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Understanding Technology Transfer Mechanisms: Assessing Impact of Technology Licensing on Performance of Nigerian Oil and Gas Industry

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Abstract

The study examined the impact of technology transfer via technology licensing on oil and gas sector performance in Nigeria between 1980 and 2021. This investigation was prompted by the concerning performance trends observed within the sector, characterized by declining oil production, divestments by key oil companies, and consequent reductions in government revenues. These challenges have led to increased volatility in foreign exchange earnings, rising job losses, and heightened environmental risks. Despite discussions at various levels aimed at enhancing sectoral performance, significant results have remained elusive, contributing to the enduring hardships experienced by consumers of oil and gas products. The study was analyzed using the Quantile Autoregressive Distributed Lag (QARDL) approach to test for the short and long-run impacts. Findings revealed that technology licensing registered has no significant impact on oil and gas production in Nigeria both in the short and long run. This suggests that there are potential inefficiencies or barriers in the technology transfer process, hindering Nigeria's ability to fully capitalize on available technological advancements to enhance its oil and gas sector output. Hence, there is a need for policymakers and industry stakeholders to critically assess the existing licensing frameworks, identify potential bottlenecks or shortcomings, and implement corrective measures to facilitate more effective technology transfer and adoption. They should prioritize efforts to strengthen the institutional and regulatory environment surrounding technology licensing activities in the Nigerian oil and gas sector.

Keywords

Technology Transfer, Licensing, Performance, Oil and Gas Industry

1. Introduction

The performance outlook of the oil and gas sector in Nigeria has been discouraging as oil production continued to drop and by implication, government revenues dwindled, divestment of some multinational companies, foreign exchange earnings remained unstable, job losses were on the increase, and the environment became more endangered in the last few years than ever before even as the quest to improve the sector's performance had been discussed at different levels with insignificant results, as was evident in the hardship consumers of the products experience in the country. A study by Bingilar and Kpolode (2021), attests that oil production in Nigeria has been declining to levels that have put the country's economy managers in uncomfortable positions. Nigeria has had to cut its oil production benchmark volume used in its annual budgeting estimates twice in 2020. Nigeria cut its production to 1.412 million barrels per day (mb/d), 1.495 mb/d and 1.579 mb/d for the respective periods of May-June 2020, July-December 2020 and January 2021-April 2022 (KPMG, 2022).

The Nigerian refineries have been gloomy as they have failed to close the gap in the supply of refined petroleum products despite their total installed capacity of 486 barrels per day (bpd) with the addition of the 10,000 bpd Niger Delta Petroleum Refinery at Ogbele, Delta State, and the 5000 bpd capacity Waltersmith Petroman Oil Limited, in Imo State in 2020. These indicators show that there is something fundamentally wrong with the sector that we need to determine.

This scenario made technology transfer management imperative as a vital variable of interest in the study. Indeed, other oil-producing nations are not facing the challenge of unimpressive oil and gas industry performance as Nigeria does. Therefore, insensitivity to the management of the industry concerning technology transfer is a major significant challenge. The issues are on technology licensing (Araújo & Teixeira, 2014).

Technology licensing is a common practice in the oil and gas industry. It involves the acquisition and use of process technologies that have been invented by firms other than the users. These licenses are typically obtained for life and may require technical support from the licensors. In heavy industries like refineries, there are licensors, process owners, and procurement contractors who license benefiting organizations. This process aligns with the definition given by Lavoie and Daim (2019), which describes a specific interaction between two or more entities during which technology is transferred.

Technology licensing is a strategy adopted by firms to benefit from innovation but little research has been done to establish its linkage to firm performance (Tsai & Wang, 2007). It deals with how the right to use the technology owner's process designs, know-how, trademarks, intellectual property, trade secrets etc. without the technology owner relinquishing its ownership rights. It may also include the right to modify the process to suit the users' objectives. This approach of business ensures the best optimal utilization of resources and saves time. However, recent trends suggest exploitation and compromise of owners (Galli & Botta, 2023) if due diligence in the agreement is not ensured (Mooi & Wuyts, 2021). In Nigeria, one begins to imagine the level of transparency involved in managing technology licensing in her oil and gas industry. Technology licensing management entails understanding the basic features of technology licensing planning, controlling, agreement drafting, execution, review, sustenance, termination and post-termination if needed.

This article focuses on one aspect that is critical to the success of the industry which is technology licensing. This is apparent as process technologies and equipment used for production continue to evolve, companies soon realize that to catch up with the competition, there is a need to up their games in research and development, or they have to acquire relevant new technologies by obtaining licenses from other companies or they will fall behind their competitors. If falling behind the competition is not an option, or there is the desire to improve on their processes through building new plants, an easy and readily available option open to them to catch up with the competition and reverse their fortunes is technology licensing, this happens often in the oil and gas industry especially when new projects are undertaken.

One question is pertinent: Did technology licensing as a channel of technology transfer (Gaitan, 2021; Canavire-Bacarreza & Castro, 2021; Martinez & Zuniga, 2017) impact the performance of Nigeria's oil and gas industry over forty-two years from 1980 to 2021 covered in this study? It is pertinent that other countries at the same level of development as Nigeria that are in the oil and gas business and are exposed to the same technological environments do not experience the kind of downturn in their oil production as Nigeria (Iheukwumere et al., 2020; OPEC ASB, 2020) in the past few years. The downturn has, for years, affected the incomes of the government and oil companies in the country and suggests the need to question whether technologies employed in the sector have been of help to the industry and whether the licenses obtained over the years have helped management in addressing this issue of low productivity in the industry.

Finally, the setback in the activities of the Nigeria oil and gas sector which are now import-driven because of the collapse of the refineries has resulted in the exportation of crude oil and the importation of refined products and created a balance of trade problems in addition to weakening the country's currency. For investors, this is discouraging as their investments continue to decline in monetary worth. This can be addressed with the right management to attract the huge investments the sector requires. If this is not done, otherwise, the challenges of the oil and gas sector will remain. The study will also investigate how trade volume mediates the relationship between technology licensing and oil and gas production.

This study explores the intricate dynamics of technology transfer management, specifically focusing on the licensing aspect and its implications for oil production within the Nigerian oil and gas sector between 1980 and 2021. Thus, we investigate how technology transfer management via licensing affects oil production in the Nigerian oil and gas sector using the quartile autoregressive distributed lag estimator. By analyzing the mechanisms and outcomes of technology licensing practices, the study aims to uncover the extent to which such activities contribute to or hinder the overall performance and growth of the oil industry in Nigeria. Through empirical investigation and analysis, the study seeks to provide valuable insights into the role of technology transfer in shaping the trajectory of oil production in the Nigerian context.

Beyond the introduction, the "Literature Review" section provides a concise overview of existing research, while the "Data and Methodology" section outlines the data collection process and the chosen methodological approach. Subsequently, the "Results and Discussion" section analyzes the empirical findings, and the "Conclusions" section concludes, emphasizing policy implications.

2. Literature Review

2.1. Technology

Technology and technology transfer have become increasingly important in this era therefore, understanding the concepts and how the different components interact is of utmost importance to managers, entrepreneurs, researchers, and those aspiring to innovate and gain usable knowledge (Bozeman, Rimes, & Youtie, 2014). The concept of "technology" is associated with tools and equipment that are becoming more advanced. Historically, it was in 1829 that the first writing on technology called "Bigelow's Elements of Technology" was unveiled.

The concept was perceived to be from the root words "techne" and "logo" (Carrol, 2017). Techne is a Greek word meaning "craft" or "technique" while logo means "study". Therefore, technology is creating a tool or technique to provide some benefits. There have been also remarks that it is a mechanism to produce other things. With this description, technology is know-how (Agar, 2020) which can be acquired or learned. One of the discussions around this is that it can be transferred. Technology transfer was first reported in 1957, as cited by Wahab, Rose, and Osman (2012). In precise terms, it is described as the flow of technology from the source to the benefiting side, whether a firm or society (Araújo & Teixeira, 2014).

According to Stasiak-Betlejewska (2021), such technology transfer entails conceiving and implementing a unique application of existing technology. Similarly, Prokhorova et al. (2019) considered technology transfer as a prerequisite for enterprises' innovative development. Such transfer occurs through sharing skills, knowledge, technologies, and manufacturing techniques with a wide range of users who can further develop and exploit the technology to create new products, processes, applications, materials, or services. By this, it is an integrated process where known technologies are applied to new environments, individuals, and applications. However, the unequal availability of resources across the world made technology transfer imperative.

2.2. Technology Licensing

Having conceptualized technology, describing what technology licensing will not be straightforward unless we proceed to also conceptualize "licensing". According to the WIPO (2015), it is an agreement between the Licensor and the Licensee where the Licensor willingly transfers the right to use the subject technology to the licensee without actually losing its ownership rights. Technology transfer occurs through licensing agreements in contracts like joint ventures and franchising agreements (Gaitan, 2021; Canavire-Bacarreza & Castro, 2021). In context, an agreement between the owner of the technology (Licensor) and the receiver (Licensee), which gives the right to use the technology developed or owned by the transferring individual or company for a specified time, is known as licensing.

It thus becomes a contractual agreement between the parties that are involved that in this regard defines the terms the parties relate to and the scope, such as period, geographical locations of usage, payment mode, royalties, or licensing fees. From growing a new business to exploring new markets, companies license products for several reasons. Licensing has been identified as a means of transferring technology (Martinez & Zuniga, 2017). It is important to note that while the licensing agreement is in force, the licensor constantly monitors and collects data on usage, performance, and other parameters to help it improve its functionality and maintain and exercise control over the use of its inventions.

Licensing deals grant the intellectual property owner more control over the use of their designs and discoveries. These business arrangements are meant to protect brands and allow product creators and designers to profit from their licensed products without worrying about unauthorized use. Licensing also provides support to intellectual property owners. A licensing agreement supports established brands by opening new revenue and promotional streams. For example, sports teams that license their logos for clothing, collectable items, or other retail goods generate licensing fees for the team and promote their brand whenever a consumer uses or wears that item. There are several different types of product licensing which include Brand licensing; Copyright licensing; International licensing; and Patent licensing.

Technology licensing is prevalent in the oil and gas industry as it is the basis on which certain process technologies invented by firms other than the users are acquired and used. Such licenses are obtained for life most times requiring support in terms of technical backup from the licensors. Heavy industries like refineries have licensors, process owners, and procurement contractors who license benefiting organizations. This aligns with what Autio and Laamanen (1995) define as a specific interaction between two or more entities during which technology is transferred.

Gaitan (2021) examined trade agreements and international technology transfer to determine the impact of trade agreements containing technology-related provisions on the export of goods, specifically for technology-intensive goods. The study uses a structural gravity model to analyze a panel of 176 countries from 1995 to 2015. The results indicate that regional trade agreements (RTAs) that include technology provisions lead to a significant increase in trade volume compared to RTAs that do not have such provisions. The increase in exports is most evident for countries that ratify RTAs containing technology provisions, particularly in the case of technology-intensive goods. His research focused majorly on how the agreements impact the trading of goods rather than on how licensing impacts the productivity of the companies involved which this study focuses on.

Lavoie and Daim (2019) in their book "Licensing as a Central Structure of Technology Transfer Agreements" affirmed that technology transfer occurs through licensing agreements in other complex contracts like joint ventures and franchising agreements. They made use of the statutes and case law of the European Union, the United States, and the Andean Community to illustrate this transfer of technology. Canavire-Bacarreza and Castro (2021) also confirmed in their research that licensing leads to productivity improvements and is a means of technology transfer. However, a study on manufacturing firms in developing economies found that the adoption of foreign technology through licensing can have a short-term disruptive effect on firm operations, with productivity growth declining by 4.5 percentage points.

2.3. Performance of the Oil and Gas Industry

There are metrics for measuring performance such as productivity, profit efficiency (Arbelo et al., 2021), production of intended outputs (Ang & Dakpo, 2021), profitability, turnover etc. Performance as a concept requires description within context. It is in practice, the industry's capacity to deliver basic goods and services expected of the industry. From a comprehensive perspective, performance refers to an industry's actual output or results as measured against its intended outputs (or goals and objectives). Specialists in strategic management, operations, finance, and organizational development, among others, are concerned with improving performance.

Over the years, studies like Bingilar and Kpolode (2021) found that oil production in Nigeria has been declined to levels that have put the country's economy managers in uncomfortable positions. Nigeria has had to cut its oil production benchmark volume used in its annual budgeting estimates twice in 2020. Nigeria cut its production to 1.412 million barrels per day (mb/d), 1.495 mb/d and 1.579 mb/d for the respective periods of May-June 2020, July-December

2020, and January 2021-April 2022 (KPMG, 2022). In this study, oil and gas production represents the measure of performance. The reason for this is that the production of oil and gas is unified across all the actors in the industry where the data from the industry's production between 1985-2021 are provided from the NNPC and the Central Bank of Nigeria. This makes the authenticity of data to be validated and trusted.

3. Methodology

3.1. Data Description, Analytical Framework and Model Specification

Considering the research philosophy, this study settles for the positivist paradigm as we focused on identifying explanatory associations or causal relationships through a quantitative approach and generating empirically based findings from the analyzed data to make inferences (Park, Konge, & Artino, 2019), and it also provides good grounds for the use of secondary data in the study as enunciated by Kenaphoom (2021). Also, the ex-post facto design was employed as the study was designed to determine the impact of the independent variable on the dependent variable including their proxies to analyze correlations and cause-effect relationships (Sharma, 2019). This study is limited to ascertaining how technology licensing as a proxy of technology transfer (Gaitan, 2021; Lavoie & Daim, 2019) impacts the performance of the Nigerian oil and gas sector in the period 1980 to 2021. The research covered only the upstream sector of the Nigerian oil and gas industry where crude oil and natural gas are the primary products.

In a functional form, the impact of technology licensing on the performance of the oil and gas sector is expressed as:

$$pog = f(tl) \tag{1}$$

Mathematically, it is stated as:

$$pog = \varphi_0 + \varphi_1 tl \tag{2}$$

where: *pog* represents the performance of the oil and gas sector; *tl* denotes the vector of technology transfer management variable as technology licensing (*tl*); and φ_0, φ_1 are parameters.

Equation (2) stands as the theoretical model of this study, and it proposes a direct link between technology transfer management and oil and gas sector performance. It means that the oil and gas sector tends to gain from the high inflow of adequate technology licensing.

Following the theoretical framework of the contingent effectiveness model of technology transfer developed in the previous sub-section and the models of previous studies like Menhat and Yusuf (2018), the adapted model relating to the links between technology licensing and oil and gas production is stated in a functional form as:

$$pog_t = f(tl_t) \tag{3}$$

In mathematical form, it becomes:

$$pog_t = \phi_0 + \phi_1 tl_t + e_t \quad (4)$$

where: *pog* denotes the performance of the oil and gas sector measured by oil and gas production; *tl* represents technology licensing; $\phi_0, \phi_{1\text{-}2}$ are parameters; *t* denotes time; and *e* is the error term.

This study used the unit root test to test for the stationarity of the time series data acquired for the research. Since most time series variables in the literature are non-stationary, incorporating non-stationary variables in the model runs the risk of producing an erroneous regression.

3.2. Quantile Autoregressive Distributed Lag (QARDL) Approach

With the aid of the cutting-edge QARDL procedure that Cho et al. (2015) introduced, this study examines the impact of technology licensing as a proxy of technological transfer on oil and gas performance while noting the contingent effectiveness model of technology transfer theory. The QARDL framework makes it possible to quickly evaluate the short and long-run quantile impact of technology transfer (which in this case is technology licensing registered in a vector form) on Nigeria's oil and gas performance.

When the variables are stationary at I(0) or integrated of order 1 (I(1), the QARDL model is thought to be the optimum estimation strategy. It is a better model than others to capture the short- and long-term effects of explanatory variables on the performance of the oil and gas industry. The consistency of integrating coefficients across the quantiles will be examined using the Wald test. The foundational ARDL method, which uses the ordinary least square (OLS) method to cointegrate variables, is also suitable for simultaneously calculating short-run and long-run elasticities for a small sample size (Duasa, 2007). The order of the variables' integration can be changed with QARDL. The model's explanatory variables, at I(0) and I(1), which are mutually cointegrated, are suitable for QARDL (Frimpong & Oteng-Abayie, 2006). But if any of the variables include I(2), it fails. The traditional linear ARDL framework was primarily explained as follows:

$$Y_t = \alpha + \sum_i^p \theta' Y_{t-1} + \sum_i^q \beta' X_{t-1} + \sum_i^q \phi' Z_{t-1} + \varepsilon_t \quad (5)$$

where: *Y* indicates the natural log of the dependent variable; *X* denotes the vector of the independent variables; *Z* is the vector of control variables; ε denotes the white noise residual explained via the bottom ground by (Y_t, X_t, Z_t, Y_{t-1}, X_{t-1}, Z_{t-1}, …); *p* and *q* are lag orders selected by the Schwarz Info Criterion (SIC); and *t* is periods.

The context of the quantile ARDL model is then recommended by adjusting Equation (5) to a framework of quantile, which is stated as:

$$Q_{Y_t} = \alpha(\tau) + \sum_i^p \theta'(\tau) Y_{t-1} + \sum_i^q \beta'(\tau) X_{t-1} + \sum_i^q \phi'(\tau) Z_{t-1} + \varepsilon_t \quad (6)$$

Thus,

$$\varepsilon_t(\tau) = Y_t - Q_{Y_t}(\tau/\varepsilon_{t-1}) \quad (7)$$

according to Kim and White (2003) $0 < \tau < 1$ is the quantile. This study uses the consecutive couple of quantiles t related to 0.05, 0.25, 0.50, 0.75, and 0.95 to achieve data estimations. In addition, the quantile ARDL model in Equation (6) is complete as follows regarding the probability of a serial correlation in the residual:

$$Q_{Y_t} = \alpha(\tau) + Y_{t-1} + \pi' X_{t-1} + \lambda' Z_{t-1} + \sum_i^p \theta'(\tau) Y_{t-1} + \sum_i^q \beta'(\tau) X_{t-1} + \sum_i^q \phi'(\tau) Z_{t-1} + \varepsilon_t \quad (8)$$

Additionally, a study of Equation (8) could provide the following error correction model for the quantile ARDL context (Cho, Kim, & Shin, 2015):

$$Q_{Y_t} = \alpha(\tau) + \rho(\tau)\left(Y_{t-i} - \pi'(\tau) X_{t-i} - \lambda'(\tau) Z_{t-i}\right) + \sum_{i=1}^{p-1} \theta'(\tau) Y_{t-1} + \sum_{i=0}^{q-1} \beta'(\tau) X_{t-1} + \sum_{i=0}^{q-1} \phi'(\tau) Z_{t-1} + \varepsilon_t \quad (9)$$

The cumulative short-run influence of earlier oil and gas performance on more recent oil and gas performance is calculated by $\theta'_* = \sum_{i=1}^{p-1} \theta'$. However, the combined short-term influence of the management of technological transfer in the present and in the past on the current stage of oil and gas performance is calculated as $\pi'_* = \sum_{i=1}^{p-1} \pi'$. The same method is used to evaluate the residual aggregate short-run impact of historical and current controlling variables (such as income, trade, interest rate, and inflation) on the current level of oil and gas performance. In Equation (9), the speed of adjustment parameter r must be significant and negative (Cho et al., 2015; Shahbaz et al., 2018). As a final point, this study used the Wald test to determine the hypotheses (null and alternate) for the long- and short-run coefficient to examine the long- and short-term asymmetric influence of technology transfer management and other control variables.

Following the earlier estimates, some encouraging data appears in Cho et al. (2015). The QARDL process parameter may differ in each quantile, showing that these parameters may have an impact at different eras, according to the first principle of long-short run parameters, which should be based on quantile. The Wald test can also be used to assess the restrictions on the long-short run coefficients between and using the quantiles (Cho et al., 2015; Zhu et al., 2016).

3.3. A'priori Expectations

Our a'priori expectation in the model specified above is that the independent variable as represented by its proxy which in this case is licensing shall be positively related to the performance of the oil and gas industry (the dependent variable which in our case is oil and gas production). We expect that an increase in technology licensing (independent variable) should lead to an increase in the proxies of the dependent variables.

4. Results and Discussion

4.1. Descriptive Statistics

The summary statistic of the variables presented in **Table 1** indicated that the

Table 1. Descriptive statistics.

Signs	Variables Measurement	Mean	Std. Dev.	Max.	Min.	Kurtosis	Skewness	Obs.
Outcome variables								
pob1	Oil production (million barrels)	712.43	131.29	918.66	450.97	−0.762	−0.419	42
pob2	Gas Production (BSCF)	1722.03	842.61	2991.44	536.51	−1.469	0.090	42
Main explanatory variables								
tl	Technology licenses registered	128.67	48.694	261	52	0.067	0.685	39
Other controlling variables								
trd	Trade volume-imports ($'billion)	27.877	26.797	89.778	2.130	−0.554	0.866	42
inc	Income (constant 2015 $'billion)	266.40	144.04	518.48	114.54	−1.240	0.643	42
int	Interest rate (%)	13	3.959	26	6	1.911	0.762	41
inf	Inflation rate (%)	18.735	16.513	72.836	5.388	2.938	1.963	42

Source: Author's computation (2023).

mean value of oil and gas performance measured by oil production and gas production stood at 712.43 and 1722.03, while their highest and (lowest) values are (918.66 and 2991.44) and (450.97 and 536.51) respectively. It indicates that the Nigerian oil sector accounts for an average of 712.43 million barrels and 1722.03 BSCF in the Nigerian economy. The mean values of technology transfer management variables measured by technology licenses registered (tl) were 128.67, while its maximum and minimum values stood at 261 and 52 respectively. The average trade volume is 27.877, while its maximum and minimum values are 89.778 and 2.13 respectively.

The average values of other controlling factors determining oil and gas performance stood at $266.4 billion, 13%, and 18.74% for income (inc), interest rate (int) and inflation rate (inf) respectively under the reviewed periods. Their maximum values stood at $518.48 billion, 26%, and 72.84% while the minimum values were $114.54, 6% and 5.39% respectively. Additionally, the standard deviation reports the rate at which these variables deviate from their mean values. All our variables have low deviation rates in varying magnitude from their mean values, as their standard deviation values are lower than average values. Moreover, oil production skewed negatively with a value of −0.419, while other indicators skewed rightward. As well, the Kurtosis identified 3.0 suggesting the normal distribution. From Table 1, none of the variables exhibits normal distribution. All are platykurtic in distribution that is, they are not normally distributed.

4.2. Correlation Analysis and Scatter Plots

Table 2 presents the partial correlation of the variables understudied such as oil production, gas production, technology licenses registered, income, interest rate, and inflation rate in Nigeria using an annual dataset between 1980 and 2021. The result of the correlation coefficients shows that oil production has a strong positive correlation with gas production (0.763), indicating a significant positive

Table 2. Correlation matrix.

	pob2	fdi	tl	trd	inc	int	inf
pob1	0.763	0.628	0.045	0.586	0.519	0.218	−0.226
pob2	1	0.612	0.459	0.665	0.708	0.033	−0.269
fdi		1	0.436	0.681	0.685	−0.112	−0.214
tl			1	0.533	0.579	−0.252	−0.185
trd				1	0.931	−0.261	−0.430
inc					1	−0.156	−0.336
int						1	0.361

Note: pob1—Oil production (million barrels); pob2—Gas Production (BSCF); tl—Technology licenses registered; trd—Trade volume—imports ($'billion); inc—Income (constant 2015 $'billion); int—Interest rate (%); and inf—Inflation rate (%). Source: Author's computation (2023).

relationship between the two. Technology licensing positively correlates with oil and gas production. A pictorial view of the relationship between technology licensing and oil and gas production is presented in scattered forms in Figure 1 and Figure 2 respectively. As to the controlling variables, the table revealed that oil and gas production had a direct level of association with trade volumes, income, and interest rates, but they indirectly correlated with the inflation rate.

Concerning other controlling factors of oil and gas production variables, technology licenses registered has a positive correlation with trade volume and income, but they in-directly correlate with interest and inflation rates. As to cross-border personnel movement, it is positively associated with trade volume, income, interest rate and inflation rate. Meanwhile, the result showed that joint venture arrangements negatively correlate with trade volumes and income but positively relate with interest and inflation rates.

The correlation relationship among the controlling variables is presented in Table 2 which shows different magnitudes and degrees. The values of the correlation coefficients revealed the absence of a multicollinearity problem. Thus, the problem of multicollinearity is avoided in the empirical analysis. Nonetheless, the results of the correlation coefficients are just preliminary analyses that are being put through confirmation in the next sub-section after considering other determinants of oil and gas production.

4.3. Pre-Estimation Tests (Unit Root)

Estimating the stationary level of the variables was accomplished with the Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) unit root estimation methods in this subsection. These estimators are utilized to uncover the stationary level of technology transfer management indicators as well as oil and gas production to provide the appropriate way by which to evaluate the parameters. Table 3 displays the findings of the unit root calculation applied to each of the indicators. The findings of the tau-statistics were employed in intercept and

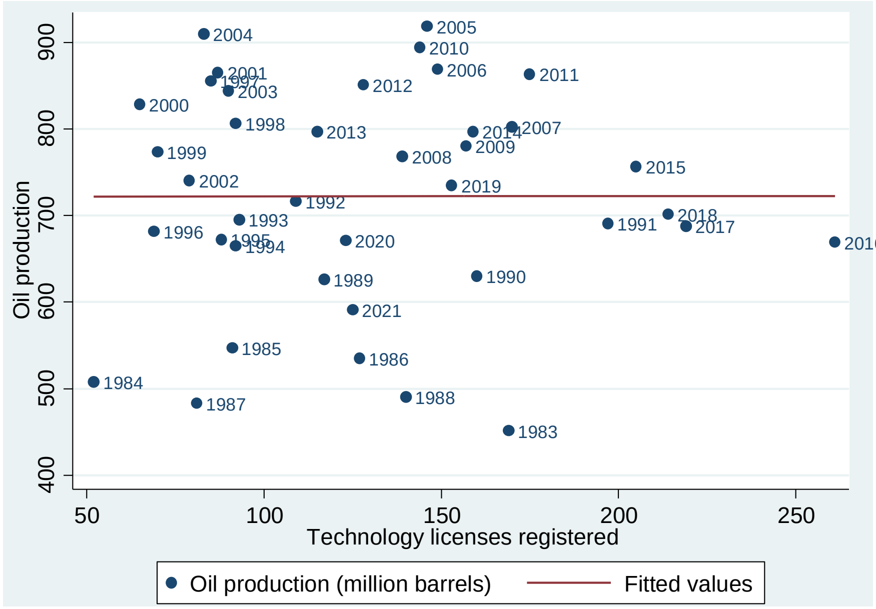

Figure 1. Scattered plots of technology licensing and oil & gas production.

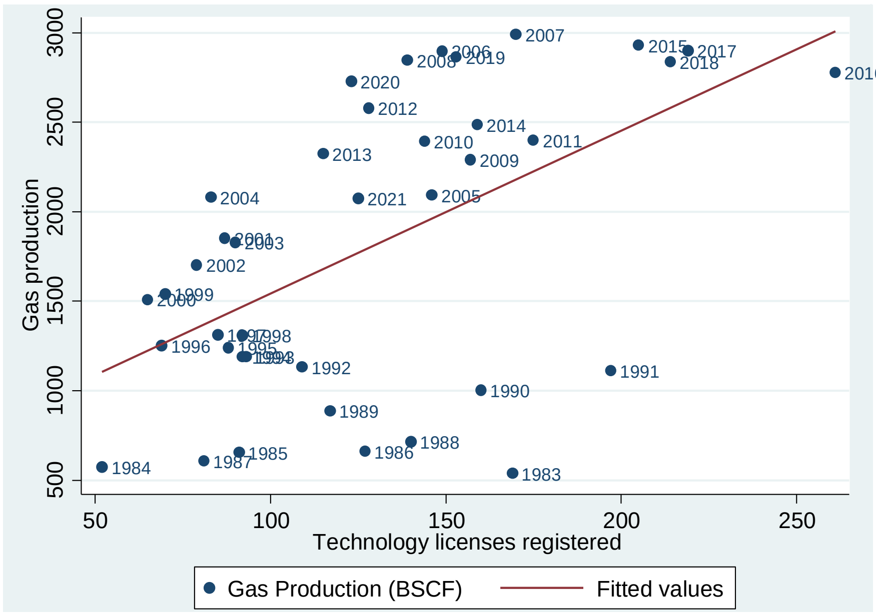

Figure 2. Scattered plots of technology licensing and oil & gas production.

trend form to determine which variables were statistically significant at 1%, 5%, and 10% critical points at levels and first difference. In addition, the lag time for determining whether the variables are stationary is chosen automatically and ideally by the Schwarz-Bayesian Information Criterion (SIC), whilst only a handful of the parameters were held constant.

Both unit root tests that are part of the conventional technique come to roughly the same conclusion about whether the estimated variables are at a stationary level. This happens regardless of the significance levels. It was discovered that the levels of technology licenses registered was stationary at levels at the 5%

level. Concerning the remaining variables, the findings of the unit root test at the 5% McKinnon significance level indicated that the null hypotheses "not stationary at level" was not rejected. After subjecting the variables that are not stationary at levels to further testing, the variables were found stationary at first differences which were found significant 5% level. The variables are oil output, gas production, trade volumes, income, and interest rates. According to the findings, the time series of the variables were stable and integrated at the first order. This indicates that, after being differentiated at one, the series converge to their long-run equilibrium, also known as their true mean.

Table 3 further displays the findings of Zivot and Andrews' unit root test estimators. These findings can be found in the table. The utilization of the ZA test allows for the structural breakdowns to be taken into consideration as well. As can be seen in Table 3, the variables exhibited discernible movement both at the levels and the first difference, which are like the results of ADF and PP. According to the findings of the study, one can consequently conclude that none of the variables were steady at the second difference. In the empirical study, the dependent variables, which are oil and gas output, were integrated at order 1, which satisfies the requirements for applying the quantile ARDL estimation technique. In addition, the integration order of the variables varies between 0 and 1, which creates a mixed order.

4.4. Empirical Results

This section addresses our question of whether technology licensing has a significant impact on the performance of the Nigerian oil and gas sector which was formulated in line with the empirical models. The evidence that there exists non-normality among the variables prompts the estimation of quantile ARDL for all the models. The distributional short-run and long-run estimates are

Table 3. Unit root test (ADF, PP and Zivot-Andrews).

Variables	ADF Test		PP Test		Remark	Zivot-Andrew Test		
	Levels	1st Diff.	Levels	1st Diff.		Break	t-statistics	Remark
lnpob1	−0.3698	−4.7006***	−1.8738	−11.845***	I(1)	1990	−6.6202***	I(1)
lnpob2	−1.5462	−5.8752***	−2.0031	−6.3750***	I(1)	2007	−6.3756***	I(1)
lntl	−3.8359**	-	−4.0389**	-	I(0)	2005	−3.6873***	I(0)
lntrd	−2.9837	−5.6873***	−2.9264	−5.6577***	I(1)	1989	−6.8571***	I(1)
inc	−2.2322	−4.1618**	−3.8041**	−4.1618***	I(1)	2002	−4.7068***	I(1)
int	−3.3383	−8.7476***	−3.2569*	−8.8767***	I(1)	1994	−9.6249***	I(1)
inf	−3.8107**	-	−3.5704**	-	I(0)	1996	−7.3048***	I(0)

Note: pob1—Oil production (million barrels); pob2—Gas Production (BSCF); fdi—Foreign direct investment ($'billion); tl—Technology licenses registered; tp—Technology patents granted; cbm—Cross-border personnel movement (net migration); jva—Joint venture arrangements (mbbls); trd—Trade volume—imports ($'billion); inc—Income (constant 2015 $'billion); int—Interest rate (%); and inf—Inflation rate (%). Source: Author's computation (2023).

shown below for the hypothesis.

The discussion in here answers the null hypothesis that the technology licensing registered has no significant impact on oil and gas production in Nigeria. It examines both the short-run and long-run relationship estimates of technology licensing registered and oil and gas production in Nigeria using the quantile ARDL (QARDL) approach. The estimated QARDL model is a composite of short-run and long-run estimates of the interrelationship among considered series in this study. The clear evidence of our empirical estimates from technology licensing and controlling variables (income, trade openness, interest rate, inflation rate) on oil and gas production are presented in **Table 4** and **Table 5**. The lag length on all variables as the model was set at one to ensure a sufficient degree of freedom based on the automatic selection of the Schwarz Information Criterion (SIC).

The short-run estimation results show the error correction term (ECT) which measures the speed or degree of adjustment. It is the rate of adjustment at which the dependent variable changes due to changes in the independent variables. The short-run analysis shows the dynamic pattern in the model and ensures that the dynamics of the model have not been constrained by inappropriate lag length specification. The coefficient of the ECT is found to be negative and statistically significant at the conventional level for all quantiles. The distributional short and long-run effects of technology licensing on oil production are presented in **Table 4**, while the distributional short and long run impacts of technology licensing on gas production are provided in **Table 5**.

As regards the long-run estimates reported in **Table 4**, the coefficients for technology licensing at all quantiles (−0.200 to 0.800) are negative. However, none of the coefficients are statistically significant at the 5% level (p-value > 0.05). It suggests that technology licensing does not have a significant impact on oil production across the quantiles considered in the long run. Meanwhile, the coefficients for income at all quantiles are positive, indicating a positive relationship between income and oil production. However, none of the coefficients are statistically significant at the 5% level (p-value > 0.05). This suggests that income does not have a statistically significant impact on oil production across the quantiles.

Also, the coefficients for trade volume are positive at all quantiles, indicating a positive relationship between trade volume and oil production. At the 0.650 and 0.800 quantiles, the coefficients are statistically significant at the 5% level (p-value < 0.05). This suggests that trade volume has a statistically significant and positive impact on oil production at the higher quantiles (0.650 and 0.800). The coefficients for the inflation rate at all quantiles are positive but very small. None of the coefficients are statistically significant at the 5% level (p-value > 0.05). This implies that the inflation rate does not have a significant impact on oil production across the quantiles. The distributional effects of these variables in the long run are presented in **Table 4**.

Table 4. Quantile ARDL estimates of technology licenses and oil production.

Variables	Quantile	Coefficient	Std. Error	t-Statistic	Prob.
Short-run Estimates					
D (Oil Production (−1))	0.200	−0.293224	0.336634	−0.871046	0.3904
	0.350	−0.111583	0.318742	−0.350073	0.7287
	0.500	0.258496	0.230793	1.120031	0.2713
	0.650	0.308220	0.226848	1.358710	0.1840
	0.800	0.284641	0.188310	1.511556	0.1408
D (Technology licensing)	0.200	0.109341	0.131419	0.832001	0.4118
	0.350	0.046960	0.111096	0.422695	0.6754
	0.500	0.018542	0.071256	0.260219	0.7964
	0.650	0.010170	0.063960	0.158999	0.8747
	0.800	−0.048410	0.053084	−0.911950	0.3688
D (Income (−1))	0.200	0.077745	0.718326	0.108231	0.9145
	0.350	0.366501	0.736303	0.497758	0.6222
	0.500	0.191699	0.527796	0.363206	0.7189
	0.650	0.669839	0.531342	1.260655	0.2168
	0.800	1.028075	0.411943	2.495673	0.0181
D (Trade volume)	0.200	−0.027540	0.089467	−0.307829	0.7603
	0.350	0.047370	0.103840	0.456182	0.6514
	0.500	0.106691	0.098580	1.082282	0.2875
	0.650	−0.007293	0.106384	−0.068551	0.9458
	0.800	0.036955	0.090643	0.407698	0.6863
D (Inflation rate)	0.200	−0.001443	0.002366	−0.609847	0.5464
	0.350	−0.000695	0.002250	−0.308730	0.7596
	0.500	0.000752	0.001409	0.533592	0.5974
	0.650	0.000456	0.001427	0.319717	0.7513
	0.800	0.000786	0.001039	0.756584	0.4550
ECT (−1)	0.200	−0.011822	0.224453	−0.052672	0.9583
	0.350	−0.130412	0.219921	−0.592997	0.5575
	0.500	−0.372088	0.167484	−2.221631	0.0337
	0.650	−0.367227	0.164042	−2.238619	0.0325
	0.800	−0.380398	0.125102	−3.040709	0.0048
Long-run Estimates					
Technology licensing	0.200	−0.143234	0.285463	−0.501758	0.6191
	0.350	−0.134880	0.218050	−0.618572	0.5403
	0.500	−0.069897	0.188178	−0.371439	0.7126
	0.650	−0.083941	0.169697	−0.494652	0.6240

Continued

	0.800	−0.201020	0.136039	−1.477663	0.1487
Income	0.200	0.221768	0.559268	0.396533	0.6942
	0.350	0.250573	0.418975	0.598062	0.5538
	0.500	0.413198	0.361273	1.143725	0.2607
	0.650	0.302328	0.337683	0.895303	0.3769
	0.800	0.328366	0.284468	1.154318	0.2564
Trade volume	0.200	0.394431	0.243752	1.618167	0.1149
	0.350	0.310091	0.163542	1.896096	0.0665
	0.500	0.277049	0.144462	1.917801	0.0636
	0.650	0.324169	0.141698	2.287750	0.0285
	0.800	0.295452	0.144827	2.040027	0.0492
Inflation rate	0.200	0.006181	0.004097	1.508436	0.1407
	0.350	0.001887	0.002715	0.694884	0.4918
	0.500	0.002218	0.002732	0.811925	0.4225
	0.650	0.001266	0.002576	0.491506	0.6262
	0.800	0.001318	0.003022	0.436286	0.6654
Constant	0.200	5.441186	2.596915	2.095250	0.0437
	0.350	5.700470	1.382571	4.123093	0.0002
	0.500	4.661040	1.189739	3.917701	0.0004
	0.650	5.261978	1.096269	4.799897	0.0000
	0.800	5.861913	1.043331	5.618459	0.0000

Source: Author's computation (2023).

The distributional short and long-run effects of technology licensing on gas production is presented in **Table 5**. As for the short-run estimates, the coefficients for technology licensing at all quantiles are negative. However, none of the coefficients are statistically significant at the 5% level (p-value > 0.05). This suggests that technology licensing does not have a significant impact on gas production across the quantiles. The coefficients for income at all quantiles are positive, indicating a positive relationship between lagged income and gas production but not significant statistically. This suggests that lagged income does not have a statistically significant impact on gas production across the quantiles.

The coefficients for trade volume are positive at all quantiles, indicating a positive relationship between trade volume and gas production. At the 0.500, 0.650, and 0.800 quantiles, the coefficients are statistically significant at the 5% level (p-value < 0.05). This suggests that trade volume has a statistically significant and positive impact on gas production at the higher quantiles (0.500, 0.650, and 0.800). The coefficients for the inflation rate at all quantiles are very small and close to zero. None of the coefficients are statistically significant at the 5% level

Table 5. Quantile ARDL estimates of technology licenses and gas production.

Variables	Quantile	Coefficient	Std. Error	t-Statistic	Prob.
Short-run Estimates					
D (Gas Production (−1))	0.200	0.011403	0.237668	0.047977	0.9620
	0.350	0.079209	0.250591	0.316091	0.7541
	0.500	0.281715	0.262482	1.073275	0.2914
	0.650	0.294742	0.270292	1.090459	0.2839
	0.800	0.338474	0.276658	1.223438	0.2304
D (Technology licensing)	0.200	0.005511	0.071963	0.076576	0.9395
	0.350	−0.033105	0.072716	−0.455263	0.6521
	0.500	−0.099484	0.053479	−1.860250	0.0724
	0.650	−0.108094	0.049899	−2.166250	0.0381
	0.800	−0.132489	0.046332	−2.859572	0.0075
D (Income (−1))	0.200	0.010908	0.710860	0.015345	0.9879
	0.350	0.295193	0.731698	0.403436	0.6894
	0.500	0.818181	0.461613	1.772441	0.0861
	0.650	0.970379	0.452375	2.145078	0.0399
	0.800	0.885129	0.391108	2.263133	0.0308
D (Trade volume)	0.200	0.086449	0.075075	1.151505	0.2583
	0.350	0.100375	0.084613	1.186282	0.2445
	0.500	0.149661	0.066093	2.264406	0.0307
	0.650	0.161375	0.060661	2.660254	0.0123
	0.800	0.136748	0.050564	2.704445	0.0110
D (Inflation rate)	0.200	−0.000290	0.001477	−0.196558	0.8455
	0.350	−1.95E−05	0.001361	−0.014331	0.9887
	0.500	−2.68E−05	0.001058	−0.025299	0.9800
	0.650	0.000194	0.000989	0.196331	0.8456
	0.800	−0.000362	0.001312	−0.275472	0.7848
ECT (−1)	0.200	−0.361352	0.209250	−1.726892	0.0941
	0.350	−0.423367	0.225639	−1.876298	0.0701
	0.500	−0.522601	0.163813	−3.190237	0.0032
	0.650	−0.571057	0.159340	−3.583898	0.0011
	0.800	−0.444200	0.137541	−3.229579	0.0029
Long-run Estimates					
Technology licensing	0.200	−0.118271	0.183673	−0.643921	0.5239
	0.350	−0.093533	0.120581	−0.775686	0.4433
	0.500	−0.123086	0.107908	−1.140651	0.2620
	0.650	−0.186339	0.111491	−1.671331	0.1038

Continued

	0.800	−0.137168	0.088354	−1.552479	0.1298
Income	0.200	−0.461628	0.253578	−1.820459	0.0775
	0.350	−0.280652	0.214941	−1.305720	0.2004
	0.500	−0.398483	0.192678	−2.068132	0.0463
	0.650	−0.296804	0.194472	−1.526206	0.1362
	0.800	−0.259644	0.191823	−1.353555	0.1848
Trade volume	0.200	0.336931	0.094787	3.554622	0.0011
	0.350	0.219951	0.081254	2.706944	0.0105
	0.500	0.265845	0.076834	3.459986	0.0015
	0.650	0.226878	0.077743	2.918314	0.0062
	0.800	0.187055	0.095403	1.960670	0.0582
Inflation rate	0.200	0.001934	0.003097	0.624437	0.5365
	0.350	0.000110	0.001866	0.058911	0.9534
	0.500	−0.000131	0.001753	−0.074577	0.9410
	0.650	0.000463	0.001955	0.236689	0.8143
	0.800	−0.000380	0.002527	−0.150360	0.8814
Constant	0.200	8.582205	0.948705	9.046229	0.0000
	0.350	7.915804	0.762345	10.38350	0.0000
	0.500	8.629602	0.651399	13.24779	0.0000
	0.650	8.500184	0.682996	12.44543	0.0000
	0.800	8.231564	0.649375	12.67613	0.0000

Source: Author's computation (2023).

(p-value > 0.05).

The table shows that the long run coefficients for technology licensing at all quantiles range from −0.1183 to −0.1863. None of the coefficients are statistically significant at the 5% level (p-value > 0.05). This suggests that technology licensing does not have a statistically significant impact on gas production across the quantiles considered in the analysis. At the 0.500 quantile, the coefficient of income is statistically significant at the 5% level (p-value < 0.05). This suggests that income has a statistically significant negative impact on gas production at the 0.500 quantile, indicating that higher income levels are associated with lower gas production. However, at other quantiles, the relationship is not statistically significant. Trade volume has a statistically significant positive impact on gas production across all quantiles considered in the analysis. Higher trade volume is associated with higher gas production. None of the coefficients of inflation are statistically significant at the 5% level (p-value > 0.05).

The coefficients for lagged income at all quantiles have mixed results. At the 0.200 quantile, the coefficient is negative, suggesting a negative relationship between lagged income and oil production. It is statistically significant at the 5%

level (p-value < 0.05). At the 0.500 and 0.650 quantiles, the coefficients are positive, indicating a positive relationship between lagged income and oil production. However, they are not statistically significant (p-value > 0.05). The coefficient at the 0.800 quantile is positive and statistically significant at the 10% level (p-value < 0.10), suggesting a positive impact of lagged income on oil production at this quantile. As for trade volume, the coefficients at all quantiles are positive, indicating a positive relationship between trade volume and oil production.

However, none of the coefficients are statistically significant at the 5% level (p-value > 0.05), except for the 0.200 quantile, where the coefficient is marginally insignificant (p-value = 0.2249). This suggests that trade volume may not have a significant impact on oil production, except for a possible weak positive relationship at the 0.200 quantile. The coefficients for interest rate and inflation rate at all quantiles are close to zero. None of the coefficients are statistically significant at the 5% level (p-value > 0.05). This suggests that interest rate and inflation rate do not have a significant impact on oil production across the quantiles.

4.5. Discussions of Findings

From the information presented above, the empirical results reveal that technology licensing registered has no significant impact on oil and gas production in Nigeria. Both the short-run and long-run estimates of the impact of technology licensing registered and oil and gas production in Nigeria were analyzed using the quantile ARDL (QARDL). The empirical findings show that technology licensing does not have a significant impact on oil and gas production both in the short and long-run. This implies that technology licensing in Nigeria does not have significant impact on the oil and gas production, meaning that poor conduct in technology licensing has been the reason the performance in the oil and gas are not at optimal levels agreeing with Adbi et al. (2020) but contrary to the findings of Rigo (2020) which inferred that acquiring foreign technology through licensing leads to significant productivity improvements.

5. Conclusion

Based on the results of the data analysis, we therefore conclude that technology licensing registered does not have a significant impact on the performance of the Nigerian oil and gas industry both in the short and long runs. This suggests that there are potential inefficiencies or barriers in the technology transfer process, hindering Nigeria's ability to fully capitalize on available technological advancements to enhance its oil and gas sector output and there is a need for policymakers and industry stakeholders to critically assess the existing licensing frameworks, identify potential bottlenecks or shortcomings, and implement corrective measures to facilitate more effective technology transfer and adoption. They should prioritize efforts aimed at strengthening the institutional and regulatory environment surrounding technology licensing activities in the Nigerian oil and gas sector.

The government, with the help of the National Assembly, must review the current law that governs technology licenses. The aim of this review should be to simplify the provisions relating to licenses to address the problem of lack of clarity. Also, there should be a collaborative effort to remove bureaucratic bottlenecks and regulatory barriers in terms of bringing in technical backup personnel to help in putting the licenses to use, the national office for technology acquisition programme should be empowered to vet licensing agreements and interface with institutions acquiring licenses to comply with statutory provisions and terms of the license.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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