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REVIEW ARTICLE

A Review of Game Theory and Multi-Criteria Decision-Making Methods with Application to the Oil Production and Price

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Abstract

The oil production and price issues have been discovered a long time ago, and always be a continuous problem to the globe especially during the current global threats of the coronavirus pandemic. This paper provides a literature review that involves game theory and multi-criteria decision-making (MCDM) methods with its applications to oil production and price problems. This paper identifies and analyses the use of the game theory and MCDM methods on oil production and price to compare the situation studied, to determine the model that has been used, the trend of past literature and also the details of the basic elements for the game theory framework. Therefore, the oil production and price problem using the game theory and MCDM methods are reviewed and numerous applications studied from the past works of literature are highlighted. The trend of oil production and price which used the game theory and MCDM methods based on the year 2001 till 2021 is still lacking sources from the Web of Science and Scopus databases. The main contribution of the recent study is the employment of the game theory and MCDM methods to the oil production and price problem.

Keywords: Game theory; MCDM; oil production; oil price

Introduction

In general, a country needs energy resources for its economic development. This causes the demand for energy resources to be higher. Among the energy sources that are in high demand is oil. Oil, also known as crude oil and petroleum that be found beneath the surface of the Earth is one of the factors of economic growth. Since oil is the most important industry to the globe, people daily life depends much on it (Losáñez et al., 2018). One of the sectors that depend most on oil is transportation, where oil is used in the form of petrol (gasoline) and diesel-derived products, for transporting goods from the producers to the consumers.

The oil prices are determined by the global supply and demand. The price of the oil is reflected based on its production and consumption movement. An intergovernmental organization that coordinates and consolidates the oil policy is the Organization of the Petroleum Exporting Countries (OPEC). The function of OPEC is to stable any volatile oil prices by controlling the productions of the member countries, supply oil to consumers regularly and ensures a fixed income to the production of oil-producing countries as well as a fair return on capital. OPEC can generally, set oil production controls for its member countries by setting targets or quotas. This oil production control is to influence the oil price shocks as a suggested strategy (Chang et al., 2014).

The oil production and price issues have been discovered a long time ago, and always be a continuous problem to the globe especially during the current global threats of the coronavirus pandemic. Some other oil price shock events are political instability, global economic crisis and natural disasters which influence the bad economic performance of the affected country. It is also a question to the economic performance of the affected countries since the continuous of the movement control order or lockdowns is worrying everybody. The continued spreading of the pandemic could be observed the impact on the declining oil prices. Hence, the oil industry players have taken place in an oil price war.

The oil price shock events also give impacts on the supply and demand of oil, reserves oil at a conflict region and the usage of the oil for daily activities such as food delivery and goods transportation. Oil production and price issue have been discovered continuously, therefore this paper discusses the topics of oil production and price jointly in this paper since the problem is close to each other.

Oil as one of the important resources for the world has been taken into account as precious assets, correlated with the conflicting interests among numerous oil players such as governments, countries, companies as well as producing and consuming countries (Araujo & Leoneti, 2018). These aspects are similar fundamentals in the game theory framework where the conflict among the oil industry players have been considered.

This paper targets to review the game theory and multi-criteria decision-making (MCDM) methods that used oil production and price as applications. There are past works of literature that combined these two methods regarding both basic elements. In game theory, the basic elements are players, strategies and payoff. While, the basic elements in MCDM are decision makers, criteria and alternatives. The optimization of the selection problem using these two methods has numerous occasions in research.

Therefore, this paper aims to highlight, review and analyze the most relevant and significant previous studies of game theory and MCDM frameworks on oil production and price applications using systematic literature review methodology. This paper identifies and analyses the use of the game theory and MCDM methods on oil production and price to compare the situation studied, to determine the model or method that has been used and also the details of the basic elements for both frameworks.

The remainder of this paper is structured as follows: Section 2 explains the research methodology used in this paper. Next, section 3 provides a review of the game theory and MCDM methods on oil production and price applications. In section 4, the results and discussion of the current trends of game theory and MCDM methods on oil production and price are depicted through tables and a graph. Finally, section 5 provides the conclusion of the paper.

Methodology

The research methodology of this paper starts with searching publications in two research databases which are Web of Science and Scopus. The search process is divided into two topics. This first topic is game theory in oil production and price while the second topic is MCDM in oil production and price. The search strings used were “game theory applications in oil production

and price", "game theory oil production", "game theory oil price", "MCDM applications in oil production and price", "MCDM oil production" and "MCDM oil price".

The next refined steps of searching are as follows:

(i) filtering the study in the last 20 years of publications from 2001 to 2021,
(ii) an advanced search was used to specify the terms of the search only in the title, abstract and keywords,
(iii) the type of the documents is articles,
(iv) the language is in English.

After the refined process, the pre-selection of the most relevant papers by assessing their titles, abstracts and keywords is done. By reading and analyzing the titles, abstracts and keywords, some papers being excluded based on several reasons which are the papers are outside the scope of the oil production and price, associate with subjects related to biofuel, palm biomass and gas market, wind farm site selection and also a simulation game.

The number of papers analyzed and merged from the two databases in this pre-selecting stage for game theory and MCDM topics is 35 and 46 respectively. The next selection process is by reading and assessing the full text of the 81 pre-selected papers from both topics. The selection criteria are as follows:

The criteria to assess the most relevant papers are summarized as follows:

(i) Involve the game theory topics,
(ii) oil production or oil price particularly, excluded gas market,
(iii) real-case applications,
(iv) contain data or payoff structures.

From the selection process of eighty-one pre-selected papers, nineteen papers are selected based on the previous assessment criteria. The sixty-two papers were excluded because of the theoretical that was not on the oil production and price scopes. Therefore, the nineteen papers are being classified into production, price and both production and price subtopics.

Review of the Game Theory on Oil Production and Price Applications

Game theory is a mathematical discipline and is largely applied by economists. In a game, the strategic interaction among the players is taken into account with the assumption all players are rational. However, the rational behavior will generate sustain decisions and remove the uncertain decisions for the long run result (Reneke, 2009). In game theory, generally, the basic elements are players, strategies and payoff. Game theory is a study on the interaction among numerous players where every player has a set of strategies that can be chosen either one or more than one strategy with particular probabilities (Bratvold & Koch, 2015). Game theory has two types of games which are competitive and cooperative. The conflict situation is called a noncooperative game while the cooperation situation is called a cooperative game. This section focuses on the oil production first then the oil price. Later, both oil production and price works of literature are reviewed.

Oil production works of literature are studied by Boyce and Vojtassak (2008) that used Nash equilibrium and subgame perfect equilibrium in game theory to examine a model of 'oil'igopoly exploration and production. The study makes sure the firms use strategic exploration to influence the rival's actions and study the strategic exploration and strategic production that affects each other. The result showed that the Nash equilibrium yield expectations differ significantly combined between over-exploration and under-yields. The Nash equilibrium concept is preferred instead of the subgame perfection equilibrium concept in this study. In making a decision, stakeholders individually have the conflict of preferences on the investment value should be invested, which in turn should they act. Willigers et al. (2010) provided a game theory framework to study players' preference relationships, uncertain solutions and commercial drivers on jointly three oil fields

where the two-player game model was used. The joint fields will support the choosing alternatives the timing and the order of the investment, also reducing the risk or negative impact on a project. The trade-offs of players' preferences to choose alternatives not taking into account any criteria in decision making.

Next, oil price works of literature studied by Reneke (Reneke, 2009) on the investment problem that takes into account the increasing oil prices due to the environmental degradation impact. The study used a two-player game model with nature's strategies with uncertainty. The alternative of the investment is evaluated using second-order statistics, the mean and variance and return rates that depend on the unsureness. The aim of the investment alternative decision is the balance of the expected payoffs and risk where the risk is defined as criteria in terms of random variability. However, the study needs more accurate results supported by numerical tests and adds more criteria to the decision. Besides that, Moradinasab et al., (2018) used Nash and Stackelberg equilibria to study the competition between government and the private sectors in the petroleum supply chain in the first level of the study. The aim is to maximize profits and job creation while minimizing the pollution that occurred. The model is tested by the national Iranian oil company. The result is the total profit using Nash equilibrium is higher than in Stackelberg equilibrium. However, it depends on the policies implemented by the government and the economic situation. The study generally mentioned the refinery product prices and the demand amount for the government and private sector, not oil prices except used in the application part.

Numerous studies have been done involving the game theory method on both production and price. Tominac and Mahalec (2017) used the game theory method which was potential and Cournot oligopoly games to determine the strategic refinery production planning due to the presence of individual refiners in competing interests for the limited market share. Each refiner or player has the same petroleum product set with similar access to the crude oil stocks. The effects of competition for strategic and tactical production planning produce the Nash equilibria of oil refineries. However, the oil market is only be used in the application while the theoretical study explained the production and price of products generally. Also, fixed price does not give competitively optimal solutions. Next, Babaei et al. (2020) studied the long-term investment field using a multi-stage Stackelberg game to attract private investors to energy zone investments. The idea is to encourage the private sector to be involved in the production field instead of importing gasoline outside the country that will impact national revenues. The result achieved using this method is the intermediate producer obtains a maximum profit by managing the production volume while the investors gain their return. However, the profit amount is not guaranteed using this method. On the government side, the subsidy coefficient that is given to the investors can be determined to encourage investment.

In addition, Chapman and Khanna (2001) elaborated the price band between $15–$20 per barrel that happened from 1986 to 1999. Game theory is used to show the political interaction, military defense and global oil markets from an economic perspective. The stability of the price and military power is of interest in this study but there is no game theory model shown yet the explanation. AlKathiri et al. (2017) introduced a global oil trade model that is based on the trade-offs among freight costs, crude oils' qualities that are being traded and the crude oil refineries' configurations. The model quantified the large players' strategic chances to maximize the revenues and minimize the costs and estimated the price of the crude oil difference by some aspects which are location, direction and volume. The Stackelberg game model is used where the exporters act as a leader and producers and importers take prices in a competitive situation among them. Another representation is the Stackelberg-Nash model where large producers and importers are in a competitive situation. Production cost was neglected since their analysis is on the price differences, not levels.

Langer et al. (2016) provided a partial equilibrium game model for global trade flows and strategic refinery investments in consideration of types of crude oil, multiple oil products, refinery configurations and transport modes. They investigate the post-impact US lifting ban crude export

on the international and North American crude oil trading. The study can determine the effects of the current policy shift of the US on the global oil market in three scopes which are upstream, midstream and downstream. The result showed that the lifting crude export ban has limited effects for the customers in the US. The model captures the price effects even the ban of crude oil is still implemented. The model used will not be affected by real global price volatility. Nicoletti and You (2019) modeled a mixed-bilevel linear program based on the game theory nature, or specifically the Stackelberg game, to represent the conflicting objectives among stakeholders regarding the crude oil supply chain. The model considered the crude oils' composition, pricing, transportation distances and impacts on the environment. Both crude oil producers and refiner's goal is to increase their profits from the sales while the crude oil refiner has another objective to decrease the impact to environment of the refinery products. The result showed the crude oil's equilibrium price in the crude oil supply chain. In addition, the trade-offs between the objectives may be considered some criteria of the economic and environmental perspectives so that the demand and price of the crude oil more preferably in decision making.

Chang et al. (2014) used the Stackelberg game approach to model the Organization of the Petroleum Exporting Countries (OPEC) (price maker) and non-OPEC (price taker) relationships on oil supply forecasting where the non-OPEC can select the production individually. The result showed that OPEC's strategies may lead to a shrink or deplete of non-OPEC's share under the action taken by OPEC in high price oil supply market scenario. However, the discussion is lacking in the strategies mentioned. The model may insert unpredictable events to strengthen the model proposed. The dynamic game was studied by Willigers and Hausken (2013) on the strategic interaction between a producer, a shipper and UK government on unstable tax impact. The suggestion result is recent tax changes could adversely affect future hydrocarbon production in the UK. The dynamic game does not change with increasing oil production and price. But, this type of game is anticipated much more complex.

Review of the MCDM on Oil Production and Price Applications

MCDM is a sub-discipline in an Operations Research field, where multiple criteria are considered in making a decision out of multiple alternatives. In most real-case problems, people face many problems that demand a solution among numerous options of conflicting criteria that need to be solved simultaneously. This section focuses on the oil production first then the oil price. Later, both oil production and price works of literature are reviewed.

Oil production works of literature are studied by Rodriguez et al. (2018) that integrated three MCDM methods which are simple additive weighting (SAW), elimination and choice expressing the reality (ELECTRE) and vlsekriterijuska optimizacija i komoromisno resenje (VIKOR) to choose the most suitable artificial lift system (ALS) for crude oil production in Colombia to minimize the failure rate. The criteria considered in the study were flowing pressure, gas to oil ratio, water cut, well depth, fluid production, casing diameter, well inclination, viscosity, sand production, location, well completion, recovery method, dogleg severity, temperature, well service, number of wells, contaminants, treatment, electrical power, space. The ALS alternatives for oil production are electro submersible pump, sucker-rod pump, gas lift, hydraulic piston pump, hydraulic jet pump, progressing cavity pumps and electrical submersible progressing cavity pump. The result showed that an optimal ALS was the hydraulic jet pump. However, this study shows the crude oil production criteria that based on the ALS.

In addition, Qaradaghi and Deason (2018) also integrated three MCDM methods which are the analytic hierarchy process (AHP), preference ranking organization method for enriched evaluation (PROMETHEE), and technique of order preference similarity to the ideal solution (TOPSIS) to aim resources optimal allocation. Eight criteria were taken into account which are recoverable oil, costs, plateau production period, distance from infrastructure, size of the reservoir,

plateau production, historical data and need for secondary recovery. While six major oilfields in Iraq were chosen as alternatives. The alternatives are Rumaila, West Qurna I, West Qurna II, Majnoon, Zubair and Halfaya. However, this study does not focus on a comprehensive evaluation of the oilfields production potential of Iraq.

Melo et al. (2019) studied a decision making on offshore oil and gas project portfolio to continue its service life using the Preference Ranking Organization Method for Enrichment Evaluations (PROMÉTHÉE) V method. The project portfolio prioritization study was beneficial during the production decline to increase oil production. The criteria used were security/safety, compliance, production, cost and ease. While twelve main projects were used as alternatives. The data and the evaluation of the criteria used from twelve main projects were obtained from the database of the organization based on the experts. The production criterion measures the potential increment of the installation efficiency of the production project.

Besides that, Wang et al. (2020) used the supply chain operation reference model to assess potential suppliers, the analytical hierarchy process (AHP) to define the criteria weight based on the expert's opinion through surveys, and the data envelopment analysis (DEA) method to rank and choose the optimal supplier in the oil industry. The model was tested at ABC Petroleum Joint Stock Company then the survey was conducted on the 10 potential suppliers as alternatives. The criteria considered in the model are reliability, ability, agile, effective asset management and costs. The result showed that the decision-making unit (DMU) 1,4 and 10 are the best suppliers. The MCDM method is used specifically to select and evaluate the oil production project or supplier in the oil industry.

Next, oil price works of literature studied by Lee et al. (2009) that proposed a strategic energy technology roadmap using integrated fuzzy theory and AHP of MCDM approach to produce the energy technology weights against high oil prices. There are four criteria taken into account, which are economical spin-off, commercial potential, inner capacity and technical spin-off. In the process of selecting the criteria, the study referred to the strength, weakness, opportunity and threat aspects for well research and development outcomes. There are six energy technologies taken as alternatives. The six energy technologies are building technology, industry technology, transportation technology, coal technology, non-conventional technology, biomass technology. The result showed that building technology is the first rank of energy technology, followed by the coal and transportation technologies as second and third rank, respectively. However, the high oil price issue in this study is only based on the experts' feedbacks and can be improved with real data evaluation.

Xu and Ouenniche (2012) investigated the rank of competing forecasting models of crude oil prices under several criteria which used elimination and choice expressing the reality (ELECTRE) III, PROMETHEE I and PROMETHEE II. The criteria used were goodness-of-fit, biasedness, and correct sign. The set of alternatives used were Random Walk (RW), Autoregressive Integrated Moving Average (ARIMA), linear regression, Vector Autoregressive (VAR) and Error Correction (EC) and Vector EC (VEC) models. The result showed that the linear regression and the exponential smoothing models were not sensitive regardless any of goodness-of-fit, importance weights or outranking methods. The study uses the statistics elements to the crude oil price, then MCDM uses to rank. There is no direct involve crude oil price in the MCDM framework.

Besides that, Ju et al. (2015) studied the oil price crisis vulnerability index using multiplicative data envelopment analysis (MDEA) to predict the response capability of China towards the oil price crisis from 1993 till 2013. To build the oil price crisis vulnerability index, the weighted product method was used and there are four criteria (indicators) involved which are economic stability, political stability, oil import dependence and oil consumption dependence. The weight of each criterion was identified using MDEA. The result showed that the three key indicators which are oil consumption intensity, gross domestic product (GDP) per capita and the ratio of oil import expenditure to GDP gave an impact on the oil price crisis vulnerability index. The oil price crisis

response capability became slower since the year 2000 yet stronger before the year 2000. The interrelation among these indicators is not mentioned in the paper.

Based on the review, there is no past work of literature that has been done on the MCDM method on both oil production and price. Therefore, this paper only elaborates the MCDM method on oil production and price. The next section discusses the results and discussion of this paper.

Results and Discussion

This section explains the data interpretation, summary of the findings, the limitation of the study as well as implications and suggestions for future research of this study area. According to Bratvold and Koch (2015), game theory in the oil and gas industry is suit one of the three categories which are competitive bidding on limited chances, jointly partnership on a project and lastly is the negotiation among the cooperated players to get a share as large as possible. The conflicting interests that have shown up based on the past works of literature reviewed in this study are joint-partnership and program development (Willigers et al., 2010). None of the studies on bidding and negotiation.

The analysis of this paper starts with the reviewing process. Tables 1 and 2 show the review of the game theory method and MCDM method on oil production and price, respectively. Table 1 highlights the players, strategies, aim of the past studies, data used, analysis and methods used and limitation or comment. The highest game theory method used based on this review is the Stackelberg game model. Stackelberg game is a strategic game in economics in which the first mover (a leader) is followed by the second mover (a follower). This model is suitable to be used in the oil market since the situations involve price makers and price takers.

Meanwhile, Table 2 highlights the criteria, alternative, aim of the past studies, data used, analysis and methods used and limitation or comment. The highest MCDM method used based on this review is the AHP. AHP is a method that structures a decision problem into a hierarchy process. It starts with the goal, criteria and alternatives. Then the calculation uses the pairwise comparison and expert opinion to be changed into the numerical calculation.

Table 1. Review on game theory method on oil production and price.

Author / Year / Reference	Production	Price	Player / Decision Maker	Strategy	Aim	Data	Analysis tools / Method approach	Limitation / Comment
(Chapman & Khanna, 2001)	□	□	OECD countries and Persian Gulf oil producers.	Price per barrel: $10 or less, $15-$20 and $30.	To elaborate the price band between $15–$20 per barrel happened from 1986 to 1999.	U.S. Arms Control and Disarmament Agency, World Trade Organization and U.S. Energy Information Administration.	No game theory model was used. Regression analysis.	A view on oil issue that uses game theory but does not implement any model of game theory.
(Boyce & Vojtassak, 2008)	□	□	Firms A, B and C.	Proved and unproved reserves for three periods.	To make sure the firms use strategic exploration to influence the rival's actions and study the strategic exploration and strategic production that affects each other.	Oil reserves of 99 countries were available in the post-World War II era.	Nash equilibrium and subgame perfect Nash equilibrium.	Results were obtained using the Nash equilibrium concept instead of the subgame perfection equilibrium concept.
(Reneke, 2009)	□	□	Nature and Player.	Savage's criteria (minimize the maximum regret).	To evaluate long-term investments using game theory on increasing oil prices and environmental degradation.	Not mention.	Two-player non-cooperative game. Statistical approach - the second-order statistics.	Need more accurate results supported by numerical tests. Add more criteria.
(Willigers et al., 2010)	□	□	Player A (upper panel)	Low fixed and variable costs, high fixed cost	To study and analyze the typical joint	Not mention.	Deterministic and	The trade-offs of players' preferences to

			and player B (lower panel)	and project abandonment.	project using game theory application.		probabilistic games.	choose alternatives not taking into account any criteria in decision making.
(Willigers & Hausken, 2013)	□	□	UK government, producers and shippers.	Tax increases, production and production declined rate and costs.	To study players' preference relationships, uncertain solutions and commercial drivers on jointly three oil fields using the two-player game model.	Assumptive.	Dynamic game.	The dynamic game does not change with increasing oil production and price. But, this type of game is anticipated much more complex.
(Chang et al., 2014)	□	□	OPEC and non-OPEC.	Increase oil production or supply and economic and geological factors.	To model the OPEC (price maker) as and non-OPEC (price taker) relationships on oil supply forecasting using the Stackelberg game.	International Energy Agency (IEA) and BP Statistical Review of World Energy.	Stackelberg game.	The discussion is a lack in strategies mentioned. The model may insert unpredictable events to strengthen the model proposed.
(Langer et al., 2016)	□	□	Midstream players - refinery capacities and investments and the shifts of global crude and product flow	Prices, production and refining capacities, global reserves, and trade routes.	To provide a partial equilibrium game model for global trade flows and strategic refinery investments.	International Energy Agency (IEA)	Generalized Nash equilibrium	The model captures the price effects where the ban of crude oil is still implemented. The model used will not be affected by real

								global price volatility.
(AlKathiri et al., 2017)	□	□	Middle East exporters and Asian importers	freight costs, crude oils' qualities traded and the refineries' technical configurations that process the crude oil.	To investigate the ability of large crude oil exporters or importers to affect the difference of inter-regional crude oil price by allocating sales or purchases respectively.	Energy Intelligence Group (EIG), IHS EDIN Midstream Refinery Database, BP Statistical Review.	Global oil trade model using Stackelberg and Nash Stackelberg games.	Production cost was neglected since their analysis is on the price differences, not levels.
(Tominac & Mahalec, 2017)	□	□	Refiners	Total purchase volume of oil stock, blend volumes and unit operating modes and product volumes and shipping destinations.	To determine the strategic refinery production planning using game theory on the effects of competition which produces the Nash equilibria of oil refineries for strategic and tactical production planning.	Natural Resources Canada, Statistics Canada and EIA gasoline and diesel products.	Non-cooperative potential game model, Cournot oligopoly game and generalized additive models for model statistics.	Fixed price does not give competitively optimal solutions.
(Moradinasab et al., 2018)	□	□	Government and private sectors.	Subsidized and unsubsidized prices.	To maximize profits and job creation while minimizing the pollution that occurred	Not mention.	Nash equilibrium, Stackelberg game and Mixed Integer Linear Programming.	Generally mentioned about the refinery product prices and the demands' amount for the government and private sector,

								not oil prices except used in the application part.
(Nicoletti & You, 2019)	□	□	Crude oil producer and crude oil refiner.	Oil refinery – The quantity of oil selection and the quantity of distilled oil produced. Oil producers – Each oil charge pricing.	To represent the conflicting objectives among stakeholders regarding the crude oil supply chain using a mixed-bilevel linear program based on the game theory.	U.S. Energy Information Administration.	Stackelberg game.	The trade-offs between the objectives may be considered some criteria of the economic and environmental perspectives so that the demand and price of the crude oil more preferably in decision making.
(Babaei et al., 2020)	□	□	Investor, government, intermediate producer, customers.	The number of subsidies and production of intermediate producers. Import supply and improves or build the refineries' productivity.	To ensures the profit of investments by providing investors with valuable information.	Assumptive.	Multi-stage Stackelberg game.	The profit amount is not guaranteed using this method.

Table 2. Review on MCDM method on oil production and price.

Author / Year / Reference	Production	Price	Criteria	Alternative	Aim	Data	Analysis tools / Method approach	Limitation / Comment
(Lee et al., 2009)	□	□	Economical spin-off, commercial potential, inner capacity and technical spin-off.	Building technology, industry technology, transportation technology, coal technology, non-conventional technology, biomass technology.	To propose a strategic energy technology roadmap using integrated fuzzy theory and AHP of MCDM approach to produce the energy technology weights against high oil prices.	Triangular fuzzy number represents the feedbacks of experts regarding the development of energy technology.	Fuzzy AHP.	High oil price is only based on the experts' feedbacks.
(Xu & Ouenniche, 2012)	□	□	Goodness-of-fit, biasedness, and correct sign	RW, ARIMA, linear regression, VAR, EC and VEC.	To investigate the rank of competing forecasting models of crude oil prices under several criteria	Not mentioned	ELECTRE III, PROMETHEE I and PROMETHEE II	There is no direct involve crude oil price in the MCDM framework.
(Ju et al., 2015)	□	□	Economic stability, political stability, oil import dependence and oil consumption dependence.	Oil consumption intensity, GDP per capita and the ratio of oil import expenditure to GDP	To study the oil price crisis vulnerability index using MDEA to predict the response capability of	Economic data: State Council Development Research Center Oil consumption data: U.S. EIA (energy	MDEA	The relation between all indicators is not mentioned in this paper

					China towards the oil price crisis.	information Administration) Oil import data: BP (British Petroleum) World's political crisis index data: ICRG (International Country Risk Guide)		
(Rodriguez et al., 2018)			Flowing pressure, gas to oil ratio, water cut, well depth, fluid production, casing diameter, well inclination, viscosity, sand production, location, well completion, recovery method, dogleg severity, temperature, well service, number of wells, contaminants, treatment, electrical power and space.	Electro Submersible Pump, Sucker-Rod Pump, Gas lift, Hydraulic Piston Pump, Hydraulic Jet Pump, Progressing Cavity Pumps and Electrical Submersible Progressing Cavity Pump.	To choose the most suitable ALS for crude oil production in Colombia to minimize the failure rate.	Field data in a case study relating to a Colombian oilfield.	SAW, ELECTRE and VIKOR.	This study shows the crude oil production criteria based on the ALS.
(Qaradaghi & Deason, 2018)			Recoverable oil, costs, plateau production period, distance from infrastructure, size of the reservoir, plateau	Rumaila, West Qurna I, West Qurna II, Majnoon, Zubair and Halfaya.	To suggest an investment plan for resources optimal allocation.	14 subject matter experts from industry and academia were involved with minimum qualifications of	AHP, PROMETHEE and TOPSIS.	This study does not focus on a comprehensive evaluation of the oilfields' production potential in Iraq.

			production, historical data and need for secondary recovery.			bachelor's degree in engineering, management, or economics, 25 years experience in oil and gas sector and also have in-depth knowledge of the six oilfields.		
(Melo et al., 2019)	□	□	Security/safety, compliance, production, cost and ease.	Twelve main projects	To study decision-making on offshore oil and gas project portfolio to continue its service life.	Database of the organization based on the experts.	PROMÉTHÉE V	The production criterion measures the potential increment of the installation efficiency of the production project.
(Wang et al., 2020)	□	□	Reliability, ability, agile, effective asset management, costs.	10 potential suppliers.	To assess and choose the optimal supplier in the oil industry.	A survey of suppliers at ABC Petroleum Joint Stock Company.	Supply chain operation reference model, AHP and DEA.	The MCDM method is used specifically to select and evaluate the oil production project or supplier in the oil industry.

Figure 1 shows the game theory and MCDM trend on oil production and price from the year 2001 to 2021. According to fig. 1, the trend of oil production and price using the game theory and MCDM methods based on the year 2001 to 2021 is still lacking sources from the Web of Science and Scopus databases. Moreover, the study of oil production and price in one field is erratic and diverse. From the year 2002 to 2007, there is no study involve oil production and price using the game theory and MCDM methods. Albeit the past literature is lacking, they are consistently being studied from the year 2012 to 2020.

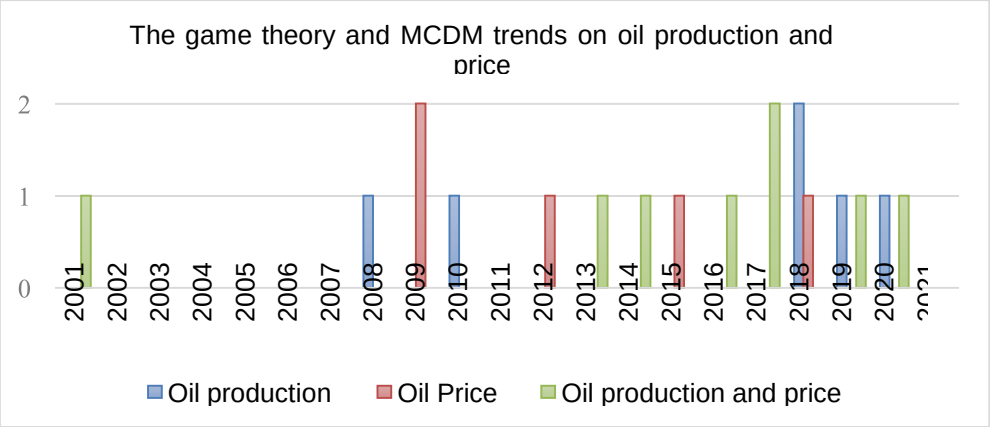

Figure 1. The game theory and MCDM trends on oil production and price.

The finding shows that there are ten application topics used in the past works of literature. The application topics are exploration and production, supply chain, supply and demand, investment, military security, government tax, technology, project portfolio, politics and economy and forecasting statistics. The classification of the applications on oil production and price is shown in Table 3.

Table 3. The classification of the applications on oil production and price.

Application	References
Exploration and production	(Boyce & Vojtassak, 2008; Chang et al., 2014; Tominac & Mahalec, 2017)
Supply chain	(Moradinasab et al., 2018; Nicoletti & You, 2019; Wang et al., 2020)
Supply and demand	(AlKathiri et al., 2017)
Investment	(Babaei et al., 2020; Langer et al., 2016; Qaradaghi & Deason, 2018; Reneke, 2009; Willigers et al., 2010)
Military security	(Chapman & Khanna, 2001)
Government tax	(Willigers & Hausken, 2013)
Technology	(Lee et al., 2009; Rodriguez et al., 2018)
Project portfolio	(Melo et al., 2019)
Politics and economy	(Ju et al., 2015)
Forecasting statistics	(Xu & Ouenniche, 2012)

The limitation of this study is the discussion only involves non-cooperative game theory and the cooperative game theory models. Suggestions for future research are the methods may be concentrated on the hybrid concept and other scopes of oil market issues. As a future trend, the game theory and MCDM frameworks may include a fuzzy system as a hybrid method particularly on oil production and price problems.

Conclusion

Game theory and MCDM methods are useful to support the evaluation, selection strategies and ranking alternatives in making a decision. In this paper, a comprehensive review of the game theory and MCDM frameworks on oil production and price is discussed and analyzed. At first, the research methodology is elaborated to make the reader clear about the databases used. Then, the classifications of 19 papers selected after the pre-selecting process are introduced. Moreover, the different classifications of the game theory method and MCDM method on oil production, oil price and both oil production and price are studied. Also, the various scope of oil production and price studied in game theory and MCDM frameworks is discussed and the trend of the game theory and MCDM methods based on the year of publication shows a lack of the trend from the year 2001 to 2021. The contribution of this paper in the game theory and MCDM field can aid researchers or economists effectively in the area of the oil market. Also, more research gaps need to be filled in the field of study.

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