ADAPTING LEARNING PROCESS IN A CHANGING OIL RESOURSE CONDITION

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Abstract

The article presents a mathematical apparatus that allows forecasting the development of innovative technologies that create a basis for profitable development of hard-to-recover hydrocarbon reserves. The author's approach is learning curves, a designated techniques have not previously been used in a comprehensive manner with real data in studies related to the oil and gas industry. The practical significance of the model in prioritizing measures aimed at innovative growth in the oil and gas sector. The approach was tested based on actual data from the Bakken formation in North Dakota. The calculations confirm the working hypothesis about prediction and forecasting the feasibility of learning and knowledge development for the efficient extraction of hard-to-recover hydrocarbons. It further suggests that the supportive function of policymakers, in creating a favorable environment to stimulate innovation and sharing of knowledge, increases learning rates and therefore enhances cost reduction. Other factors influencing the dynamic of costs should be duly investigated in further studies, while these methodologies should be extended to other energy sectors in support of a sustainable energy transition.

Keywords*:* Oil production efficiency, Cost reduction, Experience curves, Knowledge sharing, Learning rates, Capital investments, Energy analysis, Policy implications.

Introduction

The oil industry has always operated and developed in highly complex global environments defined by multi-dimensional interactions of geologic, technological, economic, and environmental factors. On the other hand, Bakken Field in North Dakota, USA, has become one of the more important test cases to understand how operators adapt to and learn from dynamic oil resource conditions. The Bakken Formation in the Williston Basin possesses unique geological features; hence it is a site with rich unconventional oil resources. In fact, for the last twenty years, horizontal drilling and hydraulic fracturing technology has hugely favored Bakken Field to be one of the key players in crude oil production in the United States of America. However, Bakken Field development is not only an evolving process reactive to technological development but a developing knowledge process regarding opportunities, constraints, and movements of the evolving market continuously. The situation of oil resources within Bakken Field is changing and related to knowledge development; operator acquisition and sharing may improve operational efficiencies while overcoming uncertainties, for which this paper argues.

The following research uses the Bakken Oil Field as a topical case study that will help in articulating knowledge development in the context of changing oil resource conditions. This research discusses how lessons from the field contribute to an overall improved understanding, through getting better management involved with unconventional resources to bring up value into reducing cost and improving efficiency in an even more globalized economic environment. In this light, this development-resource management interface becomes highly relevant in Bakken, while its operational strategy and efficiency offer a very important insight beyond its apparent domain of pertinence.

The present paper will take an in-depth look at the operational efficiencies and cost dynamics with respect to the Bakken Oil Field, being considered one of the largest shale plays of the United States. This paper dissects the complex interrelationships among the fractions of well drilling investments, invested resources, produced oil, and costs of drilling. The main purpose is to try and find out the hidden pattern defining the rules and governing dynamics of efficient production and cost structures using the most sophisticated statistical and econometric methods. This tends not only to contribute to better management of Bakken but also provides valuable insights into other major oil-producing regions around the world, especially in Russia and Libya, since they fall among the top 5 countries that have the highest technically recoverable shale oil resources worldwide [1].

Background and Context

The Bakken formation in North Dakota, USA, was such a unique geology that made producers find new ways of extracting oil in this region. The Bakken Formation is thought of as one of the unconventional shale, sandstone, and dolomite resources. The Bakken Formation is deemed a remarkable reserve about unconventional oil resources. Geologically, the Bakken Formation is quite deep and relatively complicated with over 10,000 feet wells hence was very complex during the early stages of extracting oil [2]. The Bakken formation is hosting 23 billion barrels technically recoverable reserves for North Dakota and Montana combined. 27% of the total comes from Montana, this gives 16.8 billion barrels to North Dakota [3].

Oil extraction in the Bakken Field began early in the 1950s with the first installation of wells that were vertically drilled. Earlier technologies, however, could not tap into the large reserves held in the Bakken's very dense geologic formations. It was only the trailblazing technological advances of the early 21st century—particularly in horizontal drilling and hydraulic fracturing, or fracking procedures—that the industry discovered new ways of pulling oil from the Bakken field [4]. This is where horizontal drilling introduced the possibility for operators to access larger portions of a reservoir from a single wellbore, while greatly improving production rates and recovery efficiencies. Hydraulic fracturing, more commonly known as fracking, came into play through an extraction process in which highpressure fluid was injected into rock formations; the pressure causes fractures that serve to release the trapped hydrocarbons. This dramatically changed the oil production potential of the Bakken Field to become one of the leading contributors to total U.S. oil output.

Events and milestones were able to drastically change the trend in oil production as well as the learning processes of the Bakken Field. The discovery of giant reserves, particularly made in the closing decades of the 20th century, catalyzed interest and investment in this region in the first place. Accordingly, production efficiencies first initiated by technological advancements in the early 2000s-have moved pari passu with improvements in the recoverable resource base. Operational practices and learning processes have evolved due to changes in regulations, market volatility, and environmental factors applicable to the Bakken field [5].

Learning processes in oil exploration and production

The role of learning in economic development has long been recognized. For instance, Coleman describes the gains from new knowledge or technologies as true “free lunch”, while Lucas describes growth, largely induced by learning, as a miracle [6-7]. One strand of the economics literature, exemplified in Benkard, has focused on learning by doing or the ability to reduce costs and inputs over repeated instances of production: through trial and error, the marginal cost of the 1000th widget is some fraction of that for the first widget [8]. A practice of learning in the oil exploration and production industry is described as a selfreinforcing cycle. This means the development of novel perceptions, the improvement of existing technologies, and the amendment of working practices are all based on experience and knowledge obtained from earlier attempts. This concept is also referred to as relatedness. The process of constantly developing and perfecting techniques for finding, extracting, and refining oil is done with the aim of increasing efficiency, reducing expenses, and lowering risks. Organizations have indeed been quite flexible in view of the dynamically changing conditions of oil resources in the Bakken Field. For instance, the process in extraction began with largely vertical methodologies. When the Bakken Formation was realized as having large deposits of unconventional oil reserves within shale formations, companies evolved their methodology to horizontal drilling and hydraulic fracturing. This new technology allows previously unattainable oil deposits to be accessed: that improves both recovery efficiency and production rates.

There are some of the challenges and opportunities Bakken Field has gone through and created different processes of learning and adaptation. Technological advancement resulting from geological difficulties initiated the unfolding of horizontal drilling and hydraulic fracturing in the complex nature and depth the shale rock of Bakken Formation presents [9]. Moreover, price volatility in oil, regulatory policies, and environmental concerns have been more factors that have impacted the operational strategies focusing on achieving high sustainability and efficiency in stakeholder operations [5].

Methodology

Experience curves and learning rate are of identical mathematical form, but reflect observations at different scales. The term "learning" is used when focus is on relatively wellcharacterized factors of production resulting in production cost declines of a single standardized product by one manufacturer. It covers things such as 'learning' by workers and management that reduces labor hours needed to produce a product, economies of scale. Experience has revealed, often, that broader categories of products can involve several models developed by different manufacturers [10]. The approach was later modified to model technological development [11].

Learning/experience curves, which traditionally have been used within industrial sectors, can be adapted to predict cost declines and efficiency gains related to energy technologies. Recently, in energy analysis, the experience curve methodology has been developed and are applied to the analysis of cost trends of various energy technologies. Kryukov and Gorlov assessed the relationship between cumulative output production and cost decline in wind energy projects, indicating how experiential learning and technological development have contributed to reductions in operating costs over time [12]. Finally, probable future energy costs and commercialization of new energy technologies have been projected and assessed using experience curves. Moreover, their use for the projection of the effect of policy measures on growth and commercialization of new energy technologies is estimated. The projection of experience curves in complex energy modelling for future energy scenarios is demonstrated in building on these, experience curves have proven to be very successful in research on cost reduction trends for new technologies.

Although initially developed in order to quantify the man-hour or cost decline with standardized products, these curves have been extended to include non-standardized product cost reductions manufactured at world, national, or specific firm levels as demonstrated by Wright [13]. Total costs are addressed that encompass labor, capital, administrative, research, and marketing costs. The major sources of cost reduction include production changes-process innovations, learning effects, scaling effects-product changes-incremental innovations, redesign, standardization-and changes in the prices of inputs [14]. The experience curves illustrate costs falling with cumulative production, usually declining by a constant percentage for each doubling of total units produced [15].

Data

We collect data from 2 major players in operation during the peak fracking boom at Bakken: 1) Continental Resources, which struck its first Bakken well in 2003-a year when the company gained significant acreage in the area, has been at the forefront of using horizontal drilling in concert with advanced completion techniques to maximize oil extraction. 2) Hess Co-operation: it becomes one of the largest players in Bakken Shale formation, where Hess holds approximately 800,000 net Bakken acres with proven track record of asset optimization, cost reduction, value creation. Hess Corporation has been taken over by Chevron Corporation in 2023. The deal is an alluring one, comprising the coveted assets of Hess, such as the encashment of Stabroek block in Guyana and Bakken shale assets.

The data was collected from the annual reports of companies from 2011 to 2021 and monthly Bakken oil production statistics from the Department of Mineral Resources of North Dakota. We considered two directions — improving the quality of technology and reducing its cost. As initial data, we used data on the work of two of the top operators in the Bakken during its fracking boom, Continental Resources and Hess. We used the following indicators: exploration and drilling development expenditure as investments, Oil Net production as an indicator of effectiveness and well costs as an indicator of cost reduction.

Results

- <u>Efficiency Learning</u>

From the efficiency learning of Continental Resources, it shows that 77% of oil production variability in this company can be explained by the investments carried out. This, therefore, proves a strong relationship between the levels of investment with improvement in efficiency. This would hence mean that this model has effectively grasped the learning approach (Figure 1).

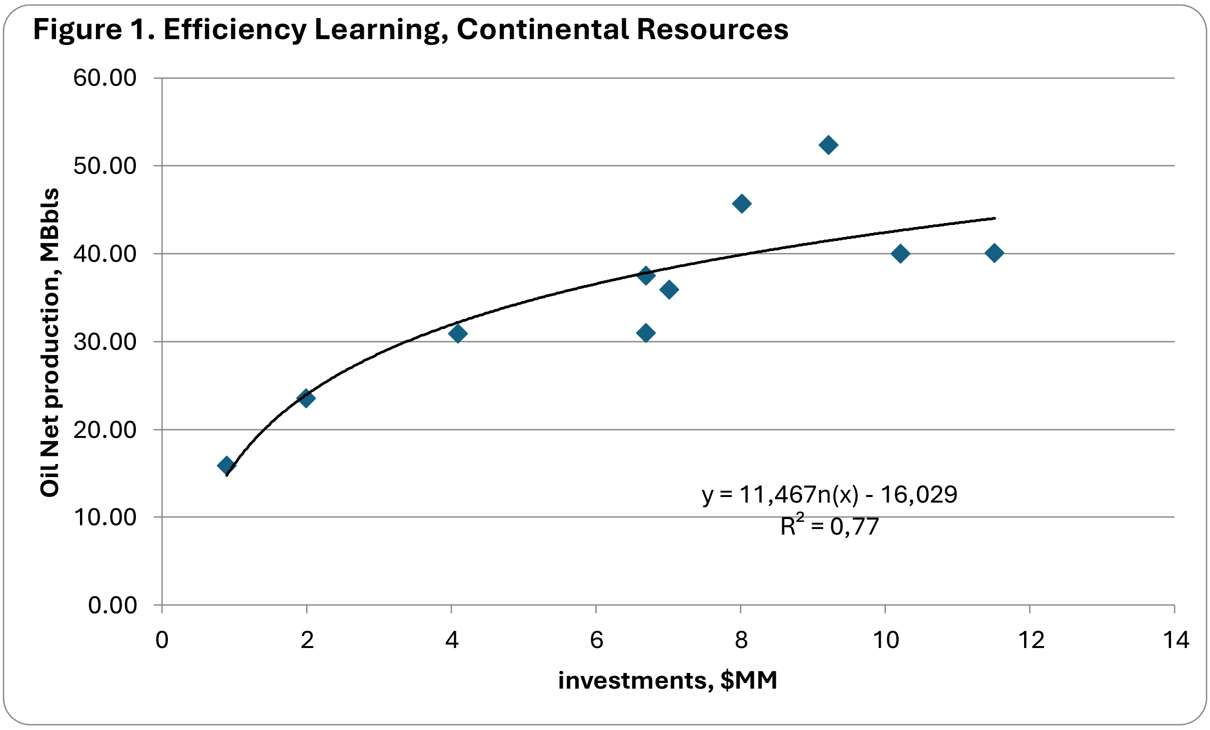

Fig. 1. exhibits the logarithmic relationship between investments and oil production. That is, as more investment is done, oil produced increases at a decreasing rate.

Clearly, Hess explains 78% of the variance, as demonstrated by the company's oil production, which solidly shows an effective correlation between investment and improvement in efficiency (Figure 2). The figure describes a logarithmic relationship. But the model is richer with two logarithmic terms and the coefficient is negative, which indicates that efficiency should decrease firstly and increase slightly afterwards. The importance of this is that for Hess, this model has a very good fit with the data, just like it does in the case of Continental Resources, while there is a slight difference in variance.

Figure 2. Efficiency Learning, Hess

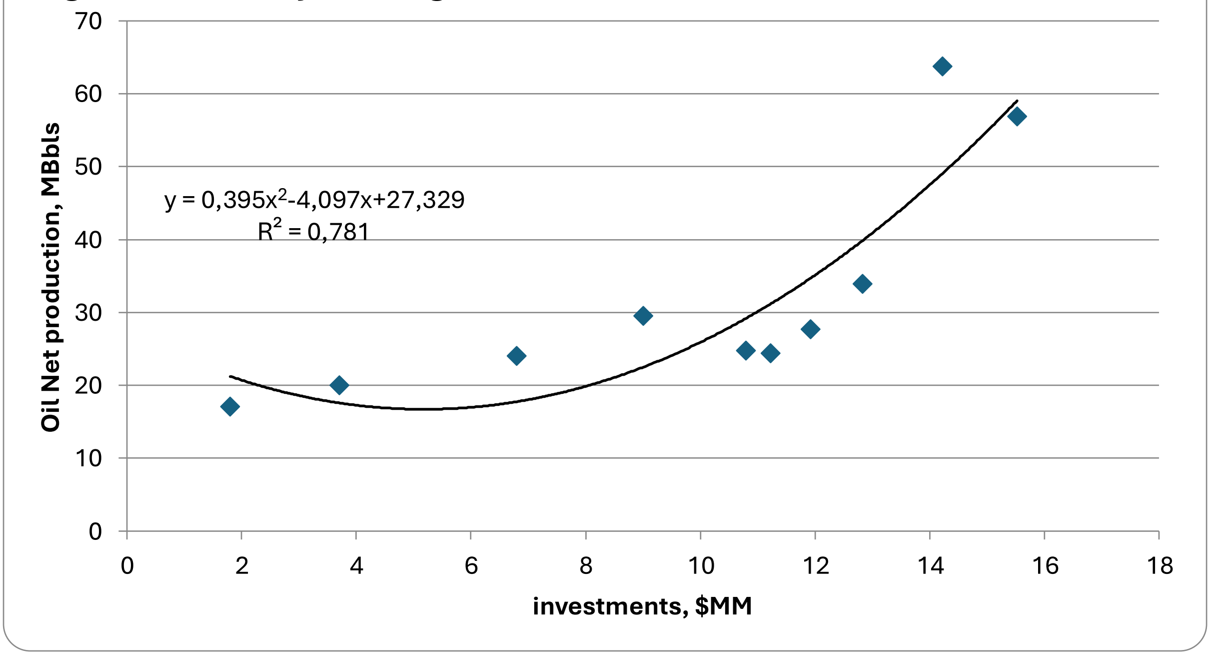

Fig. 2. describes a logarithmic relationship. But the model is richer with two logarithmic terms and the coefficient is negative, which indicates that efficiency should decrease firstly and increase slightly afterwards.

- <u>Cost Reduction (Price Learning)</u>

The R value of 0.47 depicts that 47% of the variability in the decline of the well costs for Continental Resources are explained by the investments carried out; hence, there exists a moderate correlation between investment and reduction of the costs (Figure 3).

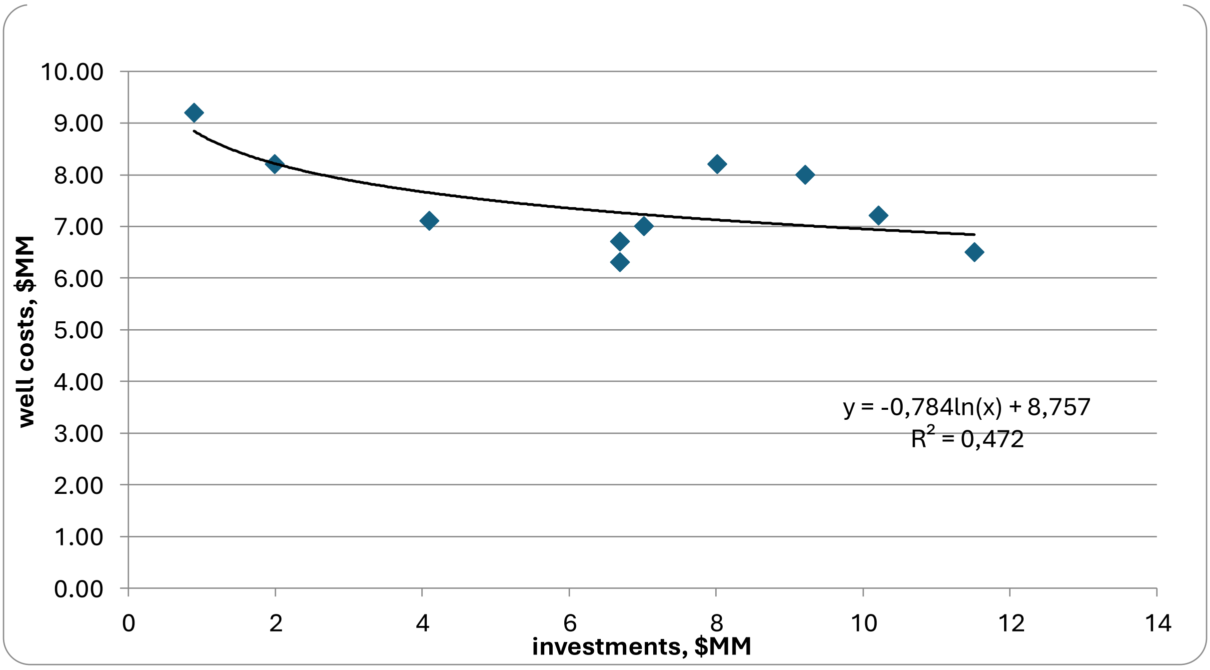

Figure 3. Cost Reduction, Continental Resources

Fig. 3. Logarithmic decrease of well cost with respect to investments. With a negative coefficient, the cost is falling.

Meanwhile, Hess scored 0.58, meaning that 58% of the variability in well costs for the company is explained by the investments made, and that a moderate to strong correlation exists between investment and cost reduction (Figure 4). In this sense, the model fits the data quite well for Hess in terms of price reduction but not as strongly as for the models of efficiency increase.

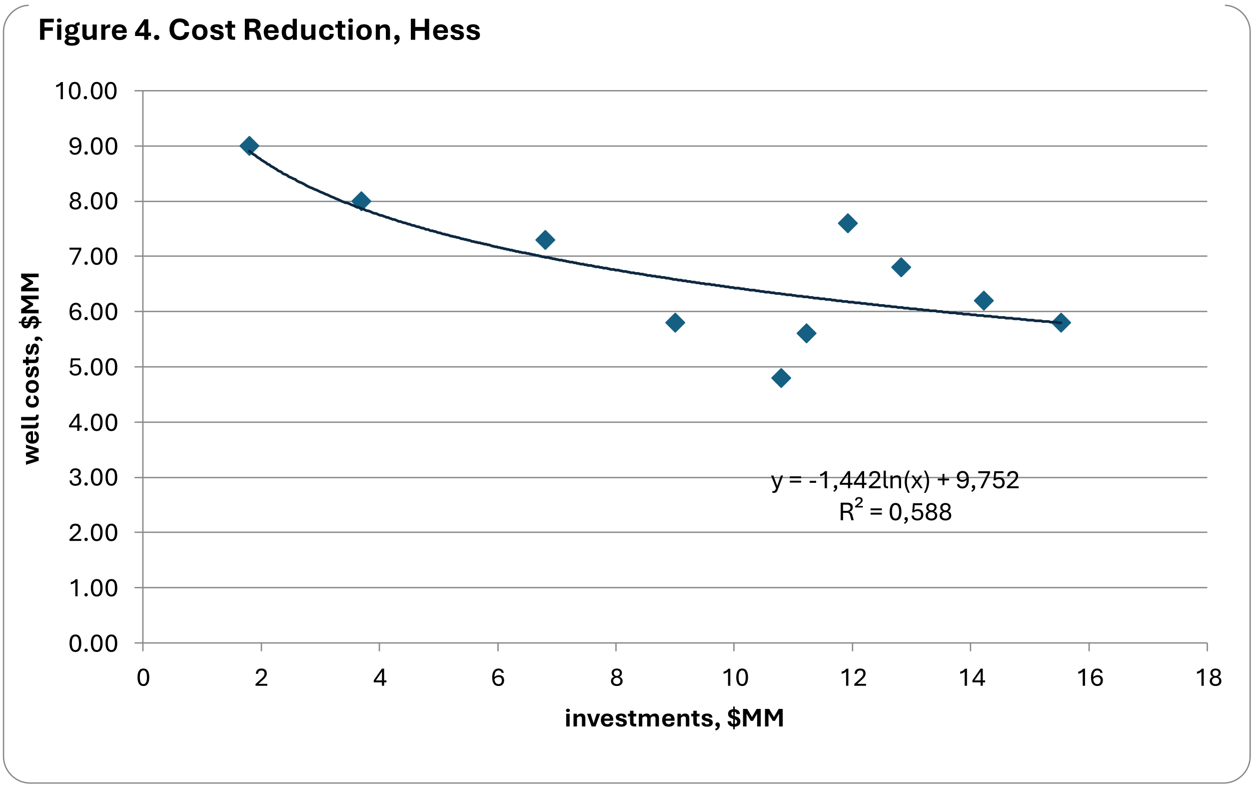

Fig. 4. shows that well expenses decrease logarithmically with increases in investments; the coefficient is negative, steeper, meaning a greater reduction.

Overall, the high R squared values of 0.77 and 0.78, respectively, reflecting those good results for efficiency-enhanced models in assessing changes in oil production efficiency due to the investments and, therefore, a strong correlation among the variables. On the other hand, cost reduction models present an r-squared value of 0.47 and 0.58. These, in turn, reflect that such models would then be less reliable in explaining changes in well cost, and this would make cost reduction subject to a wider range of factors which are not embraced in the model. These R values give an idea of the reliability of the models, pointing out which models need more data or refinements in order to have better predictive accuracy.

Sources of cost reduction can't be only investment but also could include improved skills workers, experience in engineering know-how. In fact, the state's policy also influences the cost reduction, taking for instance, the sharing knowledge every 6 months by all operators that was imposed be the state of North Dakota, and competition as every company wants to be the first to unlock the full potential of the technology and patent it to maximize its profit (Neij et al., 2003).

Overall, these learning rate insights offer valuable guidance for operational strategies in the Bakken field. Capital investment remains essential for boosting production, but effective resource and cost management will be crucial for sustaining profitability as the field matures. These insights can help shape future strategies, focusing on technological improvements, resource optimization, and investment decisions.

Conclusive Discussion: Implications and Lessons

The learning curves derived for Continental Resources and Hess have significant implications not only for other oil fields but, generally speaking, for the energy sector. Indeed, other oil fields-for example, those in Russia and Libya that reportedly hold large conventional and unconventional oil reserves could also examine in a similar way how investment levels relate to efficiencies or reductions in cost. For example, in Bakken oil fields, the vast interaction between investments and productivity implies that focused investment in technology and process improvements can result in significant and successful productivity increases. Both countries happen to be among the top 5 countries globally with the highest technically recoverable shale oil resources and they apply similar strategies which will help improve the performance of the operation as well as profitability. This finding has specific importance for oil fields located in those regions of the world where competitive advantage depends on maximizing production while controlling costs.

Other oil fields, in fact, can do so just by looking at their own learning curve as a source of valuable data that will enable them to reevaluate their investments. More precisely, they should be focusing on those technologies responsible for driving this exceptional efficiency gain in the Bakken: advanced drilling techniques and enhanced completion technologies. Investment in those areas holds the key to other fields' replicating efficiency enhancements similar to what Continental Resources and Hess have achieved. Still further, knowledge of the concept on the 'decreasing return to investment' by the logarithmic relationship between investment and production effectiveness helps such disciplines optimize capital expenditure so that maximal input is given with minimal waste spending.

Technological development and operational learning are also key. The Bakken's success in the well cost reduction from accumulated experience makes the case for technological advance crucial. Overall, producers will find their productivity in shale oil in the Russian and Libyan fields-significantly improved from advanced drilling and hydraulic fracturing technologies. A culture of knowledge-sharing and operational transparency will accelerate any learning curves and generally contribute to the performance of the fields. Lessons learned from the Bakken can thus be applied by Libya through its NOC to the Silurian "hot shale" deposit. The Silurian deposit constitutes the most significant Palaeozoic hydrocarbon source rock in North Africa, and where it is produced, there is an indication of a vast quantity of shale oil. Russia also can implement embrace some strategies from the Bakken to its biggest shale oil deposit, the Bazhenov Formation which is considered the largest unconventional shale oil deposit in the world.

Policymakers can also benefit greatly from these results. The intervention in the form of making knowledge sharing among the operators a mandate or giving them some kind of incentives to invest in certain specific projects will definitely bring in needed efficiency and cost reduction in the sector. A case example is that the technological advancement and operational practices exchanged among North Dakota‟s operators undoubtedly encouraged the efficiencies and cost controls Bakken has experienced. Such policies create an atmosphere of cooperation in which companies are placed to learn from each other, hence increasing at a rate at which the industry learns together.

The experience curves also reflect the imperatives for policy measures in order to stimulate the innovation and commercialization of new energy technologies. What policymakers can understand from these is the role that learning rates can play within bringing down the trajectory of production cost; therefore, they could also design incentives that encourage early adoption of the state-of-the-art. Some important factors include tax incentives or grants and subsidies for investments by companies in new or improved technologies. This will further enable policy makers to cut costs, reduce the cost of production, enhance energy efficiency, and likely lessen environmental impacts due to oil extraction activities.

Other important policy implications of this study, not only for the Bakken, but also for Russian and NOC Libya policymakers, are that the regulation and policy have to consider a much broader economic and environmental context while formulating oil sector-related regulations and policies. Considering the findings of the study, while there was a dire need for technological investment and efficient practices to increase efficiency, labor skills, administrative process improvement, and input price would also simultaneously strengthen cost reduction. Due to such complexity, regulators will need to address the issue from a broad viewpoint. Along with the technology advances, labor improvement, control of supply chains, and market condition regulations shall be facilitated.

Whereas different R-values were realized from Continental Resources and Hess, models of cost reduction are only effective at different levels for different firms. It is, therefore, rather unwieldy to have one size fits all policies. Instead, a policy more suitably tailored is likely to fit the singularity of the oilfield or corporation targeted. Policymakers might instead strive to devise adaptable frameworks that permit customization depending on local conditions, resource availability, and technological maturity.

In summary, the analysis of learning curves and the resulting efficiency gains and cost reductions provide a powerful tool for oil field operators, policymakers, and states. Libya’s Silurian “hot shale” deposit and the Bazhenov Formation can use these insights to optimize their investment strategies, focusing on technologies and practices that have proven successful in similar contexts. These findings can be used by policymakers in the crafting of effective regulations and incentives toward the growth in innovation sustainability. By fostering a collaborative, knowledge-sharing environment and encouraging targeted investments, both groups can work together to enhance the overall performance and sustainability of the oil industry.

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