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Government Effectiveness in the Petroleum Sector: Two-step Analysis Combining Linear Regression and Artificial Neural Networks

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Background and Purpose: To encourage petroleum industry development, a country needs to set up a regulatory framework that standardizes investment conditions. The objective of the research was to investigate the determinants of government effectiveness in the petroleum sector.
Design/Methodology/Approach: Multiple regression analysis was conducted to investigate if government effectiveness in the petroleum sector is influenced by the country's political stability, regulatory quality, the intensity of petroleum exploration and production activities, government take, and type of contract used. Artificial neural network analysis was additionally conducted to identify the importance of independent variables.
Results: Political stability, regulatory quality, government take attractiveness, and the intensity of petroleum activities positively influence government effectiveness. A more attractive government take enhances effectiveness, while the type of contract for awarding petroleum rights did not significantly impact effectiveness. Artificial neural network analysis revealed that the most important variables were regulatory quality and political stability.
Conclusion: The research concluded that political stability, regulatory quality, and the intensity of petroleum activities are key factors in enhancing government effectiveness in the petroleum sector. These findings have practical implications, as they emphasize the importance of stable and well-regulated environments for achieving higher government effectiveness in the petroleum industry. This equips policymakers and industry professionals with actionable insights for improving the sector's performance.

Keywords: *Energy policy, Government effectiveness, Petroleum sector performance, Petroleum resources management, Industry development*

1 Introduction

As petroleum production expanded in the United States, disputes arose regarding land ownership and shares in profit (Hammerson, 2011). American state courts established a legal practice regarding the rights of oil leases and the management of revenue from its production. The 1889 Pennsylvania Supreme Court decision equated the production of oil and gas to that of other minerals, concluding that land ownership does not necessarily entail ownership

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of minerals (Hammerson, 2011). Texas applied the offset rule for neighboring wells and the concept of ownership in place, which defined the ownership principles in petroleum production as either freehold ownership of the land, which included the right to minerals, or partial ownership, which did not include the right to minerals (Thurman, 2022). Capital investments in petroleum exploration and production and the return on investment in this activity could be compared to the riskiest investments in speculative trends on the capital market (Simkins & Simkins, 2013). Despite this, the possibility of exceptionally high profits in the case of a positive petroleum discovery motivated oil companies to take such risks.

The United States legal system is based on the principles of Anglo-Saxon law and precedents, and court decisions have also established the legal practice for relationships among participants in petroleum exploration and production activities. The starting point is the freehold ownership category, which, along with the land ownership, entails the right to minerals, i.e., oil and gas. In contrast, European countries implemented different forms of feudal and royal limitations regarding mining rights. The ownership of petroleum in European countries is considered a public good and is regulated by provisions governing state ownership (Thurman, 2022).

The principal dissimilarity between the petroleum exploration and production business in the United States and the rest of the world stems from the definition of mineral ownership (Seba, 2008). In countries applying Anglo-Saxon law, oil leases are based on freehold ownership, which includes the right to minerals, whereby the lease includes compensation for the land and part of the value of the produced oil and gas. In most countries worldwide, where state ownership of minerals prevails, oil companies acquire the right to minerals from the government. At the same time, the lease for the use of the land is agreed upon with landowners based on local laws and regulations (Simkins & Simkins, 2013). The relationships between the company acquiring the rights to minerals and the previous, i.e., original, owner (freehold owner in the Anglo-Saxon law or the state in continental law) are governed by a contract defining the terms and compensation for rights to petroleum. This is a specific compensation, income, or yield obtained by the landowner (state) and represents a cost for the petroleum lessee, different than all other taxes or expenses. This yield is known as a royalty, i.e., the fee for recovered quantities of petroleum. In the United States, it traditionally amounts to 1/8 (12.5%) of the market value of the produced petroleum (Johnston, 1994).

In the 20th century, contractual relationships in petroleum exploration and production developed due to the rise in petroleum production and exploration and rising oil prices. Oil and gas became essential primary sources of energy, accounting for over two-thirds of primary energy consumption. The expansion of transport led to oil becoming one of the most important primary resources, and the use of energy became important in contemporary industrial infrastructure. This increased value influenced the codification and regulation of relationships among participants in petroleum exploration and production.

In countries with a free market economy, petroleum companies conducting petroleum exploration and production activities were state-owned, forming part of a planned and targeted economy. Following the disintegration of a non-market and planned socio-economic system, free capital ownership has become a global universal principle of relationships. Ownership and contractual relationships in the area of exploration and production of valuable natural resources with high capital intensity and value, such as petroleum, have become a matter of special attention for all government instances.

Laws and legal regulations regarding petroleum production were once part of mining legislation. However, since petroleum is present in the Earth's crust in varying physical and geological forms, exploration is performed using a range of technical means, and the production technology differs from that in the production of solid mineral raw materials. Petroleum legislation sets out conditions for investments in petroleum exploration and production, legal prerequisites for development, and competitive terms regarding petroleum exploration and production (Johnston, 1994). It places significant emphasis on optimization during mineral raw material management processes while primarily protecting national interests and providing petroleum companies (investors) with security and stability as they carry out their investments and business activities (Green & Smith, 2023; Thurman, 2022).

The regulatory framework in every country is based on the nation's constitution, which grants taxing and legislative authority that governs petroleum legislation and outlines authority boundary conditions for relationships with foreign companies. The function of government is to provide an adequate regulatory infrastructure for companies to work economically productive units and ensure they do not swindle the public, exploit workers, pollute their surroundings, prosecute unethically, or engage in morally or socially reprehensible practices (Parra, 2004). Hence, establishing a regulatory framework that standardizes investment conditions is an essential step in promoting the growth of the petroleum sector.

The study aims to examine the factors that influence government efficiency in the petroleum industry. This study employs multiple regression analysis (MLA) to examine the potential impact of political stability, regulatory quality, the intensity of petroleum exploration and production operations, government take, and type of contract on government performance in the petroleum industry. Furthermore, a study of artificial neural networks (ANN) was performed to determine the significance of independent factors.

2 Theoretical background

Petroleum legislation sets out conditions for investments, legal prerequisites for development, and competitive terms regarding petroleum exploration and production. It emphasizes optimization during mineral raw material management processes and provides security and stability for petroleum companies as they carry out their investments and business activities.

The petroleum regulatory framework in a country is based on its constitution, which grants taxing and legislative authority for petroleum legislation and outlines authority boundary conditions for relationships with foreign companies. The constitution also includes specific petroleum legislation that authorizes the national oil company or responsible ministry to negotiate certain aspects of agreements between the state and foreign companies. Tax liabilities are usually included in the agreement signed between the parties (government and petroleum company) and regulated by separate laws.

Governments provide an adequate regulatory infrastructure for companies to work economically productive units and ensure they do not swindle the public, exploit workers, pollute the environment, prosecute unethically, or defraud shareholders. Changes in the economic environment and the increasing interest of foreign investors have indicated the need to regulate petroleum exploration and production in a manner defined and accepted within global practice. Petroleum legislation needs to create conditions for large investments, determine the legal prerequisites for energy development, and protect national interests in the petroleum sector.

Petroleum lease contracts are more similar to financial contracts than typical land concessions or mining concessions due to the uncertainty of petroleum prices and the increased strategic role of petroleum. Both parties have individual interests, with the oil company minimizing risk and the government increasing its share in profit distribution. This results in direct increases in fiscal revenue through royalties, taxes, and indirect contributions.

The fiscal regime, or petroleum taxation model, is a financial structure that oil companies must pay to countries for petroleum exploration and production activities. It is often represented as a government take versus an oil company take, with the government taking the percentage of profit that goes directly to the state budget and the oil company taking the percentage remaining with the company (Johnston, 2003). There are 145 countries worldwide with specific fiscal and contractual terms for engaging with oil companies for petroleum exploration and production operations (IHS Energy, 2016). These regimes can be divided into two main categories: the concessionary system (based on royalty and tax payments) and the production-sharing system (based on petroleum production sharing) (Green & Smith, 2023).

The fiscal regime, if balanced and regulated properly, can attract significant investments in exploration and production activities and create wealth for the nation. The higher the government take, the greater the probability of creating wealth for the nation. To determine the attractiveness of the fiscal regime, the government take is combined with other measures of profitability, including fiscal system flexibility, revenue risk, and fiscal stability (Johnston, 2003). The most common fiscal regime terms used worldwide are bonuses, fees, state participation, royalty, production sharing, cost recovery, and taxes (Simkins & Simkins, 2013). The terms of the fiscal regime differ among countries, and not all are included within one particular regime.

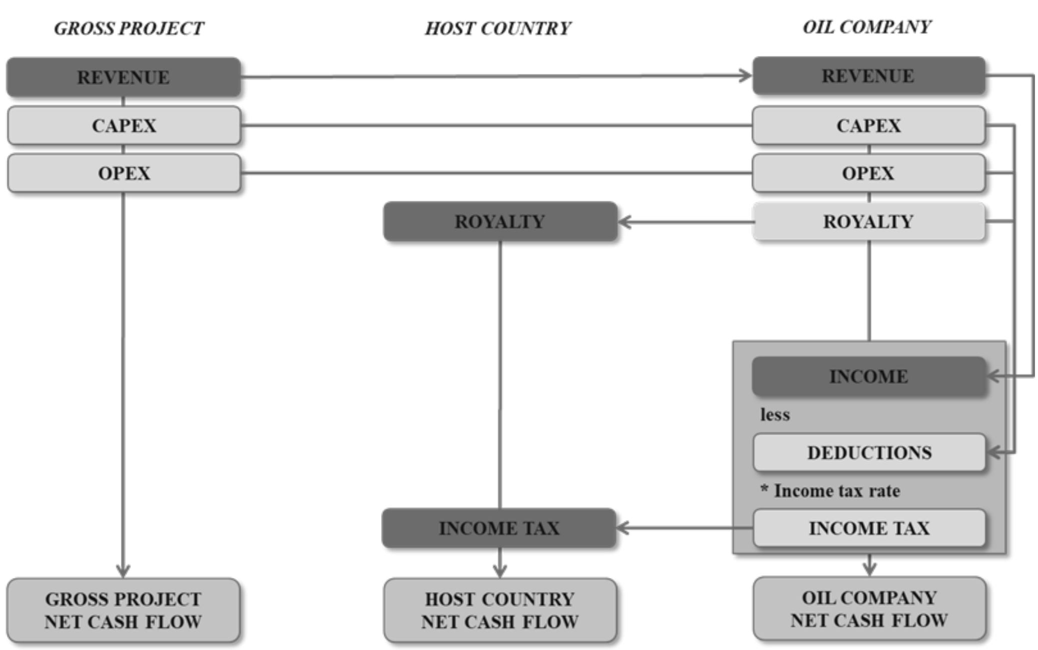
Production sharing is a fiscal regime that allows revenue from petroleum production to be shared between the domicile country and the oil company, allowing the company to recover costs and make a return on investment (Johnston, 2003). The three main elements of production sharing are cost recovery, excess cost recovery, and profit share. Taxes are common to both fiscal regime systems, including corporate income tax, additional profit taxes defined only for petroleum operation companies operating in the domicile country, and dividend withholding taxes.

The ideal fiscal regime should ensure a stable business environment, minimize sovereign risk, discourage undue speculation, provide the potential for a fair return, balance risk and reward, avoid complexity, limit administrative burden, allow flexibility, and promote healthy competition and market efficiency (Johnston, 2003). The most common petroleum industry-recognized fiscal regimes fall broadly into two categories: the concession system, which includes special fees and taxes payable in money to the country where it is operating, and the contractual (production sharing) system, which includes production sharing arrangements where petroleum is usually shared in kind between oil company and domicile country (Simkins & Simkins, 2013).

In the concessionary system, oil companies have the right to perform petroleum exploration and production at their own cost, assuming the overall risk of discovery and production risks. The royalty goes directly to the country as one part of the country's petroleum profit, and all taxes are payable on profit before income tax (Seba, 2008). Figure 1 shows the typical revenue distribution under the concession system and illustrates the hierarchy of royalties, deductions, and examples of possible taxation layers. Of the total revenues collected from petroleum produced, the royalty (percentage of total petroleum value) goes directly to the country as one part of the country's petroleum profit (state budget revenue). Before-tax calculations, royalties are deducted together with all capital and operating expenditures (CAPEX and OPEX) from total revenues to give the oil company profit before income tax. All taxes (income tax, petroleum special tax, and any other taxes) are payable on profit before income tax. Income tax goes to the country as the second part of the country's petroleum profit (state budget revenue). The remainder after taxes is the oil company's petroleum profit.

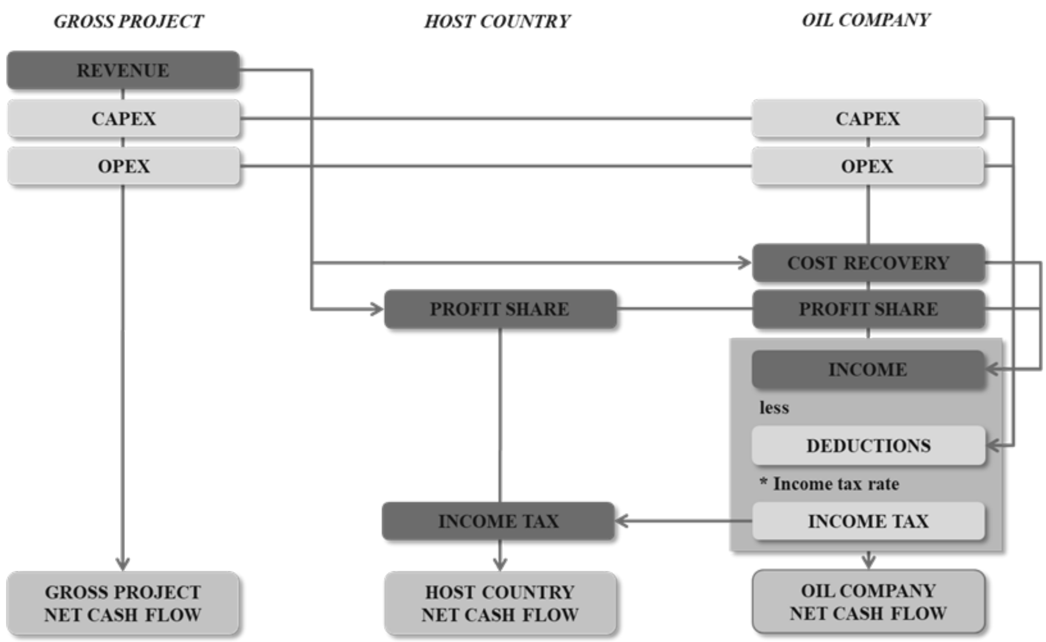
Production sharing contracts (PSC) are a newcomer to the petroleum industry, starting in 1966 in Indonesia (Markus, 2014). These contracts involve a contractual relationship between the state and the oil company, with the state owning petroleum rights and the oil company ensuring the execution, technical, and financial realization of petroleum exploration, development, and production (Seba, 2008). The aim is to maximize income and initiate economic activities connected to petroleum exploration and production. Production is split between the host government and the contractor, with the government maintaining ownership of the produced petroleum. Stabilization clauses are essential to ensure the preservation of the tax system and fiscal proportions throughout the contract. Figure 2 shows typical revenue distribution under the production-sharing system and illustrates the calculation of revenues and costs that would be experienced in a full cycle. From total revenues, collected from the petroleum produced, cost recovery is deducted first. Cost recovery includes all capital and operating expenditures (CAPEX and OPEX) borne by the oil company in producing the petroleum, and this is the oil company's revenue. What remains after cost recovery is the profit share. Profit share is then split between the country and oil company based on the contracted percentages. Profit share represents one part of the country's petroleum profit (state budget revenue), while for the oil company, it is one part of the oil company revenue. From oil company revenue, comprised of cost recovery and the company's part of the profit share, all capital and operating expenditures (CAPEX and OPEX) are deducted. What remains after deductions is subject to taxation. Income tax is paid to the country, representing the second part of the country's petroleum profit (state budget revenue), while the remainder after taxes is the oil company's petroleum profit.

Fiscal regimes are often categorized as hybrids, combining elements of both classifications, such as royalties and taxes. These hybrid systems aim to ensure petroleum profit from the start of production, with most countries using the concessionary system (royalty/tax contract) and production sharing system (production sharing contract). As shown in Table 1, most countries worldwide use these two systems: concessionary system (royalty/tax contract) and production sharing system (production sharing contract).



Source: Doric B. (2017)

Figure 1: Concession system - Typical cash flow diagram



Source: Doric B. (2017)

Figure 2: Production sharing system - Typical cash flow diagram

Table 1: Types of contracts (agreements) used worldwide

Type of contract	Number of countries
Royalty/Tax	78
Production Sharing Agreement	52
Mixed / Various	15

Source: IHS Energy (2016a)

Contract terms for oil exploration and production contracts include fiscal terms, work commitments, insurance, and local content. Work commitment is crucial for the host country to ensure the oil company commits to as much work as possible, enabling quicker development of potential new production and revenue generation. Insurance is essential to ensure high-quality work commitments and cover potential losses. Contracts often require the oil company to buy goods and services locally to boost local industry development and employ local labor. The recognition of exploration and production costs is sensitive, as the investment of funds and risk lies with the oil company. The country must establish a fiscal regime that maximizes revenues and provides investors with incentives to explore and develop petroleum efficiently. The license round procedure for petroleum exploration and production is industry-standardized and consists of several steps.

Concessionary and production-sharing systems have advantages and disadvantages, but the choice of system may not be as critical from an economic, accounting, and financial perspective (Johnston, 2003). The fundamental difference between the two systems lies in the ownership of the petroleum produced.

To encourage petroleum industry development, a country needs to set up a regulatory framework that will standardize the conditions for investments in petroleum exploration and production and lay down the legislative prerequisites for the development and competitive conditions in this activity. The function of government is crucial in organizing and managing the petroleum sector since an adequate regulatory framework will ensure that exploration and production activities are conducted in a way that will create wealth for the nation, protect the environment, and enable companies to work in a stable and competitive environment (Parra, 2004). Many authors (Falola & Genova, 2005; Shaffer, 2011; Thurber et al., 2011; Holden, 2013; Kemal, 2016) have argued that political stability is an important prerequisite for petroleum industry development and enables economic growth and generates wealth for the nation. Most of the theories to date have been based on historical information and statistical observations on the development of the petroleum industry. Thurber et al. (2011) went a step further in their empirical research, indicating that some countries implementing the Norwegian Model failed due to a lack of institutional quality and political stability, which influenced government effectiveness in the petroleum sector. This argument was further elaborated by Kemal (2016), who stated that the economic impact due to changes in petroleum governance might depend on political conditions. The literature has indicated that political stability is an essential factor that directly influences government effectiveness and thus shows the ability of the government to create a stable environment when it comes to investments in the petroleum sector.

The theory discussed demonstrated that petroleum legislation is the main factor in regulating the complex relationship between governments and oil companies in petroleum exploration and production activities. It lays down the conditions for investments, the legal prerequisites for development, and competitive terms and conditions. As political stability directly dictates the government's ability to implement adequate policies and regulations for industry development, regulatory quality is another important factor that can also impact government effectiveness.

Exploration activities are crucial for discoveries and petroleum production. The more an oil company invests in exploration activities, the greater the probability of new petroleum discoveries and developing new petroleum production. Petroleum exploration intensity depends on geological probability, which also depends on the investor's (oil company) investment in exploration and production activities and the owner's (government) ability to attract investments and enable exploration and production activities. Therefore, the intensity of petroleum exploration and production activities is another factor that may influence government effectiveness.

Moreover, suppose the relationship between the promising petroleum potential and the requirements set in the fiscal regime is unfavorable to oil companies in advance. In that case, they will not proceed with the business and investments. Thus, governments must design an optimal fiscal regime to ensure a favorable balance of mutual relations. The government take (share of the petroleum profit) is used as a measure to compare the fiscal regimes of different countries in terms of petroleum profit going directly into the state budget and the fiscal regime attractiveness for petroleum sector investments. Accordingly, the theory indicates that government take attractiveness should also influence government effectiveness.

The theory outlined in this chapter suggests that neither the type of fiscal regime system nor the corresponding type of contract is better or worse. From the economic perspective, the same objectives can be achieved through both concessionary and production-sharing contracts. Therefore, it could be concluded that the type of contract has no influence on government effectiveness in the petroleum sector.

3 Hypothesis development

According to the theoretical findings outlined in the previous chapter, the objective of this empirical study is to examine the influence of political stability, regulatory quality, the intensity of petroleum exploration and production activities, government take (fiscal regime) attractiveness, and the type of contract on government effectiveness. Based on the theory discussed, the following hypotheses were developed.

The government effectiveness variable represents the quality of public service, the quality of civil service and its degree of independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies (World Bank, 2016). Many authors focused on government effectiveness when analyzing the petroleum governance model among various oil-producing countries together with oil-sector performance. Brunnschweiler and Bulte (2008) showed that there is a significant difference in government effectiveness in various oil-producing countries. Their empirical research suggested that better government effectiveness led to less resource dependence and higher direct investments, which in turn positively affects GDP. Like many other authors, for the government effectiveness variable, they used World Bank data, arguing that these data have the advantage of extensive coverage and objectiveness due to a large survey base, making them particularly attractive for econometric analysis (Brunnschweiler & Bulte, 2008). Kaufman et al. (2004) argued that the key advantage of the World Bank Worldwide Governance Indicators (WGI) is that despite the margins of error, these indicators are sufficiently informative that many cross-country comparisons result in statistically significant differences in estimated governance. The WGI measures six dimensions of governance, which are government effectiveness, political stability, regulatory quality, rule of law, control of corruption, and voice of accountability. Government effectiveness data published by the World Bank has also been used by other authors (Heller & Marcel, 2012; Thurber et al., 2011), aiming to compare government effectiveness in the petroleum sector among various oil-producing countries.

The political stability variable represents the level of political stability and perceptions of the likelihood of political instability and politically motivated violence (World Bank, 2016). Many authors (Falola & Genova, 2005; Shaffer, 2011; Thurber et al., 2011; Holden, 2013; Kemal, 2016) used political stability in their empirical research and showed that the level of political stability would positively influence petroleum sector governance and consequently government effectiveness in the petroleum sector. The data used in the model was pulled from WGI data published by the World Bank in 2016. Based on this, the first hypothesis was developed as follows:

- *H1: Political stability positively influences government effectiveness in the petroleum sector.*

The regulatory quality variable represents the perception of the ability of the government to formulate and implement comprehensive policies and regulations that permit and promote private sector development (World Bank, 2016). As elaborated in the previous chapter, petroleum legislation is very specific, complex, and industry standardized. Moreover, the ability of the country to implement industry-standardized petroleum legislation is very important in terms of the development of the petroleum sector. Thus, regulatory quality is another variable that, in addition to political stability, should strongly influence government effectiveness. Some of the previous research related to the petroleum governance model and respectively government effectiveness in the petroleum sector used the regulatory quality indicator (Heller & Marcel, 2012; Thurber et al., 2011). The second hypothesis is developed as follows:

- *H2: Regulatory quality positively influences government effectiveness in the petroleum sector.*

The intensity of petroleum exploration and production activities variable represents the ranking of the selected sample countries in terms of the intensity of petroleum exploration and production activities in the five years from 2010 to 2016. The ability of the country to attract investments in petroleum exploration and production activities shows the country's (government) effectiveness in maximizing its potential and revenues from petroleum (Johnston, 1994). This ability can be measured in the intensity of petroleum exploration and production activities. To rank oil-sector performance and measure effectiveness, Thurber et al. (2011) evaluated the ability of the country to develop and produce petroleum, which can only be done through investments in petroleum operations and showed that this ability positively influences petroleum sector effectiveness. The above indicates the third hypothesis:

- *H3: The intensity of petroleum exploration and production activities positively influences government effectiveness in the petroleum sector.*

The government takes the attractiveness variable, which represents the ranking among selected sample countries related to the attractiveness of the fiscal regime applied by the country in terms of economic stability and balanced share of profits between the country and the oil company for 2015. Many authors (Johnston, 2000 and 2003; Seba, 2008; Thurber et al., 2011; Holden, 2013; Kemal, 2016) have used government take in their empirical research and showed that government take attractiveness will positively influence government effectiveness in the petroleum sector. This argumentation leads to the fourth hypothesis:

- *H4: Government take attractiveness positively influences government effectiveness in the petroleum sector.*

The type of contract represents the contract used among selected sample countries when concluding deals with oil companies, i.e., the production sharing contract or concession (royalty and tax) contract. Some authors, such as energy economist Daniel Johnston, have argued that the type of contract does not influence the ability of the country to maximize petroleum profit and its effectiveness in the petroleum sector since both types can achieve the same objectives. The data used in the model were pulled from the Petroleum Economics and Policy Solutions (PEPS) data published by IHS Energy in 2016. The above indicates the fifth hypothesis:

- *H5: The type of contract used for awarding petroleum rights does not significantly influence government effectiveness in the petroleum sector.*

The following chapter outlines the methodology, including data and analytical approaches, including MLA and ANN.

4 Methodology

4.1 Data

After the variables to be used in the model were identified, descriptive statistics were applied, and the variables' descriptions were presented in Table 2.

Government effectiveness data was pulled from WGI data published by the World Bank (2016). The data represents an estimation of government effectiveness in each selected country for 2015. Countries were evaluated in the range from -2.5 to 2.5, where -2.5 indicates weak effectiveness and 2.5 indicates strong effectiveness. In order to avoid negative values, the range was adjusted by 2.5, to a range from 0 to 5, where 0 means weak and 5 means strong effectiveness.

In 2015, countries were evaluated for political stability, ranging from -2.5 to 2.5, where -2.5 means weak stability and 2.5 means strong stability. These ranges were adjusted by 2.5 to a range of 0 to 5, where 0 means weak, and 5 means strong stability.

Regulatory quality data were also pulled from the WGI data published by the World Bank (2016). The data repre-

Table 2: Description of the variables

Variable	Code	Measurement	Mean	St. Dev
Government Effectiveness	GE	0-5 (0-weak, 5-strong)	2.41	0.956
Political stability	PS	0-5 (0-weak, 5-strong)	2.21	0.968
Regulatory quality	RQ	0-5 (0-weak, 5-strong)	2.41	0.966
Intensity of exploration and production activities	EPI	1-10 (1-low, 10-high)	3.19	2.739
Government take attractiveness	GTA	1-10 (1-low, 10-high)	5.98	1.504
Type of contract	TC	0-production sharing contract, 1-concession (royalty and tax based) contract	0.40	0.492

Source: Authors' work

sents an estimation of regulatory quality in 2015 in each selected country. Countries are evaluated in the range from -2.5 to 2.5, where -2.5 means weak quality and 2.5 means strong quality. The range was adjusted by 2.5 to avoid negative values, and thus, a range from 0 to 5 was used, where 0 means weak, and 5 means strong quality.

The intensity of petroleum exploration and production activities was pulled from the Petroleum Economics and Policy Solutions data published by IHS Energy (2016). Countries were evaluated on a scale of 1 to 10, where 1 means the lowest and 10 means the highest intensity of petroleum exploration and production activities.

The same source was used to extract the data to measure government take attractiveness in 2015. Countries were evaluated on a scale of 1 to 10, where 1 means lowest, and 10 means highest value.

The type of contract was measured as a dummy variable. In the model, countries with production-sharing contracts were denoted with the number 0, while countries with a concession (royalty and tax) contract were denoted with the number 1.

4.2 Analysis

To examine the influence of the defined independent variables on the dependent variable, a full MLA is run, including all independent variables that are considered predictors of dependent variables. Since one of the variables appeared insignificant due to a low t ratio, that variable was dropped, and the reduced regression model was rerun (Azcel & Sounderpandian, 2009). One of several stepwise selection procedures is used. These techniques either select or eliminate variables, one at a time, in an effort to exclude those variables that either have no predictive ability or are highly correlated with other predictor variables (Kvanli et al., 2003). Stepwise procedures consist of forward regression, backward regression, and stepwise regression, where stepwise regression is most commonly used. Stepwise regression can remove any variable whose partial F-value indicates that this variable does not contribute, given the present set of independent variables in the model (Kvanli et al., 2003).

In the MLA, many problems may occur due to a large number of variables. The purpose of model diagnostics is to detect possible weaknesses of the model and, if necessary, to transform it. Typically, four problems (multicollinearity, heteroscedasticity, autocorrelation of error terms, and the normality of error terms) need to be analyzed in order to prove the validity of the model (Šošić, 2004). If any of the four problems are detected, the basic model assumptions are not satisfied, and the validity of the model is questionable.

To test the set hypothesis, it was necessary to examine the statistical dependence among variables, which is possible using the MLA. The MLA shows the statistical dependence of one numerical variable (dependent variable) to two or more numerical variables (independent variables). To examine the influence of selected variables on government effectiveness, an MLA was used on a sample of 130 countries worldwide. The dependent variable in the defined model is government effectiveness (GE), and the five independent variables are political stability (PS), regulatory quality (RQ), the intensity of petroleum exploration and production activities (EPI), government take attractiveness (GTA), and type of contract (TC). Data were statistically analyzed using the programs SPSS 21 and EViews 7.

The correlation matrix is used to check multicollinearity. The correlation matrix shows the correlation coefficients between the variables in the model. A serious multicollinearity problem exists if the Pearson coefficient between the variables is 0.9 or greater (Belsey et al., 2004). Other multicollinearity problem indicators are variance inflation factor (VIF) and tolerance indicator (TOL), where $VIF>10$ or $TOL<0.1$ (Hair et al., 1995; Tabachnick & Fidell, 2001; Kvanli et al., 2003; O'Brien, 2007). Some authors have argued that there is a possibility of moderate multicollinearity if VIF>5 or TOL<0.2 (Bahovec & Erjavec, 2009). Since each of these indicators has certain advantages and disadvantages, they should both be examined to conclude whether multicollinearity exists.

Multicollinearity often appears in empirical research, especially in regression models. Although there is no exact solution for multicollinearity, independent variables that contribute to it may be excluded from the model (Kvanli et al., 2003). It is important to emphasize that VIF and TOL only indicate that the model is not ideal (Kvanli et al., 2003; O'Brien, 2007).

A two-step approach for assessing the proposed study model has been established in previous research (Sternad Zabukovšek et al., 2019). To evaluate the relevance of the constructs in the proposed conceptual model, an importance-performance map analysis was employed. Furthermore, we investigated and verified the impact of independent factors on dependent variables using artificial neural networks (ANN), a computerized method used to estimate complex and non-linear features of interactions between variables. Research by Alhumaid et al. (2021) proposes that an ANN has three separate modalities: transfer function, network design, and learning rule. To be more precise, these modalities may be classified as feed-forward multilayer perceptron (MLP) networks, radian bases, and convolutional networks. A widely used approach is the Multilayer Perceptron (MLP) network, comprising layers of inputs and outputs linked by hidden nodes. The input layer of a neural network transfers unprocessed data to the lower layers, known as "synaptic weights." The output of each layer is governed by the activation function employed, and the most effective active function suggested is the sigmoidal function (Karlik & Olgac 2011). Therefore, this work employs the ANN to train and evaluate the theoretical model, quantifying the importance of independent variables.

5 Results

5.1 Step 1: Multiple regression analysis

Based on all the information and inputs above, the MLA has the following form:

$$GE = 0.283 + 0.60 * TC + 0.033 * EPI + 0.115 * PS + 0.645 * RQ + 0.134 * GTA + \varepsilon \quad (1)$$

For the full model, all five variables were included in the model to suppose that they influence the government's effectiveness. The MLA results are presented in Table 3. W for the model. In contrast, the type of contract (TC) variable was not shown as statistically significant since its p-value was greater than 0.05 (p-value = 0.376). The coefficient of determination (R-square) is high (R2=0.869), indicating that the model fits the data well. This means that 86.9% of the variance of the dependent variable government effectiveness (GE) is explained by the inclusion of four independent variables (PS, RQ, GT, EPI, GTA, and TC).

Table 3: Variables in the full model

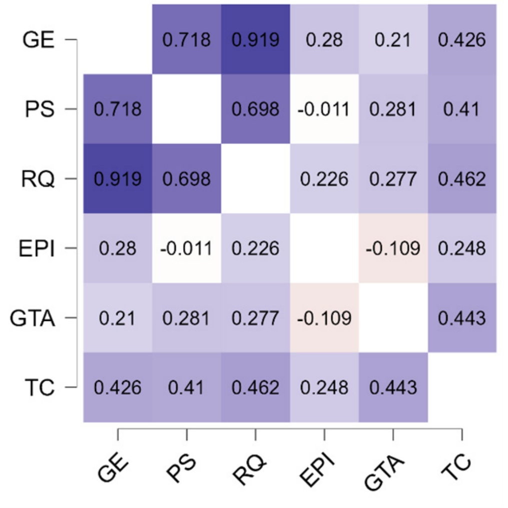
Variables	Coefficients	Standard errors	t-values	p-values	Hypothesis	Conclusion
Constant	0.283	0.142	1.995	0.048*		
PS	0.115	0.054	2.107	0.037*	H1	✓ (+5%)
RQ	0.645	0.063	10.239	<0.001**	H2	✓ (+1%)
EPI	0.033	0.011	2.896	0.004**	H3	✓ (+1%)
GTA	0.134	0.050	2.679	0.008**	H4	✓ (+1%)
TC	0.060	0.068	0.887	0.376	H5	∅

Note: ** statistically significant at 1%; * 5; Source: Authors' work

Table 4: Correlation matrix

		GE	PS	RQ	EPI	GTA	TC
GE	Pearson's r	1.000					
PS	Pearson's r	0.718**	1.000				
RQ	Pearson's r	0.919**	0.698**	1.000			
EPI	Pearson's r	0.280**	-0.011	0.226	1.000		
GTA	Pearson's r	0.210*	0.281**	0.277	-0.109	1.000	
TC	Pearson's r	0.426**	0.410**	0.462	0.248	0.443	1.000

Source: Authors' work



Source: Authors' work

Figure 3: Heatmap of the correlations between dependent and independent variables

Table 5: Tolerance (TOL) and the variance inflation factor (VIF)

Variables	TOL	VIF
PS	0.466	2.146
RQ	0.437	2.290
EPI	0.799	1.251
GTA	0.740	1.351
TC	0.617	1.621

Source: Authors' work

Results indicate that an increase in regulatory quality within a particular country will directly increase government effectiveness, which is in line with part of Hypothesis 1, defining that regulatory quality has a positive impact on government effectiveness. Besides, an increase in government take attractiveness within a particular country will directly increase government effectiveness, which is in line with the part of Hypothesis 2, defining that government take has a positive impact on government effectiveness. An increase in the intensity of petroleum exploration and production activities within a particular country will directly increase government effectiveness, which is in line with part of Hypothesis 3, defining that the intensity of petroleum exploration and production activities has a positive impact on government effectiveness. Finally, an increase in political stability within a particular country will directly increase government effectiveness, which is in line with part of Hypothesis 3, defining that political stability has a positive impact on government effectiveness. However, due to the fact that the type of contract (TC) variable did not enter into the reduced model due to its insignificance to the full model, the part of Hypothesis 5 defining that the type of contract used within the particular country does not influence government effectiveness was confirmed.

The correlation matrix and associated parameters are presented in Table 4 to test for the possible presence of multicollinearity. Among independent variables, the maximum linear correlation of 0.698 was observed between PS and RQ, while the coefficients of the linear correlations among other variables were lower. Since all Pearson's coefficients among independent variables are less than 0.9, we can conclude that there is no multicollinearity problem in the model. Figure 3 presents the heatmap of the correlations between dependent and independent variables.

Multicollinearity was also tested with tolerance and the variance inflation factor (VIF). As shown in Table 5, tolerance was higher than 0.1, and VIF was lower than 10 for all variables included in the model. Based on the results, it can be concluded that the model has no multicollinearity problem.

Additionally, the normality of residuals was tested using the Kolmogorov-Smirnov, Shapiro-Wilk, and Jarque-Bera tests. The results suggest that the empirical significance level for the Kolmogorov-Smirnov test is 0.200, the Shapiro-Wilk test is 0.786, and the Jarque-Bera test is 0.829. Accordingly, it can be concluded that at the significance level of 0.05, the null hypothesis stating that residuals are normally distributed cannot be rejected.

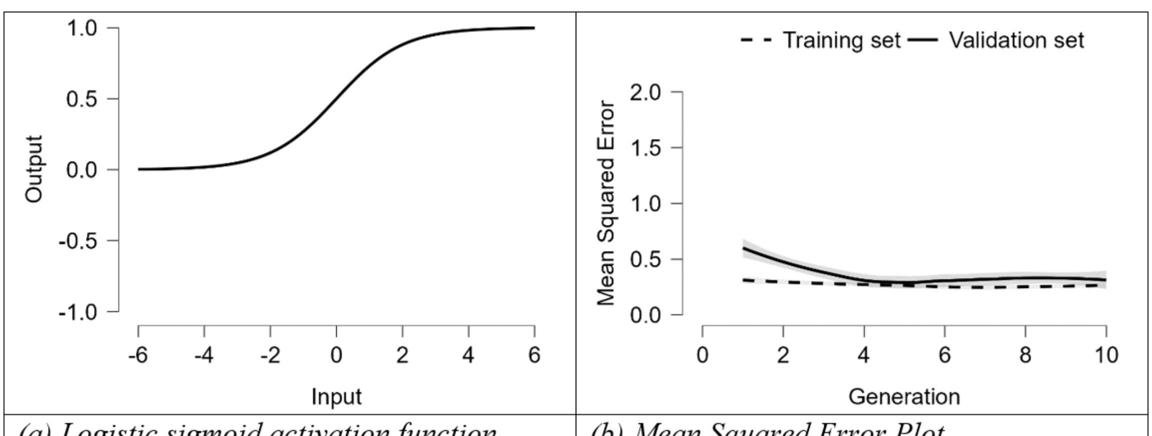
The model diagnostics have shown that each problem's analysis fulfilled the basic model assumptions and proved that the initial assumptions were not undermined.

The model diagnostics have shown that each problem's analysis fulfilled the basic model assumptions and proved that the initial assumptions were not undermined.

5.2 Step 2: Artificial neural network analysis

The ANN was conducted using JASP 0.19. The same variables were used as in the MLA. However, only those variables that were significant in the MLA were used for training in the development of the ANN, indicating that TC was discarded.

In the current study, the logistic sigmoid function aids in activating both output and hidden neurons with algorithm Rprop- (Resilient Propagation), which is a gradient descent-based optimization algorithm primarily used



(a) Logistic sigmoid activation function | (b) Mean Squared Error Plot

Source: Authors' work

Figure 4: Neural network training graphs

for training ANN (Figure 4a). It is a variant of the Rprop algorithm that modifies the weight updates by adapting the step sizes based on the sign of the partial derivatives of the loss function. Unlike traditional gradient descent, Rprop- ignores the magnitude of the gradient, focusing instead on its sign to decide the direction of the update, making it effective for handling vanishing gradients and improving convergence speed in training deep ANN (Igel et al., 2005). In order to reduce overfitting in the ANN, we employed cross-validation techniques with a ratio of 90:10:10 for testing, training, and validating the collected data. The ANN models exhibit relative errors of 0.200 and 0.344 for training data and testing data, respectively (Figure 4b). These results suggest that the optimum ideal number of layers for the models is 4. Based on the minimal rise in relative errors to testing from the training dataset, in conjunction with the use of ANN, it can be inferred that the suggested research models exhibit higher efficiency.

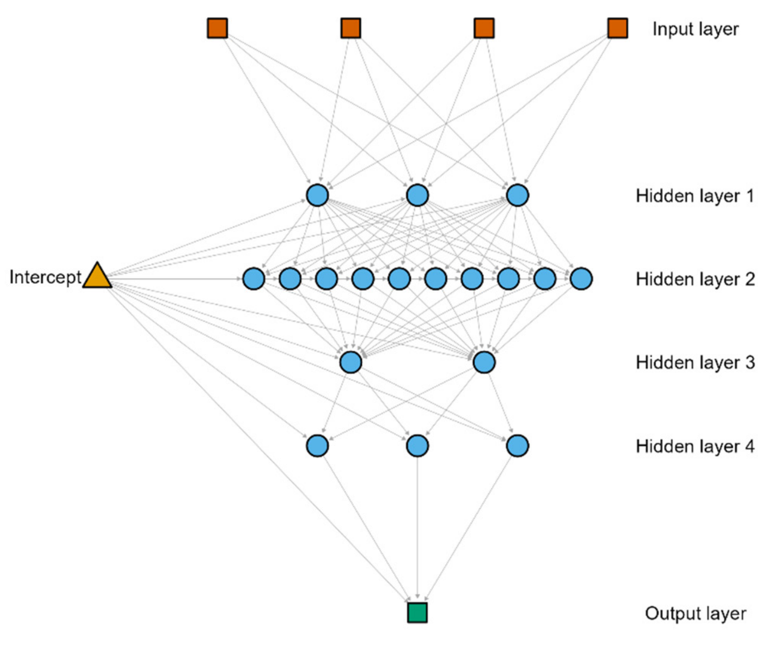
The model summary for the Neural Network Regression in Table 6 provides key metrics for evaluating the model's performance. The network consists of 4 hidden layers with 18 nodes each, and the data is split into training (n=105), validation (n=12), and test (n=13) sets. The model is optimized based on the validation set's mean squared error (MSE), which is 0.200, while the test set MSE is slightly higher at 0.344.

In the present study, the sigmoid function stimulates the activity of both output and hidden layers. The analytical method was employed to determine the optimal number of concealed layers, which was calculated to be 1 (Figure 5). Furthermore, we employed a cross-validation approach to assess and train the collected data to prevent overfitting in the ANN (Ahmed et al., 2021).

Table 6: Model Summary: Neural Network Regression

Hidden Layers	Nodes	n(Train)	n(Validation)	n(Test)	Validation MSE	Test MSE
4	18	105	12	13	0.200	0.344

Note: The model is optimized with respect to the validation set mean squared error.
Source: Authors' work



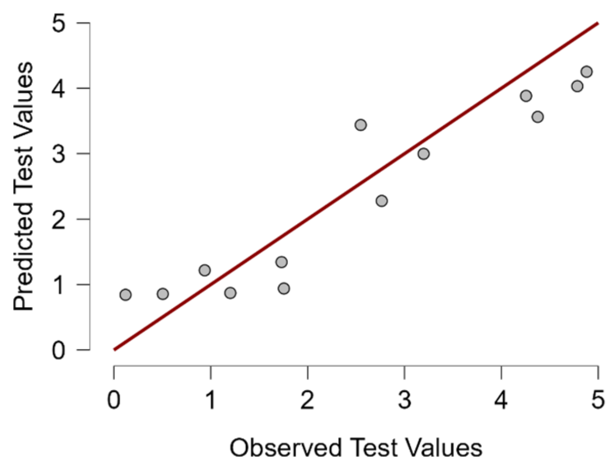
Source: Authors' work

Figure 5: Network Structure Plot

Table 7: Feature importance metrics

Mean dropout loss			
Variable	25 permutations	50 permutations	100 permutations
RQ	1.724	1.735	1.732
PS	0.631	0.635	0.641
EPI	0.609	0.612	0.613
GTA	0.559	0.558	0.555

Source: Authors' work



Source: Authors' work

Figure 6: Predictive Performance Plot

Table 7 presents the feature importance metrics, represented by the mean dropout loss, indicating the relative significance of each variable in the model. A lower mean dropout loss suggests that the variable is more important to the model's predictive capability. In this table, regulatory quality (RQ) is of the highest importance, suggesting it is the most crucial variable. Political Stability (PS) follows while Government Take Attractiveness (GTA) has the lowest importance. Different levels of permutations revealed similar results, indicating the stability of the solution.

In addition, we examined the prediction performance plot to validate the neural network's computational efficiency and precision. The neural network model of the data produced a Root Mean Square value of 0.344 and a coefficient of determination of 0.891. These values outperformed those obtained from MLS, suggesting that ANN has considerable potential for analyzing government effectiveness in the petroleum sector. Figure 6 verifies a well-defined correspondence between the observed and anticipated values of both models.

6 Conclusion

The changing relationships in global petroleum markets during the late 20th century and the increase and fluctuation of petroleum prices in the early 21st century have increased the economic importance of revenue and profit from their production. As a result, the legal relationships in petroleum exploration and production processes and the regulation of these relationships through state interventions have gradually achieved a universal value and become a crucial subject within the competence of legislative and executive government authority.

The objective of the study is to analyze the determinants that impact the effectiveness of government operations in the petroleum sector. The present study utilizes MLA to investigate the possible influence of political stability, regulatory quality, the level of petroleum exploration and production activities, government take, and contract type on government performance in the petroleum sector. Moreover, ANN was investigated to ascertain the importance of independent variables.

The empirical research indicated that political stability influences government effectiveness in the petroleum sector and additionally stressed the importance of political stability in developing the national petroleum industry. Regulatory quality was shown to be another factor influencing government effectiveness in the petroleum sector, thus proving that petroleum legislation is the main factor in regulating the complex relationships between governments and oil companies in petroleum exploration and production activities.

Accordingly, the empirical research showed that the intensity of petroleum exploration and production activities influences government effectiveness in the petroleum sector and thus demonstrated that countries with a higher intensity of petroleum exploration and production activities also have greater government effectiveness in the petroleum sector. The correlation between government take in terms of attractiveness ranking and government effectiveness verified that countries with a more attractive government take and the fiscal regime has better government effectiveness. However, empirical research has shown that the type of contract does not influence government effectiveness in the petroleum sector.

Hypothesis H1-H4 was accepted since the model indicated that government effectiveness is positively influenced by the country's political stability, regulatory quality, intensity of petroleum exploration and production activities, and government take attractiveness. In contrast, hypothesis H5 was rejected due to the lack of a relationship between government effectiveness and type of contract.

One of the most important examinations was the empirical confirmation that the type of contract used when awarding petroleum exploration and production rights to oil companies does not influence government effectiveness. The theory presented suggested that generalizations are often made about the superiority of a concessionary system over a production-sharing system from the oil company's point of view, despite the overwhelming similarities from the economic, accounting, and financial points of view, suggesting that the choice of system may not be such a critical issue. The theory suggested that neither type of contract, concession (royalty and tax based) contract or production sharing contract, is better nor worse, as, from the economic perspective, the same objectives can be achieved. The empirical research demonstrated that the type of contract did not influence government effectiveness in the petroleum sector, thus further supporting the presented theory. This is one of the most important theoretical contributions since the theory to date has speculated based on various observations without quantification through empirical research.

The neural network analysis provided valuable insights into the key determinants of government effectiveness in the petroleum sector. The neural network model, featuring four hidden layers and 18 nodes, demonstrated that regulatory quality and political stability were the most significant variables, with the highest predictive capability. The neural network's performance, as indicated by the validation and test mean squared errors, suggests a robust model that complements the findings of the MLA.

While the analysis provided significant insights, it is important to acknowledge certain limitations. The relatively small sample size may restrict the generalizability of the findings, and the complexity of the neural network model poses a risk of overfitting despite the use of cross-validation techniques. Additionally, the study primarily focused on a specific set of variables, potentially overlooking other factors that might influence government effectiveness in the petroleum sector.

Future research should consider expanding the dataset to include a broader range of countries and varying economic contexts, which could enhance the model's robustness and applicability. Further exploration of alternative machine learning techniques, such as deep learning or ensemble methods, could provide deeper insights and improve predictions' accuracy. Additionally, incorporating external factors, such as global oil market dynamics and technological advancements in petroleum extraction, could offer a more comprehensive understanding of government effectiveness in the petroleum sector.

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