and emissions simultaneously.

As per the definition of **Inventory Models** given by Nacht [8], inventory models deal with situations where production facilities, storage facilities, time, and/or money are limited. Inventory models address the time at which orders for specific goods should be placed as well as the quantity of the order. The research problems deal in discovering ways to optimise these decisions while accounting for the cost of obtaining the goods, the cost of stockpiling a unit, and the cost of shortages.

The inventory models developed till date are mainly theoretical models. But considering the real world problems present study has been done from practical standpoint.

Second, none of the studies are based on the actual scenario in India, despite the fact that a few models were developed in a real-world setting [9, 10, 11, 12].

Being the world's second-most populous country our primary motivations is to investigate the real life problem for an Indian organisation. This work is a humble attempt to address the Carbon-intensive industry with maximum profit. The model along with the assumptions and the variables used by Datta [13] are same here. Datta developed a production-inventory system with a carbon tax, with the goal of profit maximisation while simultaneously reducing costs and emissions [13]. The model developed by Datta will be extended by using the primary data obtained from the Oil and Natural Gas Corporation of India. In this article, we are applying the model by Datta [13] to the real data of ONGC available on their official website. The purpose is to check the validity of the model to the real data. Simultaneously it will help to check the difference between the theoretical optimum values and the optimum levels maintained by ONGC.

The next section i.e. **Section 2** is the **Literature Review** section; **Section 3** is the **Assumptions, Notations, and Methodology** Section; **Section 4** is the **Data Description, Parameters and Flowchart** section; **Section 5** is the

Results and Discussions section, and **Section 6** is the **Conclusions** section.

2. LITERATURE REVIEW

Several studies on crude oil inventory management have been conducted. Jabbarzadeh et al. [14] developed a mathematical model to plan for exploration, drilling, extraction, pipeline installation, and production of crude oil as a crude oil supply chain network design problem. Azadeh et al. [15] took the Persian Gulf as a case study and developed a multi-objective mathematical model for integrating upstream and midstream segments of the crude oil supply chain against the backdrop of environmental indicators. They developed a unique multi-objective evolutionary algorithm to solve the proposed mixed-integer nonlinear programming model. The results developed are then compared with the non-dominated sorting genetic algorithm and multi-objective particle swarm optimization. Azadeh et al. [16] developed a mixed-integer nonlinear programming model which can design upstream and midstream crude oil supply chain. Ribas et al. [17] proposed three models. These are (1) a two-stage stochastic model with a finite number of realizations, (2) a robust min max regret model, and (3) a max-min model. These were optimization models, which were developed to address the uncertainties of crude oil production, demand for refined products, and market prices. Shen, Chen and Chu, 2008 [18] studied an inventory routing problem (IRP) in crude oil transportation with multiple transportation modes including pipeline and tanker and proposed a new mixed-integer nonlinear programming model. Shen, Chu and Chen [19] used a Lagrangian relaxation approach to develop a near optimal solution of the inventory routing problem in crude oil transportation. Zhang et al. [20] studied the crude oil storage modes, complexity of operations, and variety of transportation modes using mixed-integer linear programming. They studied three real cases in a crude oil port depot in China. Yuan [21] studied the results of the optimization of the operating parameters such as tank operating mode and temperature, the total transportation scheduling costs of the storage and transportation system of the crude oil using C++ Builder 6 program. They found that costs can be decreased by about 9.1%. Hou et al. [22] studied the optimization problem of finding a detailed schedule to realize a given refining schedule. They used nondominated sorting genetic algorithm to solve the problem for the very first time. Karuppiah, Furman and Grossmann [23] proposed algorithm which focuses effectively on solving a mixed-integer linear programming to obtain a rigorous lower bound on the global optimum. They found that significant savings can be made. Fan et al. [24] developed a large-scale wireless temperature monitoring system to evaluate the safety of LPG storage tanks. Yu et al. [25] developed a general methodology together with a new continuous-time scheduling model for simultaneous multi-product pipeline distribution and depot inventory management of a straight pipeline with an input node and multiple output nodes. Hatibaruah and Saha [26] developed a model for ameliorating and deteriorating items for stock and price dependent demand with completely backlogged shortages.

Several carbon-emission studies and their applications on several sectors have been conducted. Huang et al. [27] studied the contribution of construction industries in increasing carbon footprint. They compared the Carbon-di-oxide emission on a global scale and found that China is the largest contributor. According to their research, the global construction sector's total CO2 emissions in 2009 were 5.7 billion tonnes, accounting for approximately 23% of total CO2 emissions produced by global economic activities. They also unearthed that gasoline, diesel, other petroleum products, and light fuel oil are the four primary energy sources for direct CO2 emissions in the global construction sector. Lal [28] investigated the atmospheric carbon emissions caused by agricultural activities. Dong et al. [9] studied China's Carbon Emission Intensity (CEI) from 1992 to 2012 and concluded that the industrial sector is critical for reducing emissions and conserving energy.

Several studies have been conducted on the environmental depletion caused by fossil fuel-related activities [10, 29, 30, 31, 32]. There are several methods for simulating the profitability and amount of emissions. We can, for example, follow the path of chemistry to simulate the amount of emissions [3, 33, 34, 35, 36, 37]. Alternatively, we can use macroeconomics to simulate profitability [4, 38, 39]. To simulate both the profitability and the amount of emissions at the same time, we must use mathematical inventory analysis concepts.

Using ongoing observations and paleoclimate data, Hansen et al. [40] investigated the climate impacts of global warming. They concluded that responsible policymaking necessitates a rising price on carbon emissions, which would prevent emissions. Li [41] investigated the impacts of promoting sustainable designs that incorporate global climate mitigation objectives during the planning stage, as well as the need for climate change policies to facilitate such processes.

Several types of production-inventory research were carried out in their pursuit of a more sustainable production system that can also ensure an efficient environment. Mishra et al. [42] developed an inventory management model with backorder and deterioration under controllable carbon emissions with a justifiable profit when compared with other back-ordering cases. Datta et al. [43] studied a production-inventory system with a hybrid carbon regulation policy and developed a model in which the parameters such as Production cost, setup cost, amount of emissions, and the demand rate depend on the quality of the product. Berghout et al. [44] developed an innovative integrated method that can identify deployment pathways for greenhouse gas emissions reductions in an industrial plant. Elgowainy et al. [45] made a number of important derivations regarding the Greenhouse Gas Emission of Petroleum Products. Firstly, they developed a mathematical formula that correlates the variation in overall refinery energy efficiency with crude quality, refinery complexity, and product slate. Secondly, they developed a methodology for calculating energy and greenhouse gas (GHG) emission intensities and processing fuel shares of major U.S. refinery products. Azadeh et al. [46] developed a multi-objective mathematical model for an actual case study in the Persian Gulf. In their problem, they developed a bi-objective optimization algorithm which considers net present value (NPV) and environmental issues. They used a multi-objective evolutionary algorithm based on decomposition (MOEA-D) to solve the mixed integer nonlinear programming model. They compared the model compared with the non-dominated sorting genetic algorithm (NSGA-II) and multi-objective particle swarm optimization (MOPSO) and found the superiority of their proposed model. Sahebi, Nickel and Ashayeri [47] studied extensively crude oil supply chain and commented that environmental impacts, global factors, and uncertain and nonlinear parameters require more research. Rahman and Khondaker [48] overviewed Saudi initiatives related to policy, plan, program, projects towards the reduction of greenhouse gases and enhancement of carbon capture and storage. Fathey Fayek Tadros [49] gave a mechanical solution to the problem of oil pollution. Kannan, Tso, Osman and Ho [50] conducted a life cycle assessment (LCA) to quantify the non-renewable energy use and global warming potential in electricity generation. The study was conducted in a typical oil fired steam turbine plant in Singapore. In the study they found that the processes consumed about 9% additional energy on top of the fuel embedded energy while the GHG emissions is about 12%.

The Carbon Tax (Green Tax) has been implemented by a number of governments around the world. Canada and Costa Rica are two North and South American countries that have implemented a Green Tax [51, 52]. Finland was the first country in Europe to implement the Green tax in 1990s [53, 52]. Following that, the Green tax was implemented in Denmark, France, Germany, the Netherlands, Norway, Ireland, Sweden, Switzerland, and the United Kingdom [54, 55, 56, 57, 58, 59]. South Africa and Zimbabwe are the only African countries with a carbon tax [60, 61]. Talking about Asia; despite being proposed, China has never implemented a carbon tax [62]; Indonesia and Singapore have Carbon Tax [63, 64]; and Japan does not have a Carbon Tax as it already has the most energy-efficient system [5]. Frey [11] used Ukraine as a case study and used a computable general equilibrium to assess the impact of different carbon tax levels on the Ukrainian economy and the environment. Al-Abdullah [65] studied Carbon tax proposals and its implications on industries like oil, coal, and gas. Liu et al. [12] took Canada as a test case and developed a model based on the General Equilibrium model to study the impact of direct and indirect carbon taxes in order to reduce greenhouse gas (GHG) emissions. Thus we can see that a whole lot of research has been done on the impact of Carbon taxes. Regarding implementation of Carbon Tax in terms of excise tax in India are discussed in the work of Singh and Deswal [6, 7]. But there is no other work regarding implementation of Green Tax etc. till date. There are huge number of firms and factories which are the main cause of Carbon emission. So in the present study, keeping in mind the profitability of Indian firms, the challenge has been taken by simulating the profits and emissions simultaneously. Thus, in our present study, the crude oil industry has been selected to consider both profitability and reduction in Carbon emission.

The developed inventory models should be consistently profitable in the long run, but the majority of the models discussed here are theoretical. Moreover, the models studied for any practical case study are not from India. The attempt has been taken in our work to simulate the profit maximisation and Carbon emission minimisation by using the primary data of ONGC.

ONGC is one of the most important corporations in India, and it is the largest crude oil and natural gas company in India [66]. It boasts about 71% of domestic production. ONGC is an upstream company, is involved in exploring, drilling, production, etc. The products of ONGC are used by various downstream companies like Indian Oil Corporation (IOC), Bharat Petroleum Corporation Limited (BPCL), Hindustan Petroleum Corporation Limited (HPCL), and Mangalore Refinery and Petrochemicals Limited (MRPL) [66]. They use crude oil to produce Petrol, Diesel, Kerosene, Naphtha, and Cooking Gas LPG [66]. It is to be noted here that HPCL and MRPL are subsidiaries of ONGC [66].

The website of ONGC clearly mentions that *"ONGC has a unique distinction of being a company with in-house service capabilities in all areas of Exploration and Production of oil & gas and related oil-field services. Winner of the Best Employer award, this public sector enterprise has a dedicated team of around 28,500 professionals who toil round the clock in challenging locations."*

ONGC has a very strict Corporate Social Responsibility program, and they pledged to donate whole-heartedly to the accounting and the abatement of greenhouse gases [67]. ONGC has started the accountability of GHG gases in 2010-2011. They have implemented cutting-edge technologies for the mitigation of emissions [67]. To name a few, they implemented Tank Vapour Recovery Units, Flare Gas Recovery Units, Waste Heat Recovery units, Energy Efficient motors, Retrofitting Equipment for Energy Efficiency, Reduction in Gas Flaring, LED lighting systems, Replacing Natural Gas with compressed air for instrumentation purpose, Casing Head gas recovery in SRP units, Replacement of old hydrocarbon pipelines, Fuel Switching, Paperless office, Green Buildings, Replacement of Diesel Gensets with Gas Generator sets, Microturbines, Dynamic Gas Blending, Renewable Energy, Green buildings, etc. [67]. ONGC has been able to limit its emission to about 10 Million Metric Tons of CO2 which is a major achievement [67]. ONGC signed an MOU with Indian OIL Corporation (IOC) to use CO2 emitted from their Jhonore thermal power Plant (Gujarat). They use it for Enhanced Oil Recovery through CO2 flooding in the Gandhar oil and gas field of ONGC. The gas field is situated 120 KM away from the Jhanore plant, in Gujarat. To curb Methane gases, ONGC is playing a big role. In 2007, ONGC is the first non-American company to collaborate with US-EPA under the Natural Gas STAR Program [67]. ONGC has procured high-tech equipment to carry out emission detection surveys and to train a dedicated "Global Methane Initiative" (GMI) team [67]. The high-tech instruments procured are infrared cameras, turbine meters, vent bags, etc. [67]. Presently leaks are regularly checked by the GMI team [67]. Through this program, the company could prevent approximately 20.48 Million Metric Standard Cubic Meters of Methane gas which is 306,250-Ton CO2 equivalent [67]. During FY-19, they carried out fugitive emission surveys at Uran Plant, Hazira Plant, and 08 production installations of Ahmedabad Asset [67]. To conduct the measurement, they used GasFindIR infrared camera technology which simplifies the process of identifying emission sources [67]. They used a combination of turbine meters, Hi-Flow samplers, and bagging techniques [67]. These are used to measure their emission rates [67]. In this work, we will take the data from the annual reports of ONGC from the FY 2020-21. We will try to verify the original profit, selling price, investment in Green technologies, and the inventories left within that algorithmic results.

The table contains a list of inventory models that are both profitable and environmentally friendly.

Table 1: Studies on Crude Oil Inventory Management

Author	Findings
Datta [13]	Datta proposed a production-inventory model under a carbon tax system which has a proportion of defective items, demand-dependent selling price, and a discount for the retail customers.
Pan et al. [68]	They proposed a production-inventory model in which the buyer and seller in the integrated supply chain agree to pool their resources to reduce carbon emissions.
Mashud et al. [69]	To reduce CO2 emissions from farm warehousing activity, they proposed a sustainable price-reliant demand inventory model with controllable carbon emissions.
Sana [70]	Sana presented a model for uncertain market capacity in a dual-channel inventory system. It considers offline and online consumer demand, incorporating factors like trust, product value, and costs.The goal is to optimize pricing, order size, and reorder point to maximize retailer profit.
Sana [71]	Sana presented a model for uncertain market capacity in explored how businesses adopt green technology for environmentally friendly products while staying competitive.
Sana [72]	Sana introduced a new inventory model for news vendors, considering the impact of green product marketing by socially responsible companies.
Aghdam et al. [73]	Aghdam et al. introduced a novel joint optimization method for integrating maintenance and inventory policies within a single-machine production system that accounts for back orders. The approach considers uncertain demand, inherent failure rate randomness, and a minimum accessibility threshold for preventive maintenance.
Sana [74]	Sana investigated a production-inventory model with preventive maintenance post-production, accommodating shifts between controlled and out-of-control states affecting product quality and rates.

3. RESEARCH GAP

The research gap brought to light in this study serves as a stark reminder of the substantial void that exists when it comes to evaluating the implications of carbon taxation within the Indian context. It's intriguing to note that despite India's position as the second most populous nation globally and its ranking as the seventh largest country in terms of land area, a conspicuous scarcity of comprehensive research is evident in the domain of studying the effects of carbon taxes. This absence of investigation becomes even more pronounced when one considers India's prominent standing as a key global player across diverse industries, including the pivotal oil sector.

The paucity of attention directed towards comprehensively analyzing the consequences of carbon taxation in the Indian scenario represents a missed opportunity of great magnitude. It is tantamount to foregoing a chance to gather essential insights that could shape well-informed policy-making and steer the trajectory of sustainable development. Given the remarkable role India plays in the international arena, its research endeavors in understanding the intricate relationship between carbon taxes and economic sectors could wield far-reaching implications, both within the nation's borders and across global discussions on carbon pricing effectiveness.

Consequently, delving into this research gap is not merely a matter of academic exploration, but rather a matter of utmost significance. By addressing this void, researchers have the potential to illuminate the ways in which carbon taxes might impact businesses operating in India. The outcomes of such research could shed light on the advantages and obstacles that come with implementing carbon taxes within the Indian economic framework. Moreover, these insights have the power to guide policymakers as they navigate the complex landscape of carbon emissions reduction and sustainable economic growth. In essence, bridging this research gap carries profound implications for India's internal policy formulation, while simultaneously contributing to the broader global conversation surrounding optimal carbon pricing strategies and their tangible effects in the real world.

4. ASSUMPTIONS, NOTATIONS AND METHODOLOGY

The assumptions are taken as per Datta [13]. The assumptions are given below.

4.1. Assumptions

1. Demand Rate: The demand rate is taken to be a linearly decreasing function of selling price. There are two types of customers viz. 1. Wholesale and 2. Retail. Here wholesale customers enjoy a discount percentage.
2. There are no shortages in the market for the product.
3. The management of ONGC can decide with the production rate.
4. We did not take the proportion of defective items. Thus the amount produced is after we substract the defective items from the original amount of items produced.

4.2. Notations

4.2.1. Decision Variables

- sp: Selling price per unit of items produced.
- P: Production rate per unit time being decided by management, which is between $Pmin$ and $Pmax$ i.e. $Pmin \leq P \leq Pmax$.

- K: Amount of capital investments which ONGC has spent on green technology to curb emission.
- *D(sp)*: Demand generated by the market per unit time. It is taken in the linear form. $D(sp) = \alpha - (\beta * sp)$, and α, β, are positive constants. where $sp < \alpha/\beta$.

4.2.2. Model Parametres

- γ: Proportion of demand that is generated by retail customers and hence $(1 - \gamma)$ is by wholesale customers.
- δ: Discount offered to wholesale customers.
- L: Quantity of items produced that can be used.
- CH: Holding cost per unit per unit time.
- CS: Setup/ordering cost per production run.
- CD: Disposal cost per unit time.
- CT: Carbon tax per unit of Carbon emitted.
- *CU (P)*: Fixed cost of the firm such as those costs which appear the same each year + Variable costs which keep on changing under variable production level.
- a: it is the amount of emission caused during setup in one production. It is kept to be constant.
- b: it is the average emission per unit of production during a production process.
- f: it is the average emission per unit item per unit time caused due to storing in the warehouse.
- h: it is the average emission per unit of production run caused due to machining operations.
- g: it is the average emission per unit caused due to disposal of defective items.
- *Kmax*: it is the maximum amount the manufacturer can invest for green technology'].
- θ: it is the maximum amount of emission that is reduced by green technologies.
- R: amount of reduction in average emission when K amount is invested in green technology.
- τ: length of production cycle which is assumed as one year in our case.

4.3. Model Development

It is assumed that the production starts at time $t = 0$ and continues till time $t = t_1 = \tau = 1$ year (in our case). The main objective of this model is to calculate the minimum amount of emission corresponding to maximum profitability.

4.3.1. Calculation of Amount of Emission of gases

To calculate average emission per unit time during a production cycle, we have to add several components. The components added are given below.

I Total emission during production process $= a + bt_1P + ht_1$
II Total emission for stock holding in warehouse $= \frac{Sf\tau}{2}$

Adding I and II and simplifying, we get the average emission per unit of time during a production cycle is given below.

$$E(S; sp; P) = \frac{aD(sp)(L - D(sp))}{LS} + \frac{[bP + h]D(sp)}{L} + 0.5fS \tag{1}$$

After the green technology investment, the average emission decreases to

$$(\theta e^{-mK} + (1 - \theta))E(S; sp, P) = (1 - \theta(1 - e^{-mK}))E(S; sp, P) \tag{2}$$

4.3.2. Calculation of Cost and Profit

To calculate **cost** we have to take into account several factors such as given below.

- Setup/ ordering cost $= CS$
- Unit Cost $= CU(P)Pt_1$
- Holding Cost $= \frac{CHS\tau}{2}$
- Amount of capital invested on green technology $= K$
- Average carbon tax per unit time in a cycle $= CT(1-\theta(1-e^{-mK}))E(S; sp; P)$

After adding all the costs and simplifying onwards, we get
Gross Revenue $= spLt_1(\gamma + (1 - \gamma)\delta)$
and hence the profit per unit time is given by

$$\begin{aligned} Pr(S, K, sp, P) = {} & \frac{sp * L * t_1 * (\gamma * (1 - \gamma) * \delta)}{\tau} \\ & - \frac{CS + CU(P) * P * t_1 + 0.5 * CH * S * \tau + CD * \lambda(P) * P * t_1 + K}{\tau} \\ & - CT(1 - \theta(1 - \exp -mK)) * E(S; sp, P) \end{aligned} \tag{3}$$

4.3.3. Objective of this model

This research is performed based on two important optimization policies. These are:

- **Profit Maximization**
- **Emission Minimization**

The maximum profit will be calculated keeping other decision variables like selling price (sp) and investments in green technology (K) as constant value and hence the maximum profit will be compared to the profit obtained as in ONGC Thereafter, we will calculate the minimum value of emission per unit time, keeping other values of decision variables at a constant level and compare it to that of ONGC.

The value of corresponding emission quantity per unit time is given as $e^{-mK}E(S^*; sp^*, P^*)$, where S^* and sp^* are inventories and selling price corresponding to maximum profit (P^*).

Thus, the optimization problem is given as:

Maximize

$$PR(S, K, sp, P) \tag{4}$$

subject to $S \geq 0$;

$Pmin \leq P \leq Pmax$

and

Minimize

$$E(S; sp^*, P^*) \tag{5}$$

subject to

$S \geq 0$.

5. DATA DESCRIPTION, PARAMETERS AND FLOWCHART

5.1. Data Description

As per law, any public listed company should submit their yearly financial report to the general public. Likewise, ONGC is a public sector undertaking whose operations are overseen by the Ministry of Petroleum and Natural Gas. Thus, ONGC submits financial reports every year to the general public. We used the annual report of ONGC for FY 2020-21. The reports are published on their official site [66].

The parameter values used in this model are given below.

5.2. Model Parameters as per data obtained from ONGC

- sp: To compute the selling price per unit, we took the weighted average of the selling price per unit for all the products sold by ONGC. In the case of Natural Gas, we converted the units of the quantity sold from thousand Cubic Metres (000M3) to Metric Tonne (MT). For all the products, the quantities sold, the revenue generated, and the selling price per unit is given in the table 2 below. The weighted average of the selling price is found to be 0.017 Rs. in million, the quantities being taken as weights.

Table 2: Metrics of products sold by ONGC

Product Name	Quantity Sold (in MT)	Revenue Generated (Rs in million)	Selling Price per Unit (Rs. in million per unit)
Crude Oil	20,713,745	493,267.36	0.023
Natural Gas	14,668,507.55	115,803.19	0.00778
Liquefied Petroleum Gas	1,010,885	31,972.90	0.0316
Naphtha	914,809	26,080.90	0.028
Ethane-Propane	241,299	4,962.80	0.020
Ethane	483,236	9,740.78	0.020
Propane	183,086	6,051.40	0.033
Butane	97,467	3,207.00	0.032
Superior Kerosene Oil	32,465	837.05	0.025
LSHS	24,623	537.56	0.021
HSD	25,788	1,530.89	0.0593
Aviation Turbine Fuel (ATF)	10,177	335.83	0.032
MTO	3,424	97.44	0.028

- P: Production rate per unit time. The ONGC management can set this at any level in (Pmin ¡= P ¡= Pmax) = 44.56 MMT
  We assume
  Pmin=44.00 MT
  Pmax=48.00MT
- Production run-time in a production cycle = 1 year
- K: Amount of capital investment on green technology for reducing emission=131.92 Rs. in million. In this case, we assumed that the maximum investment ONGC can make in Green technology development is 131.92 Rs. in million.
- γ: Proportion of demand generated by retail customers = 0.6 (Assumption)

- δ: Discount percentage on selling price offered to wholesale customers = 0.10
- Demand Rate (D): To calculate demand, we took the help of the equation, Revenue = Selling Price * Demand Rate (D) * time(t1) * $(\gamma + (1-\gamma) * \delta)$. Here t1=1 year.

  So, we get two equations for two financial years, viz. FY 2019-20 and FY 2020-2021, for crude oil. We have taken crude oil intentionally because the main product of ONGC is crude oil, and other products are just Value Added Products. The equations are:

  $$493267.36 = 0.023 * D * 0.96 \tag{6}$$

  $$664482 = 0.0311 * D * 0.96 \tag{7}$$

  From equations (1) and (2), we get two values of Demand for FY 2020-21 and FY 2019-2020. Now we know that $D = \alpha - \beta * sp$. To calculate α and β, we try to solve two simultaneous linear equations. These are:

  $$\alpha - \beta * 0.023 = 22340007.25 \tag{8}$$

  $$\alpha - \beta * 0.0311 = 22256229.9 \tag{9}$$

  Solving equations (3) and (4) we get $\alpha = 22577893.55$, $\beta = 10342882.72$
- $\lambda(P)$: Proportion of defective items produced at production level P is 0.

  In the reports of ONGC, we did not find any mention of spillage, defective items, etc. So we took it to be zero. That is even if there is any spillage or defective items, ONGC is reporting only the good items that can be used [75].
- L: Quantity of good items produced per unit time = 44.56 MMT
- CH: Holding cost per unit per unit time. To calculate CH for ONGC, we added values of several cost variables such as:

  I Royalty = 81,353.57
  II Port Trust Charges = 432.73
  III Other Levies = 734.43
  IV Workover Operations = 15,425.72
  V Water Injection, Desalting and Demulsification = 10,233.97
  VI Insurance = 1,189.55
  VII Power and Fuel = 3,013.04
  VIII Repairs and Maintenance = 18,520.98
  IX Contractual payments including Hire charges etc. = 15,709.86
  X Other Production Expenditure = 9,456.42
  XI General Administrative Expenditure = 34,918.97
  XII Exchange Loss (Net) = 0
  XIII Employee Benefit Expenses = 101,265.40

The units of the above items are Rs. in million. All the above items are added and then divided by the total amount of products sold to get the Holding Cost per unit per unit time. Thus,
CH = 0.0076 Rs. in million per MT.

- CS: Setup/ordering cost per production run.
  To calculate CS for ONGC, values of several cost variables are added such as:

  I Consumption of Raw materials, Stores and Spares = 19,807.30
  II Transport Expenditure = 3,185.21
  III Transportation and Freight of Products = 12,410.32

  The units of the above items are Rs. in million. All the above items are added and then divided by the total amount of products sold to get the setup Cost per production run per unit. Thus,
  CS = 0.00092 Rs. in million per MT.

- CD: Disposal cost per unit.
  To calculate CD for ONGC, we added values of several cost variables such as:

  I Depreciation, Depletion, Amortization and Impairment = 163,273.77
  II Other impairment and Write Offs = 3,785.96

  The units of the above items are Rs. in million. All the above items are added and then divided by the total amount of products sold to get the Disposal Cost per unit. So that we get, we get,
  CD = 0.004 Rs. in million per MT.

- CT: Carbon tax per unit of carbon emitted. In India, there is no definite Carbon Tax. So we have taken the excise duty and the pollution control tax for the carbon tax.
  To calculate CT for ONGC, values of several cost variables are added such as:

  I Excise Duty = 539.08
  II Pollution Control = 2,222.76

  The units of the above items are Rs. in million. All the above items are added and then divided by the total amount of Carbon and Methane gas emitted. The emission in FY 2020-21 is 10.16 MMTCO2e [76]. Thus, we get,
  CT = 0.00027 Rs. in million per MT [76].

- CU(P): Unit cost, taken in the exponential form. According to Datta [13], we get the following description of Cu(P).

  $$CU(P) = m1 + m2, m1, m2 > 0 \tag{10}$$

  Here, m1 is the fixed cost component and m2 is the variable cost component.

- m1: Fixed Cost. We have found out that the audit fees is 32.57 Rs. in million which remained unchanged. So it is the fixed cost. Now, the fixed cost per unit of item sold is $8.479 * 10^{-7}$
- m2: Variable Cost.
  To calculate m2 for ONGC, we added values of several cost variables such as:

  I Promoting Education = 824.97
  II Promoting Health Care = 649.29
  III Empowerment of Socially and Economically Backward groups = 21.90
  IV Promotion of Nationally recognized and Para-Olympic Sports = 65.23
  V Imparting Employment by Enhancing Vocational Skills = 56.41
  VI Swachh Bharat Abhiyaan = 30.46
  VII PM CARES Fund = 3,000.00
  VIII Others = 750.56
  IX Certification and Other Services = 12.75
  X Travelling and Out of Pocket Expenses = 2.39
  XI Finance Cost = 22,145.41
  XII Tax Expense = 51,563.53

  The units of the above items are Rs. in million. All the above items are added and then divided by the total amount of products sold to get the Variable Cost per unit. And hence we get, m2 = 0.0049 Rs. in million per MT.
- a: amount of emission per production run due to setup, which is constant per production run. It is equal to one-third of the summation of the six different sources listed below. All these items are from Direct Emissions.

  I Oil and Natural Gas Corporation (ONGC) = 9.66
  II Mangalore Refinery and Petrochemicals Limited (MRPL) = 3.79
  III ONGC Mangalore Petrochemicals Limited (OMPL) = 0.97
  IV ONGC Petro additions Limited (OPaL) = 1.78
  V ONGC Tripura Power Company Limited (OTPC) = 1.37
  VI ONGC Videsh = 0.625

  The units of the above items are in MMT. We take one-third of the summation of the above items as the amount of emission per production run due to setup.
  And hence,, we get a = 5458500.0 MT
- b: average emission per unit of production during production process. It is equal to one-seventh of the summation of the six different sources listed below and divide it by the amount of items sold. All these items are from Direct Emissions.

I Oil and Natural Gas Corporation (ONGC) = 9.66
II Mangalore Refinery and Petrochemicals Limited (MRPL) = 3.79
III ONGC Mangalore Petrochemicals Limited (OMPL) = 0.97
IV ONGC Petro additions Limited (OPaL) = 1.78
V ONGC Tripura Power Company Limited (OTPC) = 1.37
VI ONGC Videsh = 0.625

The units of the above items are in MMT. We take one-seventh of the summation of the above items and divide it by the amount of items sold to obtain average emission per unit of production during production process.
So that we get, we get b = 0.3315 MT

- f: average emission per unit item per unit time for storing in warehouse. It is equal to half of the summation of the six different sources listed below and divide it by the amount of items sold. All these items are from Indirect Emissions.

  I Oil and Natural Gas Corporation (ONGC) = 0.50
  II Mangalore Refinery and Petrochemicals Limited (MRPL) = 0.054
  III ONGC Mangalore Petrochemicals Limited (OMPL) = 0.02
  IV ONGC Petro additions Limited (OPaL) = 0.078
  V ONGC Tripura Power Company Limited (OTPC) = 0
  VI ONGC Videsh = 0.16

  The units of the above items are in MMT. We take half of the summation of the above items and divide it by the amount of items sold to obtain average emission per unit item per unit time for storing in warehouse.
  Thus, we get f = 0.0105 MT

- h: average emission per unit of production run-time generated due to machining operations. It is equal to half of the summation of the six different sources listed below and divide it by the amount of items sold. All these items are from Indirect Emissions.

  I Oil and Natural Gas Corporation (ONGC) = 0.50
  II Mangalore Refinery and Petrochemicals Limited (MRPL) = 0.054
  III ONGC Mangalore Petrochemicals Limited (OMPL) = 0.02
  IV ONGC Petro additions Limited (OPaL) = 0.078
  V ONGC Tripura Power Company Limited (OTPC) = 0
  VI ONGC Videsh = 0.16

  The units of the above items are in MMT. We take half of the summation of the above items and divide it by the amount of items sold to obtain average emission per unit of production run-time generated due to machining operations.

  And hence, we get h = 0.0105 MT

- g: average emission per unit for disposal of defective item. Here g = 0
- Kmax: manufacturer's budget for investing on green technology/modernization project. We took it to be K. So Kmax = K = 131.92 Rs. in million.
- θ: maximum fraction of emission that can be reduced by investing on green technology
- R: fraction of reduction of average emission when K amount of capital is invested on green technology, This is having a mathematical relation, $R = \theta * (1 - e^{-mk})$. We have R = 4.4% [76], K = 131.92 Rs. in million. So we get $\theta = 0.06$. We took $m = 0.01$ in our research.
- τ: Length of a production cycle = 1 year

We have to find out the optimal values of the following factors:

1. PR: average Profit per production run
2. S: maximum level of inventory in a cycle

5.3. Flowchart

The flowchart for the entire algorithm we used is given in Figure 1.

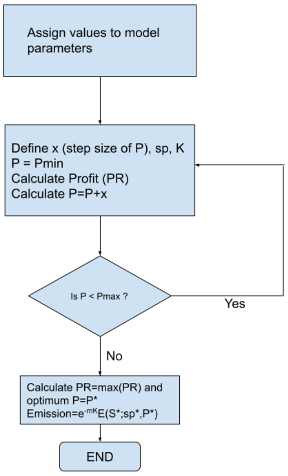

Figure 1: Flowchart

6. RESULTS AND DISCUSSIONS

We performed the tests as per the algorithm given by Datta [13]. The step size for maximum production is taken as 1000 MT and the selling price per unit is assumed to be 0.001 Rs (in Million) per MT. The comparison between the actual data and the calculated data is given in table 3. It is worth mentioning here that ONGC is involved in many businesses like Natural Gas, Liquefied Petroleum Gas, Naphtha, Ethane-Propane, Ethane, Propane, Butane, Superior Kerosene Oil, LSHS, HSD, Aviation Turbine Fuel (ATF), MTO, and others. So the selling price is the weighted average of all the products manufactured by ONGC, the weights being the quantities produced.

Table 3: Results

Variables	Real Data	Our algorithm	Units
Profit	112464.37	121169.47	Rupee (in million)
Investment in Green Technologies	131.92	131.92	Rupee (in million)
selling price per unit	0.01757	0.01757	Rupee (in million)
Production	44560000	44000000	MT
Emission	10.16	10.40	MMT

As we can see from table 3, the metrics when compared with the real data give quite impressive results. As far as the total profit is concerned, the calculated value is 8% more than the original value. In this research, the share of profit of Government Of India has not been deducted. This can be explained by the fact that we did not exclude the Government of India's share of profit from that of ONGC. So, the profit can be seen more than the original profits.

As per our algorithm, for production of 44560000 units the profit is 122,711.62 Rupee (in million), and the emission is 10.53 MMT. Thus we conclude that as per the algorithm developed by Datta [13], it is more sensitive for both profit maximisation which is 9.11%, and for minimisation in emission which is 3.64%. But the method may be improved by using simulation.

7. MANAGERIAL IMPLICATION

The managerial implications drawn from this research are of profound significance for businesses aiming to enhance their operational efficiency and profitability. By leveraging this innovative model, companies have the unique opportunity to forecast their potential profitability prior to embarking on operational endeavors. This study, grounded in the analysis of authentic field data extracted from ONGC, carries substantial weight due to its rare utilization of genuine industry data within the domain of inventory research. This facet alone underscores the practical applicability and reliability of the findings. Enterprises can harness the insights from this research to make informed decisions regarding inventory management, resource allocation, and strategic planning, thereby fostering a competitive edge in an ever-evolving market landscape. The integration of real field data into scholarly exploration undoubtedly elevates the utility of the present research, rendering it an indispensable tool for corporate decision-makers seeking to optimize their business processes.

8. CONCLUSIONS

Due to its location in India, this study holds significant importance. India stands as the world's second most populous nation and the seventh largest in terms of geographical expanse. However, there exists a notable research gap within India concerning the assessment of carbon tax implications. Adding to this, ONGC, as India's leading upstream oil enterprise, has made substantial investments in eco-friendly technologies. Consequently, a meticulous investigation into ONGC's emissions and profitability stands to provide invaluable insights to policymakers globally. Some salient findings extracted from these studies are outlined below:

I ONGC, a state-owned enterprise engaged in oil and gas exploration and production, contributes around 70% of India's crude oil and 84% of its natural gas. The company steadfastly adheres to stringent Corporate Social Responsibility norms and maintains a dedicated investment strategy for green technologies. This rationale underpins the selection of ONGC, an Indian upstream oil entity with noteworthy commitments to sustainability.

II The observed reduction in carbon emissions has yielded substantial profit gains, underscoring the potential of the proposed model for diverse business organizations seeking to optimize profits through sustainable technologies. The alignment between the current situation and the model's efficacy is evident. The validation of the model [13] using real-world ONGC data enhances its practical applicability to other potential manufacturing entities.

III An additional pivotal insight from this study is the close alignment between simulation outcomes and actual results, indicating that the implementation of a Green Tax would not culminate in financial losses. Policymakers can leverage this model to formulate industry-specific tax policies beyond the scope of the oil sector.

IV While India lacks a specific Green Tax for oil-related industries, it does impose excise and pollution control taxes. For practical purposes, these are collectively referred to as the Carbon Tax (Green Tax). Given the minimal divergence between our results and ground truth values, it is feasible to combine these terms for calculating the Green Tax in India.

V The paramount inference drawn from the aforementioned research lies in the potential to devise distinct inventory models within the framework of India's carbon pollution scenario. This can be accomplished by assimilating pertinent parameters linked to the successful implementation of sustainable technologies.

While this study contributes valuable insights, it is important to acknowledge its limitations. Firstly, the study's scope is confined to a specific focus on ONGC, which, while significant, might not fully encapsulate the diversity of the Indian oil industry. The findings might lack generalizability to other oil companies with distinct operational structures or degrees of investment in green technologies. Secondly, the study relies on simulation models, which, while grounded in real-world data, inherently simplify complex realities. These models might not account for all intricate variables and potential interactions that can arise in a multifaceted industry. Additionally, the lack of a comprehensive historical carbon tax framework in India limits the study's ability to provide insights into long-term effects. Furthermore, the study predominantly examines economic implications and may not fully address broader socio-environmental aspects of carbon taxation. Lastly, as the study draws on available data up to a certain point, its conclusions might not account for potential shifts in ONGC's strategies or external factors beyond that timeframe. Recognizing these limitations underscores the need for cautious interpretation of the study's findings and encourages avenues for further research to paint a more comprehensive picture.

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